IRRC

Special IRRI Report

Meta-Impact Assessment of the Irrigated Rice Research Consortium

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IRRI

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 that is a member of the CGIAR Consortium (www.cgiar.org). It is supported in part by government funding agencies, foundations, the private sector, and nongovernment organizations.

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EXECUTIVE SUMMARY

The Irrigated Rice Research Consortium (IRRC) was established in 1997 with the aim of providing a platform to facilitate identification, development, dissemination, and adoption of natural resource management (NRM) technologies suitable for irrigated rice-based ecosystems in several Asian countries. With funding support mainly from the Swiss Agency for Development and Cooperation (SDC) through four project phases (Phases I–IV from 1997 to 2012), the IRRC has provided a mechanism that expedited partnerships between national agricultural research and extension systems (NARES) and scientists from the International Rice Research Institute (IRRI). It is estimated that 1.2 million farmers have been reached by the NRM technologies promoted by the IRRC.

In light of the more than 15-year history of IRRC, there is natural interest in whether IRRC's efforts resulted in meaningful impacts and whether benefits from the outputs of IRRC's research outweigh the research investments. Hence, the objective of this study is to determine the multi-dimensional impacts (i.e., economic, sociocultural, environmental, policy, scientific, institutional) of the technologies developed and/or disseminated by IRRC, as well as document the pathways and mechanisms that led to successful adoption of these technologies. A "meta" impact assessment approach is used where the analysis of impact evidence mainly relies on existing documents (or studies), easily accessible data sources, and short field visits.

Overall, our assessment indicates that the IRRC has provided a wide-ranging array of impacts in multiple dimensions—from micro-level impacts on farmer livelihoods to national—level agricultural policy influence. The analysis suggests that the overall impact of IRRC more than compensates for the research investments made. It can be strongly argued that IRRC has been an effective international platform for strengthening NRM research in Asian irrigated rice-based systems. IRRC's institutional emphasis on partnerships, collaborations, and cross-country learning has strongly contributed to the variety and magnitude of impacts generated. Hence, agricultural research and extension organizations, especially those involved in NRM technology development and dissemination, should strongly examine the value of IRRC's "consortium-based" approach and consider it in their operations.

Economic impact: Based on an economic surplus analysis approach, we find that the improved economic welfare of farmers from adoption of these technologies more than compensates for the research investments made to develop and/or disseminate it. Even only considering the period that covers the four phases of the project (1997–2012), the rate of returns to the total research investment ranges from 6% to 30% (or benefit-cost ratios [BCRs]) ranging from 1:1 to 4:1). When considering all technologies in the surplus analysis, total research investments of around US$18.5 million resulted in economic benefits of about US$70.5 million. If a longer 1997–2016 period is considered (where we project benefits 4 more years to the future), rate of returns to total IRRC research investments has an even larger magnitude ranging from 25% to 43% (or BCRs from 4:1 to 16:1). Given that the economic surplus generated by IRRC technologies is more than the total research investments (from all sources), rate of return of the research investments from the SDC alone has even higher values (e.g., 14–34% for the 1997–2012 period and 29–46% for the 1997–2016 period). These rates of return figures are consistent with those pointed out by existing studies that evaluated different NRM technologies (see, for example, Renkow and Byerlee 2010). But these measures are still typically lower than the surplus measures calculated for genetic/varietal improvement (or breeding-based) research. Note, however, that the analysis here only considers a subset of NRM technologies for a select set of countries and it may be possible that the surplus measures for IRRC can come close to the varietal improvement research values when all technology-country combinations are considered. Nevertheless, the impact evidence suggests that the economic surplus generated from the NRM technologies developed and disseminated by IRRC is well worth the cost.

Sociocultural, gender, institutional, and policy impacts: In general, existing impact studies suggest that IRRC technologies produced tangible sociocultural, gender, institutional, and policy impacts. Common sociocultural impacts documented are improved farmer livelihoods and well-being, improved food security, reduced vulnerability to adverse economic and climatic conditions, changed farmer beliefs on traditional agricultural practices, improved social cohesion in communities (i.e., for ecologically based rodent management [EBRM] and alternate wetting and drying [AWD]), and reduced social conflicts.

Environmental impacts: Primarily based on participant observation, farmer interviews and responses from various adoption studies by the IRRC Coordination Unit, there is some evidence on the environmental impacts of selected IRRC technologies. For example, there are studies that revealed the important greenhouse gas implications of site-specific nutrient management (SSNM) and AWD (Pampolino et al. 2007). Reduction in chemical rodenticide use was observed in EBRM impact studies, and possible increased use of preemergence herbicides (and weed resistance) was noted in impact studies of direct-seeded rice.

Scientific and human resource development impacts: The citation analysis of IRRC publications indicates that a total of 461 publications have been produced over the four phases of the project. Outputs ranged from peer-reviewed articles and books to conference papers and unpublished theses. IRRC outputs have been cited over 5000 times in total. IRRC publications evolved such that NARES partners and scientists became increasingly included in the scientific outputs as the consortium progressed through its four phases, which is indicative of successful capacity-building in partner countries. IRRC's human resource development efforts include training, workshops, seminars, internships, and advanced studies leading to graduate degrees (master's and/or doctorate degree). The beneficiaries of IRRC's human development efforts have included NARES personnel, farmers, NGOs, the private sector, and students. Experiences from IRRC research initiatives have also been included in university agricultural curricula of partner countries.

Impact pathways, process evaluation, and policy influence: Analysis of the impact pathways for the different technologies shows a wealth of country-specific strategies used for increasing knowledge and access to technologies and for promoting farmer uptake. Greater impact was realized where there are strong multistakeholder groupings and/or local "technology champions." Moreover, based on a process evaluation, we find that IRRC's multistakeholder partnership approach has been successful in allowing them to meet demands of country partners, as well as external institutions (i.e., IRRI, donors, and governments). IRRC demonstrated a high degree of flexibility and responsiveness to the experiences and lessons learned throughout the four phases of the project. IRRC's position as a consortium established a wide stakeholder interest group and created a direct connection to country policy and research/extension practice which, in its absence, would have been difficult for IRRI researchers to achieve for multiple countries. The continuity of IRRC over its 15 year period has fostered trust among country partners and, in turn, provided the necessary stability to encourage participating researchers to be creative, share ideas, develop concepts, and test new approaches in an interdisciplinary fashion. Hence, IRRC has also been instrumental in shaping research and extension priorities of partner countries. NARES set their own collaborative research and extension agendas, with IRRC facilitating the process and making sure that these agendas meet the needs of farmers and other major stakeholders. IRRC also influenced national research and extension agendas through professional and technical support and capacity strengthening, primarily through participatory approaches and by encouraging networking and policy dialogue.

Recommendations and lessons learned: The IRRC should be commended for the resources that were devoted to documenting the different impacts of the technologies developed and disseminated. The number of studies that use both qualitative and quantitative methods to analyze the impacts of various technologies in different partner countries is quite impressive. However, there are areas where the impact assessment work of IRRC could be improved to make the assessments more persuasive, such as: 1) investigating the heterogeneity of impacts across different groups of farmers and/or stakeholders, and by gender; 2) using state-of-the-art impact assessment methodologies to examine the economic and sociocultural impacts of IRRC technologies and account for such issues as selection bias; 3) enhancing consistency in the impact evaluation across work groups and technology; and 4) more carefully monitoring the take-up and adoption numbers for at least the "high-potential" IRRC technologies. To achieve these desired improvements, it is critical that scientists responsible for the development and dissemination of the NRM technologies include an impact assessment researcher from project inception (i.e., in the planning stages) and not just bring in the researcher after the diffusion of the technology.

1. Introduction

The Irrigated Rice Research Consortium (IRRC) was established in 1997 with the aim of providing a platform to facilitate identification, development, dissemination, and adoption of natural resource management (NRM) technologies suitable for irrigated rice-based ecosystems in several Asian countries. With funding support mainly from the Swiss Agency for Development and Cooperation (SDC) through four project phases (Phases I–IV from 1997 to 2012), the IRRC has provided a mechanism that expedited partnerships between national agricultural research and extension systems (NARES) and scientists from the International Rice Research Institute (IRRI). Through these IRRC-fostered partnerships, NRM technologies that address irrigated rice farmers' needs have been identified and developed through interdisciplinary research and outreach efforts. Instead of a "top-down" research and dissemination approach, the institutional structure of IRRC was expressly developed to emphasize the importance of partnerships and to make sure that local NARES are involved in identifying technologies that would be appropriate for further study and research. In recent years, the IRRC has also focused on strengthening the dissemination and uptake of these technologies in target Asian countries, through the partnerships established. Arguably more than 1 million farmers have been reached through the efforts of IRRC (see Table 1.1).

In light of the IRRC's 16-year history, a review team has been commissioned to conduct a meta-impact assessment that aims to determine the multidimensional impacts (i.e., economic, environmental, policy, scientific, sociocultural, etc.) of the technologies developed and disseminated by IRRC. Pathways for successful adoption of the IRRC technologies are also analyzed and documented. The goals and specific aims of the meta-impact assessment are listed in the Terms of Reference (see Appendix 1). The review team for this assessment is composed of: Roderick M. Rejesus (economist, North Carolina State University, USA), Adrienne Martin (social anthropologist, Natural Resources Institute, University of Greenwich, UK), and Phrek Gypmantasiri (agronomist, Chiang Mai University, Thailand).

Note that the present study is a "meta"-impact assessment rather than a traditional impact evaluation, since the analysis of impact evidence mainly relies on existing documents/studies, easily accessible data sources, and short field visits. Primary data were not collected in light of the short (approximately 10-month) assessment period. Nevertheless, this meta assessment is more comprehensive in nature as compared with previous individual studies of NRM technologies and/or projects (see individual impact studies summarized in Waibel and Zilberman 2007; Renkow and Byerlee 2010).

Many of the recent NRM impact studies only focus on a single technology (or technology package) and have limited geographical scale. With the limited geographical scale of these NRM impact studies, international spillovers from NRM research outputs (and the "international public good" aspect of this type of research) has been questioned (SPIA 2006). The existing impact literature on NRM also noted the importance of institutions (i.e., country-level extension capabilities, likelihood of farmer collective action, property right regimes) in the success of NRM outputs, yet there has been limited documentation on the sociocultural effects of NRM research investments and institutional structures needed to make it work. Environmental benefits from NRM research have also been widely recognized in past studies but are not usually documented. Hence, a comprehensive meta-impact assessment of IRRC, which allows for analysis of multiple NRM technologies on a wider geographical scale and for evaluation of impacts in multiple dimensions, can contribute to the literature by providing a better understanding about effective NRM technology research and dissemination approaches.

Table 1.1. Estimated number of farmers reached by IRRC technologies (by 2012, based on existing studies).

Technology	Country	Farmers reached (estimated no.)	Reference/Source	Comments
AWD	Philippines	100,000	Lampayan et al. 2012a; Palis et al. 2012c	
AWD	Bangladesh	100	Kurschner et al. 2010	
SSNM/LCC	Bangladesh	500,000	Flor et al. 2011	Reflects the median number of LCCs distributed (i.e., from a 400,000-600,000 estimate)
DSR & SDV	Bangladesh	500,000	Palis et al. 2012a	
DSR only	India	60,000	Malabayabas et al. 2013	
EBRM	Vietnam	50,000	Palis et al. 2011a	
FBD	Myanmar	24,350	Myo Aung Kyaw	Based on an interview with Dr. Myo Aung Kyaw in 2010
Combination (3R3G/1M5R)	Vietnam	15,000	Quicho et al. 2012	Considers An Giang province only
Combination (ICM)	Indonesia	200	Singleton et al. 2011a	Based on a pilot study only
Combination of IRRC technologies	Philippines	10,000	Sumalde et al. 2012; Corrales et al. 2010	Used AWD as entry point for dissemination.
Total		1,259,650		

Note: For the purpose of this table, the term “estimated number of farmers reached” typically refers to farmers who used or adopted the technology. However, there are cases where the estimate may not really reflect adoption per se (e.g., SSNM in Bangladesh reflects LCC distributed but may not reflect actual adoption). Please see the “Comments” column for more information about the figures reported above.

Source: Compiled with the help of the IRRC Coordination Unit.

As part of the overall meta-impact assessment endeavor, the third output/deliverable of the project is this Final Report. This report includes (1) a section that gives a brief description of the IRRC work groups and the technologies disseminated; (2) an economic impact section that includes an inventory of economic impact evidence, an economic surplus analysis, and a poverty impact assessment of various IRRC technologies; (3) an inventory of sociocultural, gender, institutional, and policy impact evidence; (4) an inventory of environmental impact evidence; (5) a citation analysis of IRRC scientific publications (to determine scientific impact); (6) an assessment of the human resource development and educational/curricular impacts; (7) an impact pathway analysis that identifies the ways in which IRRC technologies have been disseminated and adopted in specific countries; (8) a process evaluation that examines the program implementation, the factors that have prompted change, and how the IRRC adapted across the four phases of the project; (9) an influence analysis that examines how the IRRC has influenced the policies and strategies of NARES and other institutions; and (10) a concluding section that summarizes major findings and discuss recommendations.

2. IRRC work groups and brief description of technologies

2.1 Labor Productivity and Community Ecology (LPCE) Work Group

The Labor Productivity and Community Ecology (LPCE) Work Group started as separate work groups in 2001 (i.e., Weed Ecology and Rodent Ecology work groups). The joint LPCE Work Group was formed in Phase IV of IRRC (2009) with the main goal of improving labor productivity and fostering effective community action for managing weeds and rodents. The Work Group conducts research and development activities that improve methods of rice crop establishment and ecological approaches to weed and rodent management. The LPCE Work Group is led by Dr. David Johnson.

Direct-seeded rice (DSR) and weed management practices have been introduced in Bangladesh, China, India, Indonesia, Malaysia, the Philippines, Sri Lanka, and Thailand to help address labor shortage issues (especially during crop establishment and weeding) and to reduce yield losses due to weeds in irrigated areas. The typical benefits from DSR include lower labor and irrigation costs for rice and higher income for wheat. DSR can mature 10–15 days earlier than transplanted rice, enabling farmers to plant wheat (or other crops) earlier; this results in higher yields. DSR and weed management were introduced with short-duration varieties in Bangladesh and with aerobic rice (AR) in the Philippines.

The rodent ecology work of LPCE has focused on breeding ecology and management options for rodents. These studies were undertaken in Vietnam, Philippines, Laos, Indonesia, and Myanmar. Addressing the rodent problem is mainly done through ecologically based rodent management (EBRM). EBRM requires community action to be effective and sustainable, but practices are expected to vary for different species because their biology and ecology in specific agricultural landscapes differ. In cases where losses due to rodents are greater than 10%, the community trap barrier system (CTBS) can be used. It is a trap and fence system that uses plastic fence and traps to catch rodents. The use of CTBS was initially introduced and adopted by some farmers in Vietnam in Phases I and II of IRRC.

2.2 Post Production (PP) Work Group

Established in 2003, the PP Work Group focuses on increasing the value of rice harvest through improved postproduction techniques and market knowledge. The PP Work Group is led by postharvest specialist Martin Gummert. He also leads the Asian Development Bank (ADB) co-funded postharvest project of IRRC. Poor storage and delayed (or improper) drying are the two main problems being addressed by the Work Group. Activities are conducted in Cambodia, Indonesia, Laos, Myanmar, Philippines, and Vietnam. In 2009, the PP Work Group established three national Learning Alliances in Cambodia, the Philippines, and Vietnam. This helped establish local supply chains for postharvest technologies and helped address some of the postharvest issues in those respective countries.

The PP Work Group helped verify the effectiveness of the simple hermetic storage systems (HSS), also known as the IRRI Super Bag, to reduce postharvest losses and maintain grain quality. Extensive field verification has demonstrated that the air-tight HSS controls insect grain pests without using chemicals, protects the grain from rodents, maintains a high seed germination rate, and results in less broken grains during milling relative to open storage systems (Gummert et al. 2006).

Another technology optimized by the PP Work Group is the mechanical dryer. It reduces physical losses and doubles head-rice recovery compared with the traditional practice of sun-drying (Kyaw and Gummert 2010). As a result of the training conducted by the Work Group, dryers have been installed in Cambodia, Laos, Myanmar, Indonesia, and Vietnam. This enables farmers to dry their rice on time and at a premium price even in the wet season. Other postharvest technologies the PP Work Group helped promote include combine harvesters, laser leveling, rice mill improvement, rice quality tools, and market information boards.

2.3 Productivity and Sustainability (PS) Work Group

The PS Work Group focuses on improving nutrient and crop management practices for increased profitability in rice farming. The PS Work Group is headed by Dr. Roland Buresh. Activities are conducted in Bangladesh, China, India, Indonesia, Myanmar, Philippines, and Vietnam.

The PS Work Group, formerly Reaching Toward Optimal Productivity in Intensive Rice Systems Work Group (2001 to 2004), was instrumental in the development and promotion of site-specific nutrient management (SSNM), including the use of the leaf color chart (LCC), as an approach for improved nutrient management for rice (Witt et al. 2002). During Phase I of IRRC, the Reversing Trends in Declining Productivity (RTDP) Project (1997 to 2000) developed principles for SSNM. It was developed in Asian rice-producing countries through partnerships within the IRRC. SSNM aims to apply nutrients at optimal rates and times to achieve high yield and high efficiency of nutrient use by the rice crop.

In 2008, the PS Work Group led the use of SSNM principles to develop a computer-based decision tool, named *Nutrient Manager* (http://www.irri.org/nmrice), which can quickly give guidelines on the amount and timing of fertilizer (nitrogen [N], phosphorus [P], and potassium [K]) required for matching crop needs in a specific field. Further work is being conducted to make this decision-tool available on mobile devices (i.e., smartphones).

2.4 Water Savings (WS) Work Group

In recent years, availability and quality of water for agriculture have been declining. This poses a big challenge in rice production because producing 1 kg of rice requires a large amount of water (3,000 to 5,000 liters). The Water Savings (WS) Work Group became part of IRRC in 2001. It was formed to help farmers cope with water scarcity and to introduce ways to use water more efficiently. The WS Work Group developed and introduced the alternate wetting and drying (AWD) technique and the aerobic rice (AR) method to areas that are typically experiencing water scarcity. The WS Work Group is led by Dr. Ruben Lampayan.

AWD is done by allowing the field to be alternately flooded and nonflooded. The nonflooded state in AWD can vary from 1 to more than 10 days. A “field water tube” is used to monitor the depth of ponded water. Irrigation should be applied when ponded water has dropped to 15 cm below the surface of the soil. The threshold of 15 cm water depth below the surface is called “safe AWD” because it is not expected to decrease the yield. With safe AWD, there is usually a 15–30% water savings. AWD was introduced in the Philippines in 2002, Vietnam in 2003, and Bangladesh in 2005. The technology was initiated in Indonesia, Laos, and Myanmar from 2005 to the present. The activities on AWD are still ongoing in all of these countries and AWD is continuously being promoted under the "One Must Do, Five Reductions" program in southern Vietnam.

Aerobic rice is a production system wherein specially developed AR varieties are grown in well-drained, nonpuddled, and nonsaturated soils (Bouman and Tuong 2001). These varieties are typically intended for rainfed and "water-scarce" areas. AR varieties have longer roots, aiding water absorption and improving air circulation in these water-short environments. AR needs 50–70% less water than lowland (flooded) rice and produces fairly acceptable yields under flood conditions. Activities on AR by the WS Work Group were conducted in China and India from 2001 to 2007, and in the Philippines (from 2001), Myanmar (from 2006) and Laos (from 2010) to present.

2.5 Other work groups/units and integrated technologies

Over the four phases of the IRRC, the institutional structure, administrative unit, and working groups evolved and changed over time. In Phase I, for example, the PS Work Group was associated with the RTDP project. The Integrated Pest Management Network (IPMNet) was also an original "working group" of the IRRC in Phase I. This group spearheaded some of the early IPM dissemination work in Vietnam, which was the precursor to some of the integrated programs in Vietnam such as the "Three Reductions and Three Gains" (3R3G) program and the "One Must Do, Five Reductions" (1M5R) program (see Section 2.5.3 below). This section briefly describes some of the other units or groups within IRRC.

2.5.1 Crop Health and Climate Change work groups

The Crop Health and Climate Change work groups are the two newest work groups of the IRRC, both initiated in the Consortium's Phase IV. Recognizing significant changes in crop management environments over the past two decades, the Crop Health Work Group (CHWG) was launched to address the effects of these shifts in crop production contexts on crop health. It regards crop health as one key outcome of crop management decisions with regard to choice of rice variety, crop establishment, and fertilizer and water management practices. Primarily diagnostic, the Work Group's activities look at disease, pest, and weed problems in various field sites in the Philippines, Thailand, and Vietnam through on-farm experiments and surveys. The work group is currently led by Dr. Adam Sparks (Banks et al. 2011, Macasero et al. 2012).

With an aim to develop decision support tools for crop health, the CHWG has already produced helpful technologies since its establishment in 2009. A simple epidemiological model, EPIRICE, was developed and linked to a crop establishment date model and to a climate database in 2010. The technology enables modeling of the potential of rice epidemics of blast, brown spot, bacterial blight, sheath blight, and tungro (IRRC 2010). Another notable technology developed is the RICE-PRE tool, a crop health syndrome model based on surveys from 467 rice fields in tropical and subtropical Asia and is used to predict crop health issues before the cropping season begins. This technology has been adopted as a framework for crop health management in the Philippines, Thailand, and Vietnam (IRRC 2010, Macasero et al. 2012).

The Climate Change Work Group (CCWG), on the other hand, was established in the latter part of IRRC's Phase IV (2011). The Work Group focuses on advancing methods and aiding farmers in mitigation of greenhouse gas emission and adaptation to climate change (and more severe climate extremes).

It intersects with the IRRC and CURE (Consortium for Unfavorable Rice Environments) research programs as adaptation to climate change is particularly critical in unfavorable environments, and some favorable conditions may become hostile due to climate change (and vice versa) (Banks et al. 2011). Directing the CCWG is Dr. Reiner Wassmann.

Note that the CHWG and CCWG are new work groups and the technologies developed by these groups are still in their early stages. Hence, assessing the impacts of technologies from these work groups is not yet feasible and, thus, the available studies of technologies from these work groups are not considered in this assessment.

2.5.2 Coordination Unit and Communications Team

The IRRC Coordination Unit (CU) facilitates the interdisciplinary research efforts within IRRC and provides general facilitation of consortium-wide research and delivery activities. It complements the existing work groups by coordinating the integration of their activities, facilitating cross-country learning, developing the research-extension interface, developing communication strategies, conducting impact assessments, and managing of the IRRC country outreach programs (ICOPs). It also provides expertise to assist IRRI and national scientists working on natural resource management of rice, in learning end-user attitudes in technology adoption, moving research into extension pipelines, and measuring impacts of research at a local scale (Banks et al. 2011; IRRC, 2005, 2009, 2010). The Unit is led by Dr. Grant Singleton.

One significant function of the CU is to ensure that the IRRC implements an effective multifaceted communication strategy to promote best management practices to irrigated rice farmers in Asia. Communication materials such as newsletters (e.g., the *Ripple* newsletter), briefing papers, fact sheets, press releases, flyers, posters, books, and other publications are produced and disseminated to promote IRRC technologies and its impacts. Other tools such as Web sites, social networking sites, and other online avenues are also used and managed by the Communications Team of the IRRC. Documentation of NRM technology adoption through participatory video approach (such as those developed in Indonesia and the Philippines), and addressing the needs of partners through various media and activities (such as radio plugs, business forums, and video workshops) are also done under the supervision of the communications component of the CU (Mendoza 2012).

Another program managed by the CU, the IRRC ICOPs, was initiated in Phase III of the Consortium. It is a platform through which IRRC technologies are validated, scaled out, and their impacts realized in local contexts. ICOPs are usually implemented in collaboration with or through the programs initiated, led, and sponsored by the NARES of a particular country. Stakeholders include various organizations, from research to extension, government and nongovernment organizations, the private sector, and farmer organizations/groups. These ICOPs began in October 2005 and have been established and implemented in Myanmar, the Philippines, Indonesia, Vietnam, and Thailand (Palis et al. 2010a).

2.5.3 Integrated technologies and others

2.5.3.1 Three Reductions, Three Gains (3R3G) Program: Vietnam

The 3R3G (*Ba Giam, Ba Tang*) program is a technology package designed to reduce production costs, improve farmers' health, and protect the environment in irrigated rice production in southern Vietnam. The program was launched in Can Tho Province in 2003 to motivate farmers in reducing their seed rate and properly utilizing fertilizer and pesticides. It was planned as an incremental extension to the "No Early Spray" (NES) campaign launched in 1994 in the Mekong Delta (see Section 2.5.3.3). The 3R3G program involves collaborating with research and development partners (with extensive farmer participatory experiments), getting local expertise to train extension staff and farmers, and working together with all stakeholders to plan and implement the outscaling initiative (Huelgas and Templeton 2010, Heong et al. 2010).

2.5.3.2 One Must Do, Five Reductions (1M5R) Program: Vietnam

Building on the 3R3G program, the 1M5R project was launched in 2009 in An Giang Province, Vietnam through the collaboration of IRRC and the Vietnamese Ministry of Agriculture and Rural Development. This technology package aims to improve rice cultivation practices of farmers through reducing environmental pollution, reducing production cost, improving rice yield and quality, and increasing the profit of farmers. The program is locally known as *Mot Phai, Nam Giam* where it implies to farmers that for better rice production, "one must do" is the use of certified seeds, and farmers must also practice "five reductions" on the amount of seed, nitrogen application, pesticide use, water use, and postharvest losses (Pha et al. 2010).

2.5.3.3 Integrated pest management (IPM) information dissemination work: Vietnam

Integrated pest management (IPM) is generally referred to as any control alternative that can be used in place of a preventive, calendar-based application of chemical pesticides and/or automatic use of chemical pesticides in response to an infestation. Essentially, it examines and integrates a holistic and wide range of control methods (from the biological, cultural, genetic to chemical) to manage pest populations through economically and ecologically balanced approaches (Rejesus et al. 2010).

Two primary methods were used to propagate IPM information in Vietnam: the farmer field schools (FFS) and the NES campaigns. Using a more experiential and participatory approach, FFS is designed to strengthen farmers' capacity to attend to his/her own pest problems through the proper use of different agronomic practices. The IPM FFS method also encourages farmers to reduce or eliminate insecticide spraying to maintain a healthy field ecology, where insect predators are in sufficient numbers to manage pest populations (Rejesus et al. 2010).

NES, on the other hand, uses a more straightforward approach of media tools that directly delivers the simple message of not spraying insecticide for leaf-feeding insects in the first 40 days after sowing to farmers. IRRI research findings reveal that leaffeeder control is unnecessary during the early stage of rice growth as the plant naturally makes up for any injury caused by these insects. Several mass media instruments such as posters, pamphlets, cassette tapes with radio drama, billboards, cars with speakers, and printed calendars were used in this campaign (Rejesus et al. 2010).

2.5.3.4 Integrated technologies in Indonesia

In April 2008, an adaptive research project was initiated in South and Southeast Sulawesi in Indonesia to better understand the factors affecting adoption of rice technologies and address the reasons behind the low yields in irrigated rice systems in the two provinces (such as technical constraints to crop production, and limited access to and uptake of knowledge-intensive crop management practices). Research and capacity-building activities were held in farmer's fields and included controlled benchmarking of technologies, technology adoption and adaptation by farmers in an adaptive research framework, and development and implementation of an integrated cropping management FFS (ICM-FFS) that ran for a cropping season. Technologies benchmarked were AWD, IPM to control stem borers and other insect pests, storing of rice using the IRRI Super Bag (HSS), DSR using a drum seeder coupled with appropriate weed management, EBRM, and two SSNM approaches (Singleton et al. 2011a).

3. Economic impacts: evidence, surplus analysis, and poverty

One specific objective of the meta-impact assessment is to conduct an economic benefit-cost analysis that aims to estimate the rate of return of donor investment(s) in IRRC research and outreach activities (see TOR in Appendix 1). The interest is in calculating quantitative economic impact measures for specific technologies developed by the different IRRC work groups and for the IRRC as a whole. To achieve this objective, we first reviewed the existing economic impact evidence based on the existing literature and then conduct an economic surplus analysis consistent with the accepted literature on economic impact assessment of agricultural research (Alston et al. 1998). The inventory of economic impact evidence provides information that would help in operationalizing the economic surplus models. A poverty impact assessment was also performed to provide an indication of how IRRC technologies may affect farm poverty in specific study areas.

The analytical approach utilized in this study allows for calculation of changes in economic surplus measures (i.e., changes in producer/consumer surplus due to adoption of an agricultural technology), net present values (NPV), BCRs, and internal rate of returns (IRR) for the various IRRC technologies developed in specific countries and for IRRC as a whole. In this section, we review the existing economic impact literature (by work group), describe the empirical approach used in the economic surplus analysis, present the main results from this analysis, and discuss the poverty assessment conducted.

3.1 Inventory of economic impact evidence

3.1.1 Labor Productivity and Community Ecology (LPCE) Work Group

3.1.1.1 Direct-seeded rice (DSR)

Several studies have been conducted to evaluate the economic impact of DSR. These evaluations of DSR typically incorporate complementary technologies such as weed management (e.g., herbicide) and short-duration varieties. These "packages" of technologies are then compared with the typical transplanting (TP) method of crop establishment. Most of the empirical evidence on the economic effects of DSR is from studies in Bangladesh.

In Bangladesh, Jabbar et al. (2008), Mazid and Johnson (2010), and Palis et al. (2012a) are three studies that examined economic effects of DSR. Jabbar et al. (2008) surveyed farmers in 2005 (n=113) who participated in on-farm trials of DSR and those who did not participate (and not adopted DSR). Yields of farmers who adopted DSR were 3–5% higher than those of farmers who transplanted rice without using herbicides. However, the yields of these DSR farmers were 1–3% lower than yields of farmers who transplanted and used herbicides. In terms of costs, Jabbar et al. (2008) found that DSR farmers typically had 10−20% lower costs compared with farmers who transplanted (regardless of whether herbicides were applied or not). These lower costs were mainly due to lower seed, crop establishment (labor), and weeding (labor) costs. In light of these results, net incomes of DSR farmers tended to be 2−32% higher than farmers who used transplanting.

Utilizing farmers' field trial data in Bangladesh (n=38 to 100), Mazid and Johnson (2010) found that farmers who used DSR produced yields that are about 11−25% higher than farmers who used TP (for the 2005−07 wet season). They also indicated that, in the 2005 season, there was an almost 96% reduction in labor requirement for sowing under DSR. Note that Mazid and Johnson (2010) primarily evaluated DSR in conjunction with shorter duration varieties, proper weed management, and use of either *lithao* or drum seeder (for sowing). The study also indicated that hunger (during the *monga* period in Bangladesh) would likely be reduced with the use of DSR because of increased employment opportunities at harvest time (November-December) due to use of earlier maturing varieties.

Based on survey data in Bangladesh (n=196), Palis et al. (2012a) also presented results showing that farmers who used DSR (in conjunction with short duration varieties, weed management, and *lithao* (or dry seeder)) had 17% higher rice yields than farmers who used TP (and longer duration varieties). These observed higher rice yields, combined with the lower labor cost associated with DSR (approximately 8% lower), produced a net income for DSR that is 28% higher in the wet season and about 90% higher in the dry season (which is also likely due to early harvest that allowed for planting of other cash crops aside from rice).

These three studies from Bangladesh generally show that DSR, combined with short duration varieties, tend to moderately increase rice yields and lower labor costs, such that net income for farmers who use these technologies tend to be higher than those of farmers who use traditional TP. Note that the impact studies in Bangladesh usually do not report whether the differences in yields, costs, and/or income are statistically different (except for Palis et al. 2012a) and none of them control for possible selection issues (i.e., control for observable and unobservable farmer characteristics) that may introduce bias into their impact estimates. Future work should use methods that would control for selection problems and allow for getting a better counterfactual. Most of these studies are also not published in peer-reviewed journals.

Aside from evidence from Bangladesh, there are other economic evaluations of DSR in India that compared DSR farmers vis-à-vis non-DSR farmers (Singh et al. 2008, 2010). Singh et al. (2008), based on experimental data, indicated that DSR generated yields not substantially different from TP, but there were cost savings (labor, irrigation, and tillage) from DSR that made net income higher for this technology than for TP. The study by Singh et al. (2010) found that Indian farmers who used DSR tended to have lower yields than those who used TP (i.e., they did not specify magnitude), but net income still tended to be higher for DSR farmers because of lower costs (from lower land preparation and crop establishment labor). Note that these studies suffer from the same limitations we list above for Bangladesh.

Malabayabas et al. (2013), on the other hand, conducted an ex ante impact evaluation of DSR in India and found that yields of DSR farmers were typically 5% less than those of farmers who used TP. But lower labor and fertilizer costs from the DSR practice compensated for the lower yield, such that DSR adopters had higher net income than TP farmers. Based on these farm-level impacts of DSR and using an economic surplus framework, Malabayabas et al. (2013) estimated that the net present value of DSR systems in India (for 2000−29) is more than US$33 million and the BCR is larger than 36:1.

3.1.1.2 Ecologically based rodent management (EBRM)

The economic impacts of EBRM have been documented by several studies in Vietnam, Indonesia, and the Philippines. But a preponderance of available economic evaluations was noted in Vietnam. Among the earlier studies that examined EBRM in Vietnam are Palis et al. (2004a), Palis et al. (2005), and Brown et al. (2006). There were also more recent studies conducted by Palis et al. (2010b), Brown (2010), Palis et al. (2011a), Johnson et al. (2012), and Ninh et al. (2012).

Earlier studies of EBRM primarily compared treatment groups (who predominantly used CTBS) and control groups who did not use this technology. They all showed substantial reductions in yield losses caused by rodents. The studies by Palis et al. (2004a), Palis et al. (2005), and Brown et al. (2006) indicated a reduction in rodenticide use by EBRM farmers relative to non-EBRM farmers. However, there is some evidence in Palis et al. (2005) and Brown et al. (2006) showing some increases in cost due to expenses for building the CTBS. The early evidence on the yield effects of EBRM was also slightly mixed. For example, Palis et al (2004a) and Palis et al. (2005) showed yield increases in different regions of Vietnam ranging from -9% to 22%, while Brown et al. (2006) observed yield increases from -4% to 1%. Even with this mixed results in terms of yield changes, the marginal BCRs of EBRM (vis-à-vis the traditional control method) calculated in Palis et al (2004a) and Palis et al. (2005) were still strong (i.e., all above 2:1).

More recent evaluations of EBRM typically study the more "holistic" version of this technology where rat campaigns and other community-based practices (e.g., synchrony of cropping, reducing irrigation bank widths, improving general hygiene) are combined with CTBS. In this more comprehensive EBRM approach, CTBS is only recommended when losses for a particular cropping season is expected to be greater than 10%. Palis et al (2010) assessed the EBRM experience in the Han Nam province of North Vietnam using a "before-after" framework (i.e., survey before EBRM use [in 2005] and after EBRM use [in 2009]). Yield loss due to rats decreased by more than 90% and resulted in consequent yield increases of about 9%. Rodenticide use was reduced by more than half (62–90%). Net income increases after EBRM use was about 35% (mainly due to the improved rodent management practices). The peer-reviewed article of Palis et al. (2011a) essentially provides results similar to the earlier Palis et al. (2010b) book chapter. Yield loss due to rats was observed to still have been reduced by over 90% and yield increase due to EBRM was about 9–14.5%. However, the observed rodenticide use reduction was only between 52% and 60% and net income increase was only about 18–20%.

Brown (2010), on the other hand, found more modest reduction in rice losses due to rats (88%) and also lower yield increases attributed to EBRM (around 0.9–1.9%). Observed reduction in rodenticide use is over 50%. Johnson et al. (2012) also reported more modest impact numbers, 33–50% reduction in yield loss due to rats and an observed yield increase of 2–5% for EBRM. Reduction in rodenticide use due to EBRM was in the 62–90% range.

A recent study by Ninh et al. (2012) more carefully examines the yield and income impact of EBRM in Vietnam through the use of econometric approaches that account for selection issues. A combined propensity score matching and difference-in-difference econometric technique for panel data was used to control for selection bias from observable and unobservable variables. This allows for more precise estimation of the yield and income effects of EBRM. The study found that EBRM increase yields by 10–12% and net incomes by 30–48% when selection issues are addressed. These effects were statistically significant at the 1% level. The estimated impact of EBRM on yields and incomes tend to be overestimated (i.e., by about 2% for yields and 40% for incomes) if selection issues are not addressed. This highlights the importance of addressing selection bias when estimating the impact of technological innovations on farm outcomes.

Studies in Indonesia (Singleton et al. 2005, Brown 2010, Sudarmaji et al 2010) and the Philippines (Flor and Singleton 2011) found EBRM impacts similar to those observed in Vietnam. Singleton et al. (2005), Brown (2010), and Sudarmaji et al. (2010) all found that EBRM increased mean yields by about 5–6% in Indonesia. These studies also showed that yield losses due to rats were reduced by 33–50% when EBRM was used by rice farmers. In the Philippines, Flor and Singleton (2011) showed that farmers who used EBRM have, on average, 8–13% higher yields relative to those who did not use EBRM. Studies by Brown and Khamphoukeo (2010) and Frost (2007) also reported similar impacts of EBRM in Lao and Cambodia, respectively (e.g., yield impact of 5% in Cambodia).

Although there have been a number of impact studies that examined EBRM in several different countries, most of these impact studies did not use a rigorous counterfactual framework that controls for possible selection issues. The study by Ninh et al. (2012) was the only one that more explicitly addressed selection issues due to observable and unobservable variables (i.e., by using propensity score matching and difference-in-difference techniques). Only a handful of studies indicated whether differences in yields, input levels, and/or costs were statistically different. In addition, most of the studies cited above were not published in peer-reviewed journals (with the exception of three or four studies). These limitations point to fruitful future impact studies that could help better understand the economics and economic impacts of EBRM.

3.1.2 Post Production (PP) Work Group

3.1.2.1 Hermetic seed storage (HSS)

Only a few studies/reports have examined the potential economic impact of IRRC's HSS (or Superbag) technology. Gummert (2012a) presented qualitative observations on the potential economic benefits of HSS and some general yield/income numbers encompassing his experience with the technology in several Southeast Asian countries (Cambodia, Indonesia, Laos, Myanmar, Philippines, Vietnam). Field studies in Southeast Asia have shown that HSS controls insect grain pests without using chemicals, protects the grain from rodents, maintains a high seed germination rate, and results in less broken grains during milling relative to open storage systems (Gummert 2012a). Yi et al. (2010) also found evidence of higher germination rates for seeds stored through HSS in Myanmar. Hence, rice farmers who use HSS to store seeds for their own use generally reduce storage losses from pests (at lower costs) by 2–10% and can sell surplus seeds in the market (i.e., since seeds stored with HSS have higher germination rates, farmers can use lower seed rates in their operation by 30–60%). Gummert (2012a) also mentioned that seeds from HSS have higher grain quality that can potentially improve prices received by farmers who sell their seeds (i.e., 30% higher price). A presentation by Flor (2012) also cited lower seed rates and higher incomes when Cambodian farmers used HSS.

Ryan (2007) investigated the financial viability of individual farmer investments in HSS in Cambodia and Vietnam. In both countries, Ryan's (2007) analysis suggests that, over a 5-year period, farmers who invested in HSS would essentially recoup their investment with BCRs ranging from 0.8 to 4.1:1. The higher prices of seeds (5–25%) and reduced storage losses (~25%) from HSS allow for a return on the investment. Investment in larger scale HSS systems (e.g., cocoons) by farmer groups in Vietnam was also investigated and Ryan (2007) found that the BCR was around 0.3–1.2:1, which means that it is still marginally viable.

The Phase IV external review document (Banks et al. 2011) also took note of the positive economic benefits cited above but also explains that a farmer who adopts HSS (and use his own high-quality seeds) can avoid the high prices of certified seeds at planting time. Banks et al. (2011) also mentioned that uptake of HSS has been limited. They argue that this may be due to the price of HSS being too high for some farmers, inadequate supply of HSS in some regions, and/or farmers not fully understanding the benefits of HSS. Tado (2012), in his presentation to the assessment team, also indicated that HSS in the Philippines may be better suited for seed farmers (rather than rice producers themselves) and that industry partners (manufacturers such as GrainPro© and distributors such as Pacifica Agrivet©) will have to play important roles in the wider dissemination of HSS.

Although the studies/reports above have shown areas where HSS could have positive economic impacts, there have been no rigorous impact studies that quantitatively explored the economics and economic impacts of HSS through analysis of survey data. Even the Phase IV external review document for IRRC (Banks et al. 2011; p. 14) noted that "The Postharvest Work Group is full of promise, but there are no impacts identifiable for capacity building. The Superbag is interesting, promoted by NARES, but adoption is still weak." But as Gummert (2012a) has indicated, conducting economic impact studies on postharvest technologies tends to be difficult (relative to traditional production technologies) because uptake of these engineering technologies typically takes longer and involves activities/actors further down the rice supply chain. Nevertheless, there is room for more studies that quantitatively assess the economics and economic impacts of HSS, especially ones that account for selection issues.

3.1.2.2 Flatbed dryers (FBD)

Formal studies that evaluate the economic impact of the FBD technology in Southeast Asian countries have been missing. As with the HSS technologies, only informal case studies that report potential economic impacts of FBD are available in the literature (typically the 4T Vietnamese type that is being promoted by IRRC). Gummert (2012a) suggests that, for Southeast Asian countries in general, drying losses are reduced from 2–6% when using traditional sun drying to about 1% or less with FBD (i.e., a 50–80% reduction in drying losses). The quality of the rice grains is also maintained with FBD such that the improved quality provides an additional 30% price premium over sun-dried paddy.

Several other country-specific studies indicate the same quality improvement for rice dried with FBD and the consequent price enhancement. Country presentations documented in a postharvest workshop report by Gummert (2012b) suggest that FBD provides a 2.5% increase in milling yield for farmers who used FBD in Indonesia. Reports from Myanmar show a 10% increase in milling output and 5% higher price received by farmers who used FBD instead of sun drying (Gummert 2012b). Flor (2012) reveals that farmers who used FBD in Myanmar have 0–5% higher incomes in good-weather years and 51–53% higher incomes in bad-weather years, as compared with farmers who used traditional sun drying. Consistent with this experience in Myanmar, Ryan (2007) also reports the financial viability for a group of farmers (~ nine) investing in a 4-t FBD in Cambodia and Vietnam. With farmers sharing the initial investment in FBD (~US$2000-3000), Ryan (2007) found 5-year BCRs of 0.7–1.6:1 and 0.8–1.2:1 for Cambodia and Vietnam, respectively.

Ryan's (2007) results support IRRC's business model of targeting promotion and adoption of FBD toward farmer groups at the village or cooperative level. However, as the Phase IV external review document indicates (Banks et al. 2011), the level of adoption by these groups has been limited (especially in Cambodia) and millers are the main adopters of the technology (with subsequent increases in contract drying). But the external review document also points out that dissemination and uptake of FBD has been occurring outside of IRRC efforts and commercialization has taken place in most countries. In spite of the available impact studies/reports above, more formal economic impact assessment methods that use surveys (baseline and follow-up) and statistical techniques that control for selection are still needed to more fully understand the economics of FBD in Southeast Asia.

3.1.2.3 Combine harvester (CH)

Combine harvesters allow farmers to mechanically harvest the rice crop instead of manually harvesting it (i.e., cutting, threshing, cleaning, and bundling). Thus, one potential economic impact of this technology on rice farmers is the reduction in harvest labor required (Gummert 2012a, b; Ryan 2007). The reduced labor requirement is especially important when labor is scarce due to out-migration of rural workers to urban areas in key times of the year (including harvest). Ryan (2007) suggests that about 50% of labor costs in Cambodia can be saved with CH, while Banks et al. (2011) suggest that harvesting costs can be reduced by 30–40% in Cambodia.

In addition, the use of CH allows rice farmers to avoid delays in harvesting, which, in turn, reduces postharvest losses (i.e., spoilage) and maintains rice quality (Gummert 2012a). For several Southeast Asian countries, Gummert (2012a) observes that harvesting losses are reduced from 2–6% for manual harvesting to about 1–2% when using CH (i.e., 50–66% reduction in harvest losses). Prices of better quality rice harvested using CH were also observed to be up to 30% higher when properly dried (Gummert 2012a). Despite the higher prices and lower costs, Ryan (2007) found that a group of farmers (~12) investing in CH would not find CH financially viable in Cambodia (with a BCR of 0.3–0.9:1), while farmer groups investing in Vietnam would only find CH marginally viable (with BCRs of 0.5–1.9:1 in north Vietnam and 0.3–1.0:1 in south Vietnam).

As with the other postharvest technologies being promoted by the IRRC, there are no formal studies that evaluated the economic impact of CH using survey methods and statistical techniques that control for selection issues. More formal economic analysis needs to be done to more fully understand whether the benefits of CH outweigh the investment cost and maintenance cost.

3.1.2.4 Laser leveling

Laser leveling is another technology being promoted by the PP Work Group of the IRRC in Southeast Asian countries. This technology involves smoothing the land surface using a laser-equipped drag scraper for precision leveling, resulting in land that is smoothed to within 1-2 cm of its average elevation (Lybbert et al. 2012). In comparison, traditional leveling methods can reduce variation to only within 4–5 cm of its average elevation. At this point in time, the dissemination of this technology to Southeast Asian countries is in its initial stages. But laser leveling has been widely disseminated in India where the number of contractors grew from zero in 2001 to approximately 10,000 now.

Given the longer Indian experience with laser leveling, the available economic impact studies are typically for this region. Jat et al. (2006), as cited in Lybbert et al. (2012), suggests that laser leveling can result in 10–30% irrigation savings, 3–6% effective increases in farming area, 6–7% increases in nitrogen use efficiency, 3–19% increases in yield, and increases in annual farm revenue of US$200–300 per hectare. Gummert (2012a) point out that laser leveling in India may increase yield by 5–15%, reduce water use by 10–30%, lower harvesting losses, improve milling quality, improve weed control, and reduce pesticide use. Workshop presentations documented in Gummert (2012b) show that laser leveling increases crop productivity by ~7%, ~ 20% of irrigation water can be saved, 10–13% higher agronomic efficiency of nitrogen can be attained, and profitability would be about US$113–175 per hectare higher. Presentations in Gummert (2012b) also show that custom service providers of laser leveling services have substantial yearly net returns (~US$3595) and there would be regional employment benefits. A study by Lybbert et al. (2012) also suggests that demand for laser leveling services is elastic and subsidies may work well in encouraging farmer adoption.

Given that laser leveling has only been recently introduced in Southeast Asian countries (i.e., Vietnam and Cambodia), economic impact studies of laser leveling in this region have been limited. But workshop presentations documented in Gummert (2012b) showed some initial economic impact findings for Vietnam. Some initial economic benefits observed in Vietnam are as follows: average yield increases of 0.5 t ha^{-1} (range of 0.35–1.5 t ha^{-1}), ease of weed control with 70% less labor required for weeding, no need for postemergence herbicide, reduced irrigation cost, increased effective land area by 5–8%, and reduced lodging losses by 5–9%. Except for this Vietnam assessment, there are no available studies that have looked at the economic impact in other Southeast Asian countries (i.e., Cambodia, Philippines, Indonesia). Again, the economic postharvest studies listed above for laser leveling also did not use rigorous economic assessment methods that use farm surveys and controls for selection issues. It is important that economic impact studies be conducted as experience with laser leveling grows in Southeast Asia. Lybbert et al. (2012) indicate that their research group will conduct more formal economic evaluation in India as a follow-up to their present demand study. Similar studies have to be conducted for Southeast Asian countries.

3.1.2.5 Rice mill improvement, market information, quality tools, and integrated technologies

Aside from the major technologies that the PP Work Group has helped develop/disseminate in Southeast Asian countries, the Work Group has also provided rice mill improvement support, market/price information delivery mechanisms, and rice quality tools for farmers. Gummert (2012a) explained that the PP Work Group interacted with local rice mills in Cambodia, Myanmar, Lao PDR, Indonesia, and Vietnam to upgrade/improve rice mill efficiencies and to develop appropriate business plans. The potential farm-level economic impacts of these improved milling facilities are 10–15% more rice return for contract milling through the improved mills and better price received (due to higher quality milled rice). Ryan (2007) also found that, when Cambodian and Vietnamese village farmer groups (~20 households) invest in a IRRC village rice mill, they will find it financially viable with BCRs of 1.2–3.2:1 for Cambodia and 0.7–1.7:1 for Vietnam.

The PP Work Group also provided notice boards with market price information in Cambodia. Smallholder farmers used this information to bargain for good prices and allow then to get higher prices (Gummert 2012a). But the Phase IV external report suggests that these price boards were not being updated regularly and were eventually abandoned. Promotion and dissemination of rice quality tools were also conducted by the PP Work Group. Gummert (2012a) suggests that these tools allow farmers to accurately assess moisture contents so that they can bargain for better prices and also reduce quality losses. It is important to note that the economic impacts for rice mill improvements, market price delivery, and rice quality tool provision are (at best) anecdotal. Formal economic studies still need to be conducted to more adequately assess its impact (once there is sufficient adoption).

Outside of the assessments for individual postharvest technologies above, there is one study by Flor and Maligalig (2009) that examined the impact of an “integrated” package of postharvest technologies introduced in Cambodia that includes HSS (e.g., the small-scale Super Bags and the large-scale 5-t cocoons), rice milling improvements, market information boards, weighing scales, and moisture meters. Based on 2008 survey data of farmers in project sites and in control villages, a “with-without” comparison of means was undertaken to assess the impact of the integrated postharvest package on several outcome indicators. The Flor and Maligalig (2009) study was fairly careful to assure that the sociodemographic characteristics were not statistically different between the project site farmers versus the control site farmers. This approach essentially attempts to account for selection due to observable characteristics. However, there are still some observable characteristics (e.g., membership in cooperatives) that are still significantly different between the two groups. Note that farmers in project sites are considered adopters of the integrated package if they adopted at least one of the postharvest technologies.

Results of the analysis in Flor and Maligalig (2009) indicate that seeding rate of farmers who adopted integrated postharvest technologies (primarily the HSS) had a 22–28% lower seeding rate than farmers in the control site and this difference was statistically significant. There were no statistically significant differences between farmers in the project sites versus those in the control sites with respect to labor use and total costs. But prices received by farmers in the project site were statistically higher (13%) than those in the control sites. Mean yields of farmers in the project site were also 15% higher compared with those of the control farmers, although there was no mention whether this difference is statistically significant. Gross income and net income of farmers who adopted the integrated postharvest technologies were found to be 30–>100% higher than those of producers in the control site (but no mention whether these figures are statistically significant).

Flor and Maligalig (2009) is the only study we found that utilized survey data to assess the impact of postharvest technologies disseminated by IRRC. Although this study attempted to account for possible selection problems due to observable variables, there is still room for future work by using more advanced statistical methods that account for selection problems due to both observable and unobservable characteristics.

3.1.3 Productivity and Sustainability (PS) Work Group

The PS Work Group primarily developed, promoted, and disseminated site-specific nutrient management (SSNM) as an approach for improved nutrient management in rice. SSNM improves nutrient management in rice through better targeted applications of fertilizer (in terms of amount and timing). It is a field-specific approach that dynamically applies fertilizer as and when needed. Some of the tools used to facilitate adoption of SSNM principles are the leaf color charts for N management (LCC) and the *Nutrient Manager* decision tool (this tool is extended to farmers through the Internet, mobile/smart phones, videos, CDs, and/or printed quick guides).

The PS Work Group has been in existence since the inception of IRRC (under different names) and a number of economic impact studies have already assessed SSNM. Two types of assessment studies have been conducted for SSNM: 1) earlier studies (before 2010) that have relied primarily on controlled field experiment/trial data, and 2) more recent studies (2010–12) that have used more formal economic assessment methods (i.e., survey techniques, economic surplus models, and methods that account for selection). The earlier studies that have evaluated SSNM through field experiment data in different countries are those of Dobermann et al. (2002) and Pampolino et al. (2007), among others.[1] For eight key irrigated rice production domains in Asia (China, India [two locations], Indonesia, Philippines, Thailand, and Vietnam [two locations]), Dobermann et al. (2002) found that average grain yields of SSNM field sites were 7% higher than the fields that used traditional fertilization practices (statistically significant at 1%). On average, SSNM plots had 4% less nitrogen (N) fertilizer than plots that used traditional fertilization techniques, but phosphorus and potassium levels of SSNM plots tended to be 8% and 90% higher, respectively, than traditionally fertilized plots. SSNM plots were also found to have fertilizer uptake efficiencies that were statistically higher for SSNM practices (30–40%). Lastly, Doberman et al. (2002) found that profitability of SSNM plots tended to be 6% higher than non-SSNM plots and the amount of profitability increase was about 12% higher than average returns of farms in the different regions. Note, however, that the figures reported above are averages across regions and that there is some impact variability across sites (Dobermann et al. 2002; see country-specific studies in Dobermann et al. 2004). But the positive yield effect and improved N uptake efficiency are typically observed in all sites.

Pampolino et al. (2007) is another study that investigated the potential economic impacts of SSNM using field trial data from India, Philippines, and Vietnam. Based on focus group discussions of farmers who participated in SSNM field trials (SSNM adopters) and those who did not (nonadopters), Pampolino et al. (2007) observed that average grain yields across countries for the SSNM adopters were 8% higher than for non-SSNM adopters, with yield increases of around 11–25% in India, 2–10% in the Philippines, and -1–9% in Vietnam. Field trial data also suggested that SSNM farmers used fairly similar number of fertilizer applications as did non-SSNM farmers, but SSNM farmers in the Philippines and Vietnam tended to have lower N applications than non-SSNM adopters (i.e., 10% and 14%, respectively). Nitrogen efficiency also increased in all countries for SSNM users. Even when there are cases of lower input use for SSNM farmers, input costs of SSNM farmers were not significantly different from the input costs of nonadopters (on average) across all countries. Hence, the observed positive profit differentials of SSNM farmers relative to nonuser farmers in India, Philippines, and Vietnam (47%, 10%, and 4%, respectively), were mainly attributed to the yield increase from SSNM rather than from fertilizer

[1]There are several country-level SSNM studies that relied on field experiment/trial data. See, for example, the county-level studies in Dobermann et al. (2004) for China, India, Indonesia, Philippines, Thailand, and Vietnam. The study by Alam (2005) also examines the yield and profit impact of SSNM in Bangladesh using field trial data. In the interest of conciseness, individual country-level results are not discussed here (i.e., too many to discuss individually). Thus, only studies that more comprehensively report field experiment-based SSNM evaluations across countries/locations are discussed.

use reductions. SSNM farmers across all countries had 14% higher profits, on average, than non-SSNM farmers.

More recent economic impact studies of SSNM have relied on survey data and more formal economic modeling techniques. Nga et al. (2010) examined the economic impact of SSNM in the Red River Delta of Vietnam using a 2007 survey of SSNM adopters and nonadopters (i.e., a “with-without” technology comparison of means; n = 372). In spring 2007, mean rice yields for SSNM adopters were 3.4% statistically higher than the yields of nonadopters (at the 1% level) for the study site in Ha Nam province. Moreover, a 6.6% higher yield for SSNM adopters was also observed for the study site in Ha Tay province (in spring 2007). However, summer-season and total full-year yields were not statistically different between SSNM adopters and nonadopters. Fertilizer applications (N, P, and K) in the spring season were also typically lower for SSNM adopters (especially in the spring of 2007) for both study provinces. Using the estimated yield and cost differences, a partial budget analysis by Nga et al. (2010) found that SSNM farmers would earn approximately US$78 and US$58 ha^{-1} per year in Ha Nam and Ha Tay provinces, respectively. An additional economic surplus analysis using the Dynamic Research Evaluation for Management (DREAM) model suggests that, over the 1997–2006 period (and at a 5% discount rate), research investment in SSNM in Ha Nam and Hat Tay more than outweighed the research cost, such that the estimated rate of return on investment would be 120% and 147% in Ha Nam and Ha Tay, respectively. Hence, the authors point out that research investments in SSNM generated net social welfare gains in the Red River Delta of Vietnam.

The recent study by Rodriguez and Nga (2012) used the 2007 spring season data in Nga et al. (2010) (n=371) and more carefully accounted for potential selection and endogeneity problems in the data using instrumental variable (IV) techniques. They found that the impact of SSNM on yields and profits may be underestimated when selection issues are not accounted for in comparing behavior of SSNM adopters versus nonadopters. Rodriguez and Nga (2012) estimated that SSNM statistically increases yield by about 11% relative to non-SSNM users, which is substantially higher than the 3–6% estimated yield impact when selection is not accounted for (as in Nga et al., 2010). SSNM was also found to have no statistical effect on nitrogen fertilizer and pesticide use. With higher yields and statistically similar input use/costs, the profit effect of SSNM was estimated at US$145 ha^{-1} in Rodriguez and Nga (2012) (i.e., 29% higher than nonadopters), while it is only about US$57-78 ha^{-1} (11–58% higher) in the previous Nga et al. (2010) study that did not account for selection issues. The difference in estimated economic impact magnitudes indicates the importance of controlling for potential selection problems in analyzing the effects of technology interventions.

A study by Flor (2011), on the other hand, used key informant interviews and focus group discussions (FGDs) within a rapid rural assessment framework to specifically understand the adoption and impacts of LCC adoption in Bangladesh (rather than SSNM impacts in general). She found that LCCs have been distributed to about 400,000–600,000 farmers by 2011, among which, 225,000 have been trained. In various study sites, about 2–31% of farmers were the estimated users of LCC by 2011. Results of the key informant interviews reveal that farmers reduced their urea application by about 50%. There was, though, some evidence of increased P and K application, as well as increased labor use for the LCC readings. Based on the FGD, Flor (2011) also found that farmers who use LCC tended to have 12–31% higher yields than those who did not use LCC, though there seems to be uncertainty as to the profit effect due to fluctuating fertilizer prices. Note that the data used in Flor (2011) were not wide-scale survey data and selection issues were not addressed.

3.1.4 Water Savings (WS) Work Group

3.1.4.1 Alternate wetting and drying (AWD)

The AWD technology is one of the more "mature" IRRC technologies with evidence of widespread adoption in several countries (e.g., Philippines and Vietnam). Lampayan (2012) estimates that AWD adoption in the Philippines and Vietnam is about 81,687 farmers (~93,000 ha) and 40,688 farmers (~50,000 ha), respectively.

Most of the existing economic impact studies for AWD were conducted in the Philippines, given its widespread adoption in that country. The first few economic studies of AWD in the Philippines were typically for pump irrigation systems (i.e., deep tube wells) where IRRC conducted field trials. Lampayan et al. (2004) suggest that farmers who used AWD had irrigation water savings of 5–20% based on field trials conducted in 2002. Yields were not statistically different between AWD adopters and nonadopters. Farmers who used AWD had -6–42% higher profits relative to farmers who did not use AWD. Similar results were reported by Lampayan et al. (2012a) for the 2003 and 2005 crop years where water savings of about 16–30% were observed. Yields of farmers who used AWD were observed to be -4–16% different as compared with non-AWD farmers. Nevertheless, labor and fuel cost tended to be consistently smaller (1–46%) for AWD farmers. The profit differential observed for AWD farmers (vis-à-vis non-AWD farmers) ranged from -0.1% to 31% (Lampayan et al. 2012a).

Based on data collected through semi-structured interviews and key informant interviews, Palis et al. (2004b) also examined the economic behavior of the same deep well system (i.e., AWD farmers who participated in the farmer field trials in Lampayan et al. [2004]). Their results indicate that AWD farmers also had 5–30% water savings, lower labor costs, no significant yield penalty, and profit increases ranging from -0.1% to 8%. Based on 2005 survey data in central Philippines (i.e., collected in the same areas as the studies above; n=146), Rejesus et al. (2011) also examined the potential yield, profit, and input cost impact of AWD using propensity score-matching techniques to control for selection issues. When controlling for selection on observable variables, Rejesus et al. (2011) found that AWD farmers use 38% less irrigation hours than non-AWD farmers (significant at the 5% level). However, yield and profits of AWD farmers were not statistically different from those of non-AWD farmers. But Rejesus et al. (2011) still notes that selection based on unobservable variables may still invalidate the inferences from the analysis and future work that addresses this issue would be needed.

As explained in Lampayan et al. (2012a), with the apparent success of AWD in pump-irrigated systems in central Philippines, AWD was then also introduced in large-scale gravity/canal irrigation systems in the area, as well as in southern Philippines (Bohol province). These large-scale irrigation systems are government-owned, and managed by the National Irrigation Administration (NIA). In these systems, farmers are organized into irrigators' associations (IAs) and they pay a nominal fee on an area-basis to get access to water. As Sibayan et al. (2010) had shown, distribution of water in these systems was typically not equitable, with upstream and/or middle-stream farmers getting the bulk of the water and downstream farmers receiving less (or none in some areas). Through demonstrations, training, and farmer cooperation within IAs, AWD was implemented in several large-scale gravity systems in the Philippines. To date, only the studies of Sumalde et al. (2012) and Valdivia et al. (2012) examined AWD adoption and impact in publicly managed large-scale gravity irrigation systems.

Sumalde et al. (2012) used a "before-after" AWD framework to assess the farm-level impact of this water-saving technology in Bohol, Philippines. This means that a survey was conducted before implementation of AWD in the system (in this case, in 2005) and the same farmers were surveyed after implementation of AWD (in 2010). Sumalde et al. (2012) found that yields were significantly higher after implementation of AWD (11–13%), but noted that the farmers did not attribute the yield increases to AWD per se. Regression analysis controlling for input use and other variables (in addition to AWD adoption) corroborated this farmer perception when the coefficient associated with AWD adoption was found to be statistically insignificant. Costs were observed to be higher after AWD implementation, but returns were also substantially higher. This resulted in a 31–76% increase in profits for farmers in the area. But they note that increases in net income may be due to the higher prices received in 2010 relative to 2011. Nonetheless, Sumalde et al. (2012) observed that the difference in yields between upstream and downstream farmers have been significantly reduced after AWD and attributed this to the more equitable distribution of water within the AWD system. In addition, the total area irrigated increased for the whole system (~16%) and the average farm size of farmers increased by about 17% after implementation of AWD. This suggests that water became more available for farmers (especially downstream farmers), thereby prompting increases in farm size.

Valdivia et al. (2012) also used the "before-after" framework as a tool to assess the impacts of AWD in a large-scale gravity irrigation system in Bohol, Philippines but focused more on the dry-season crop. On average, farmers had 9% higher yields after AWD implementation in the system, with yield increases being felt more by downstream users. But, like what Sumalde et al. (2012) noted, farmers in the area did not attribute this yield increase to AWD. Regression analysis supported this conclusion as well, with AWD being insignificant when other observable factors were accounted for (i.e., inputs). There were some decreases in input use (fertilizer and pesticides) but input cost levels remain similar before and after AWD. Net income of farmers was observed to be substantially higher after implementation of AWD (~37–130%), although this was attributed by farmers to better prices received in 2011. Similar to findings in Sumalde et al. (2012), results in Valdivia et al. (2012) showed that total area cultivated by farmers within the irrigation system increased by ~30% and average farm size of farmers increased by 38%. This again indicates that water availability improved after AWD, such that increasing farm size is now feasible.

Aside from AWD studies in the Philippines, most of the existing AWD impact studies are for Bangladesh where the typical irrigation system used and studied is pump irrigation (deep tube well and shallow tube wells). Unlike AWD adoption in the Philippines and Vietnam, Kürschner et al. (2010) and Palis et al. (2012b) indicate that adoption in Bangladesh is only in its early stages. A comprehensive study by Kurschner et al. (2010) showed that AWD farmers surveyed in Bangladesh have 9–12% higher yields as compared with those who did not use AWD. The number of irrigation applications and irrigation cost were observed to be about 18–28% lower as well. However, Kürschner et al. (2010) indicate that labor and input costs of AWD farmers tended to be higher due to additional weed problems with AWD. Nevertheless, about 81% of the farmers surveyed (n=113) found AWD economically beneficial with profit increases of about 38% (on average).

In contrast to Kürschner et al. (2010), Lampayan (2012) reports AWD impacts based on Syngenta trial results. He revealed that water consumption by AWD users decreased by 30–50%, irrigation cost went down by about 21–27%, and yields increased by 2–9%. Lampayan (2012) also noted that AWD users had reduced labor, fuel, and machinery costs. Based on a survey that asks farmer perceptions about AWD, Palis et al. (2012b) reports that about 77% of farmers surveyed believed that AWD saves water, 32% believes that AWD lessens irrigation cost, 30.5% believes AWD increases yield, 17.5% believes AWD saves fuel, and 7.5% believes that AWD saves electricity.

Other countries with some economic impact evidence on AWD are Vietnam, India, and China. Note that AWD is typically included in the 1M5R integrated program in Vietnam, and more discussion about the impact of this integrated program is discussed in the next subsection. But Lampayan (2012) reports that farmers in Vietnam perceived reduced irrigation frequency (30–40%) with AWD; lower pumping and labor costs were thus observed. In India, Singh et al. (1996) reports that AWD resulted in reduced water use by about 40–70% without significant yield loss. Similar results were found in Cabangon et al. (2001) and Moya et al. (2004) for China, where there was strong reduction in irrigation use but no significant yield and profit penalties.

As reflected above, the existing impact evidence for AWD has been numerous. The existing studies rely heavily on both field trial data and/or farm survey data of treatment and control groups. However, most of these studies do not explicitly control for selection issues, although Rejesus et al. (2011), Sumalde et al. (2012), and Valdivia et al (2012) control for selection due to observable variables by using propensity score matching and/or regression techniques. Future studies that control for selection issues based on both unobservable and observable variables would be very important to further our understanding about the economic impacts of AWD.

3.1.4.2 Aerobic rice (AR)

The existing literature on the economic impact of AR is mainly concentrated in the Philippines and China. Based on surveys in 2005 and 2006 (n = 80), Lampayan et al. (2012b) provides a socioeconomic assessment of AR in Bulacan, Philippines, by comparing the performance of farmers who adopted AR versus those who used transplanting (lowland rice). The study found that mean rice yields of AR adopters were about 11–20% lower than those of nonadopters. Rice producers who used AR was observed to have statistically lower hired labor use (34–47% reduction) and irrigation frequency (80–85% reduction). However, herbicide use also statistically increased by 50–80%. Since AR is typically direct-seeded, the observed changes in input use are expected. Overall, AR producers had lower total costs relative to non-AR adopters, and the profitability of both practices (AR vs transplanting) was comparable. The study concluded that AR can be a good alternative to farmers in rainfed and water-short areas, but it would still not be a viable substitute to flooded rice in areas where water is available.

A study by Templeton and Bayot (2011), on the other hand, found that AR rice producers in the Philippines had about 25% lower yields compared with farmers who used transplanted lowland rice. Based on key informant interviews in Tarlac, they pointed out that farmers could save about \$330–395 ha^{-1} in irrigation cost if they use an AR production system.

The remaining economic evidence on the impacts of AR is predominantly in China. Ding et al. (2010) shows that AR producers in several villages in North Anhui, China had about 55% lower yields (on average) than lowland rice producers. But there was one village where AR yields were comparable with yields of lowland rice (i.e., Funan). The authors also noted reduced variability in yields over time. Labor cost was substantially lower for AR rice producers (~10% lower). Net income for AR producers was still substantially lower compared with farmers who used lowland rice.

Templeton and Bayot (2011) also found similar results in China. AR producers tended to have 28–37% lower yields than lowland rice producers, but AR farmers had 19–20% lower labor costs. Gross margins of AR producers were about 50% lower than those of lowland rice farmers. However, Templeton and Bayot's (2011) analysis of the benefits of research investments in AR still indicated a 22:1 BCR.

The existing impact studies on AR are still limited. Only evidence from the Philippines and China is available. Moreover, no impact study of AR has yet used statistical techniques that account for potential selection issues due to both observable and/or unobservable characteristics of producers.

3.1.5 Integrated technologies and others

3.1.5.1 Three Reductions, Three Gains (3R3G) Program: Vietnam

Two studies have examined the economic impacts of the 3R3G program in the Mekong Delta. First, Lang et al. (2008) utilized household survey data collected for the dry season (December 2004 to April 2005 winter-spring season) to compare the economic performance of 3R3G adopters relative to non-adopters in three provinces in the Mekong Delta (Can Tho, An Giang, and Soc Trang). Using simple comparison of means (e.g., t-tests), Lang et al. (2008) found that 3R3G farmers have used 21% lower seed rate, 18% lower nitrogen fertilizer, but used 26% higher potassium fertilizer, as compared with non-3R3G farmers. All of these input use effects were statistically significant. However, total pesticide use of 3R3G adopters and non-adopters was not found to be statistically different from each other. Total frequency of pesticide applications was statistically lower (14%) for 3R3G adopters. Lang et al. (2008) showed that paddy yields and total costs of 3R3G farmers were not significantly different from non-3R3G farmers. But net income was found to be statistically higher (10%) for 3R3G producers as compared with non-3R3G producers. Through an ordinary least squares (OLS) regression, Lang et al. (2008) reveals that the 3R3G program had a statistically significant positive effect on net income (by about 11.5%) when observable input cost characteristics and yields were accounted for. The authors argue that 3R3G prompted the use of better quality rice seeds that resulted in better quality rice production and higher prices received. This explains the statistically significant 3R3G impact on net income despite the non-significant effect on yields and total costs.

The second study that investigated the economic impacts of the 3R3G program in Vietnam is Huelgas and Templeton (2010). This study used farm survey data for the wet-season (May to July 2006) and dry-season rice production in the provinces of Can Tho, An Giang, and Soc Trang.[2] This study defines a 3R3G adopter as one who indicates that he/she has used at least one of the three reductions (i.e., reduced at least one of seed rate, fertilizer, and pesticide).

For the 2006 wet season, Huelgas and Templeton (2010) indicate that the following inputs were statistically lower for 3R3G adopters relative to non-adopters: seed rate (14% lower), nitrogen fertilizer (8% lower), phosphorus fertilizer (9% lower), insecticide (35% lower), molluscicide (16% lower), and fungicide (16% lower). The total cost of 3R3G farmers was also observed to be statistically lower by 12% in the 2006 wet season. But yields of 3R3G producers were not significantly different from those of the non-3R3G producers. Huelgas and Templeton (2010) did observe a statistically higher net income for the 3R3G adopters in the 2006 wet season.

For the dry-season data considered in Huelgas and Templeton (2010), findings similar to the wet-season data were observed. The following inputs were found to be statistically lower for 3R3G adopters: seed rate (13% lower), nitrogen fertilizer (8% lower), phosphorus fertilizer (9% lower), insecticide (31% lower), and molluscicide (17% lower). Total cost was statistically lower for 3R3G adopters as well (10% lower). But, unlike the wet season results, yields were statistically lower for 3R3G farmers (4% lower), and there was no significant difference in the net incomes between 3R3G and non-3R3G farmers.

Aside from these simple mean comparisons, Huelgas and Templeton (2010) also ran a unit cost ($US t^{-1}) regression where unit cost was a function of yield, farm size, province variables, and a 3R3G adoption variable. This analysis showed that, conditional on the observable independent variables in the specification, the 3R3G program resulted in a statistically significant reduction in unit cost by 7% and 8% for the wet and dry season, respectively. Using a stochastic frontier production function,

[2]The dry-season data used are for the December 2005 to April 2006 season in Can Tho and An Giang provinces. The Soc Trang data are for the December 2006 to April 2007 season.

Huelgas and Templeton (2010) also indicated that inefficiencies were lower for 3R3G adopters than for nonadopters. The potential poverty impact of 3R3G was also assessed. Comparing the net incomes of the producers in the sample to the prevailing poverty line, Huelgas and Templeton (2010) argues that most of the producers were well above the poverty line, and that the positive net income effect of the 3R3G program is likely to further improve the livelihood/well-being of producers who follow the program recommendations.

The studies of Lang et al. (2008) and Huelgas and Templeton (2010) provide a fairly comprehensive analysis of the economic impacts of the 3R3G program. But these two studies largely relied on simple comparison of means and did not account for possible selection issues due to unobservable variables. It should be noted, however, that the regression approaches used to study the net income effects (in Lang et al. 2008) and the cost effects (in Huelgas and Templeton 2010) did account for some observable characteristics. But, as indicated in the conclusions of Huelgas and Templeton (2010), further work could be done to better account for potential bias due to selection problems (from both observable and unobservable variables).

3.1.5.2 One Must Do, Five Reductions (1M5R) Program: Vietnam

The 1M5R program builds on the 3R3G program by adding two more "reductions"—water use and postharvest losses. This program was primarily implemented in An Giang province, Vietnam starting in 2009. Several studies have already investigated the possible economic impact of this rice technology program.

Based on a 2010 survey (n = 146) conducted by the Department of Agriculture and Rural Development in An Giang province, Pha et al. (2010) compared the mean input use and yield of farmers who adopted the 1M5R package versus those who did not. The study suggests that mean seed rate, nitrogen use, and frequency of water pumping were statistically lower for 1M5R producers relative to non-1M5R (i.e., 24% lower seed rate, 11% lower nitrogen use, and 12% lower water pumping). There was no statistically significant difference between the mean yields of the 1M5R producers and the non-1M5R producers. But net returns above cash cost were found to be 14% higher for 1M5R producers and this difference was statistically significant.

Singleton et al. (2011b) also reports some figures that show the potential economic effects of the 1M5R program. However, they only reported the absolute magnitudes of the difference between 1M5R and non-1M5R farmers.[3] Based on survey data from the 2010–11 dry season and 2011 wet season, Singleton et al. (2011b) reveals that farmers who adopted 1M5R reduced their seed rate on average by 70–74 kg ha^{-1} and nitrogen fertilizer by 24–28 kg ha^{-1}. Rice producers who adopted 1M5R also reduced their insecticide sprays by 2.5 applications and their frequency of irrigation pumping by about 1-1.3 times. However, mean yields of 1M5R producers and of those practicing traditional practices were very similar. But production costs were 17–20% lower, such that profits of 1M5R producers were about 4–4.9 million VND (Vietnamese dong) higher. Singleton et al. (2011b) did not report whether these differences were statistically significant or not.

Palis (2012) compared the means of key input and output variables for farmers who used 1M5R and those who did not. Based on 2009 survey data (n = 471), Palis (2012) reports that producers who used 1M5R have used 20% lower seed rate, 6% lower nitrogen fertilizer, and 11% lower potassium fertilizer. All of these differences were statistically significant. There were no statistically significant differences between 1M5R and non-1M5R producers with regard to mean phosphorus fertilizer application, irrigation cost, pesticide cost, and yields. The net returns above cash costs of 1M5R producers were statistically higher (by 14%) relative to non-1M5R

[3]Since only the absolute differences are reported in Singleton et al. (2011b), we are not able to calculate the percentage difference between 1M5R and non-1M5R producers that would allow us to be consistent with how we report economic impacts in this section (i.e., reporting percentage differences). Hence, we only report the absolute differences here (as reported in Singleton et al. 2011b).

producers. Another survey similar to the one used in Palis (2012) was conducted in 2011 and analysis of these survey data is reported in Chi et al. (2012) and Quicho et al. (2012). These studies report that seeding rate of 1M5R producers was statistically lower (by 14%) compared with that of non-1M5R producers. Irrigation cost and irrigation frequency for 1M5R farmers were statistically lower by 20% and 21%, respectively. Total pesticide costs were also statistically significantly lower by 21% for 1M5R adopters. Yields and net income of 1M5R farmers were statistically higher by 3% and 13.5%, respectively (Chi et al. 2012, Quicho et al. 2012).

The existing literature on the economic impacts of 1M5R primarily relies on simple comparison of mean outcomes. None of the studies above have accounted for potential selection issues that may have caused bias in the impact estimates. More in-depth studies that account for selection problems (due to observable and unobservable variables) are needed to more fully understand the adoption pattern and economic impact of 1M5R in the Mekong Delta, Vietnam.

3.1.5.3 Integrated pest management (IPM) information dissemination work: Vietnam

Prior to the 3R3G and 1M5R programs, there were significant information dissemination efforts about IPM to encourage reductions in pesticide use among farmers in Vietnam. Mass media campaigns using the “No early spray” (NES) slogan and IPM farmer field schools (FFS) were used as the primary dissemination approaches. The potential insecticide use impact of the NES campaign and IPM-FFS was analyzed by Rejesus et al. (2009) using cross-sectional survey data from 2005. In this study, endogeneity and selection problems were controlled by using an instrumental variable (IV) approach and by appending an inverse mills ratio in the specification (i.e., consistent with a Heckman [1979] two-step approach). Rejesus et al (2009) found that IPM-FFS farmers had significantly reduced insecticide use relative to the control farmers, but NES exposed farmers did not have significantly different insecticide use compared with the control farmers. However, the technical efficiency analysis in Rejesus et al. (2009) reveals that both IPM-FFS and NES farmers were more technically efficient than the control farmers.

Rejesus et al. (2012a), on the other hand, used panel data and a difference-in-difference (DID) approach to investigate the impacts of IPM-FFS on insecticide knowledge, insecticide use, and yields. Availability of panel data allows Rejesus et al. (2012) to control for selection issues through the DID approach that accounts for both selection on observables and unobservables. The study found that IPM-FFS did not result in statistically significant difference in insecticide use and yields over the time period examined. They argued that FFS may have an initial knowledge-improving effect and insecticide-reducing effect, but this was not sustained over time, either due to knowledge erosion or continuous advertisements of pesticide companies. Rejesus et al. (2012a) also did not find empirical evidence on the effectiveness of re-training farmers (based on a small subsample in the data).

3.1.5.4 Integrated technologies in Indonesia

In 2008, an IRRI-led project was initiated in eastern Indonesia to develop and disseminate rice agricultural technologies. The technologies included AWD, IPM, HSS, direct seeding using a drum seeder (together with proper weed management), EBRM, and SSNM. These technologies were primarily disseminated as a package through an integrated cropping management farmer field school (ICM-FFS). Three studies provide some analysis of the economic impact of the ICM-FFS program (and the aforementioned technologies).

Singleton et al. (2011a) discusses this project in detail and indicates that farmer cooperators (n = 10–15) in four project villages who adopted the ICM-FFS technologies had higher mean yields ranging from 0.5 to 2.3 t ha^{-1} (in the 2009/2010 season) relative to a baseline of 3.0–4.5 t ha^{-1} that was observed in the 2008/2009 season prior to project implementation (i.e., yields were 16–51% higher after project implementation). The difference in average costs of farmer-cooperators in the 2009/2010 dry season compared with the baseline 2008/2009 season ranged from -10.8% to 16.5% (i.e., there are cases where costs increased and cases where costs decreased). In general, mean farmer income was observed to have increased by 22–566% for the ICM-FFS farmers (relative to the baseline income prior to the project). However, comparing cooperators vs noncooperators in the 2009/2010 season, Singleton et al. (2011a) showed that the yields of farmer-cooperators were higher by only 8–20% and that mean cost differentials between cooperators and noncooperators ranged from 0% to 9%. Mean incomes of farmer cooperators were higher by about 21–50% as compared with nonfcooperators in the 2009/2010 season.

Flor et al. (2012) also describes the ICM-FFS efforts in Indonesia. This study focused on the use of and knowledge about the different technologies promoted by ICM-FFS (n=223–230), although some economic impact measures were reported. Flor et al. (2012) indicates that ICM-FFS farmers (in project sites) had 25–39% higher yields than nonadopters in control sites and this difference was statistically significant. They also have results showing net income increases of around 40–50% (although it was not mentioned whether this was statistically significant). Input use was generally found to be lower for farmers in project sites compared with those in control sites (e.g., fertilizer 22% lower, insecticide 32% lower, herbicides 5% lower, and labor 16% lower).

A more thorough economic impact study of the ICM-FFS program in Indonesia was done by Dikitanan et al. (2012). This study used cross-sectional data on ICM-FFS farmers and non-ICM-FFS farmers in 2010. The propensity score matching (PSM) technique was used to control for selection bias based on observable variables. The PSM results suggest that net incomes and yields were statistically higher (by 53% and ~20%) for ICM-FFS farmers compared with non-ICM-FFS farmers. Unlike Flor et al. (2012), Dikitanan et al. (2012) found no significant difference in input use using the PSM technique.

The existing evidence on the impact of ICM-FFS in Indonesia is limited, given that only a few studies examined the issue. The body of evidence is also limited because selection issues from unobservable variables were not addressed in the analysis (although Dikitanan et al. [2012] controlled for selection bias due to observable characteristics). Further analysis of the baseline and follow-up survey data collected in the project is necessary to more fully understand the economic impact of ICM-FFS in Indonesia.

3.1.6 Synthesis, analysis, and lessons learned from economic impact evidence

The existing economic impact evidence on the various IRRC technologies has certainly been numerous and already provides an indication of the strong positive economic effects of these technologies to rice farmers in various Asian countries. There is a large body of work that assesses the different technologies developed and disseminated by IRRC. Majority of these existing economic impact studies have relied on (1) cross-sectional survey data to provide “with and without” comparisons or (2) data for the same sample across two time periods to provide “before and after” comparisons. Comparison of mean outcomes is the typical approach used, where tests to identify statistical differences in outcomes is often undertaken (but not always). Key informant interviews (KII), focus group discussions (FGD), and field trial comparisons are also some of the other approaches often seen in the literature assessing the economic impact of IRRC technologies. The economic studies to date provide a compelling argument as to the strong positive economic impact of IRRC technologies. However, even with the existing evidence on the economic impacts of the different IRRC technologies, there are still several areas that could be improved to strengthen the economic impact estimates and make it more convincing.

First, selection bias needs to be addressed in all impact evaluations of IRRC technologies. Majority of the existing economic impact studies do not use a rigorous counterfactual framework to account for selection problems due to observable and unobservable variables. If one simply relies on simple comparison of means (without randomization), it is hard to attribute the outcome differential (or impact) solely to the “treatment” or the technology intervention. This differential may be due to other underlying differences between the treatment and control group. Attributing the differential to technology intervention and identifying this as an impact would not be persuasive in this case. Using methods to address selection issues would improve the rigor of the impact evaluations.

Although there are examples of existing economic impact studies that used methods to account for selection problems (PSM, OLS regression with control variables, and panel data DID), these are in the minority. There is a need to conduct economic impact evaluation of IRRC technologies that are more in line with current methods available in the literature (i.e., see approaches discussed in the World Bank publication of Khandker et al. 2010). If resources and the opportunity are available, the more advanced impact assessment options recommended by de Janvry et al. (2011) for the CGIAR would be preferable.

Due to limited funding and resources, it is understandable that these methods cannot be implemented for assessment of all technologies. But it would be good practice to collect baseline and follow-up surveys, as well as consider randomization when possible. For cases where cross-sectional survey data is the only option, researchers should make it a habit to try and collect instrumental variables. In addition, it is recommended that researchers should plan the impact assessment before, and conduct it during, diffusion and dissemination of a new technology. Even though impact assessments tend to be conducted after a technology has been disseminated, this should not suggest that the assessment should be planned and performed after the fact.

Second, the existing impact literature on IRRC technologies has not addressed the potential differences in economic impact across different groups of farmers and/or stakeholders. Most of the existing studies focus on the “mean” impact of the technology intervention to the “average” farmer/stakeholder. Questions of whether the technologies affect small farmers versus large farmers differently (or low-income versus high-income farmers) have not been adequately addressed. Resources permitting, future studies may want to assess whether there is heterogeneity in the impact of IRRC technologies across various groups or countries. Statistical approaches that allow for evaluating heterogeneous impacts (i.e., quantile regressions) should be considered in the future.

Third, there is a large variation in the quantity and quality of impact assessments across the different IRRC technologies and working groups. There are some work groups where there are an abundant number and good quality assessments of their technologies. But there are some work groups where there have been minimal impact assessments done. This is understandable due to the differences in funding/resources across work groups and some of the technologies of the work groups are more “mature” relative to the technologies of the other work groups. Nevertheless, it would be ideal if at least one technology for each work group (especially the ones that are considered to have high potential impact) is thoroughly and rigorously assessed. In addition, it would be beneficial if the IRRC researcher in charge of impact assessment be involved in the assessment of the “high-potential” technologies for all work groups so that there would be some consistency in the analysis of the technologies across work groups. It would not be efficient if the impact assessment scientist is involved in only several technologies for a couple of work groups and not involved at all in others.

Fourth, there should be some efforts to more carefully monitor adoption numbers for at least the "high-potential" IRRC technologies that have been developed and disseminated. In Table 1.1, we report the estimated number of farmers reached by IRRC based on existing studies –which is approximately 1.2 million. These figures were mainly compiled with the help of IRRC CU researchers and (as evident in the table) were mainly from disparate/fragmented sources. One thing to note here is that some of the figures are more reliable than others (also see discussion in Section 3.2.2.2). Hence, there should be more serious investment in time and resources to rigorously estimate adoption numbers in the future. Aggregate economic impact (and specifically economic surplus) measures critically depend on accurate technology adoption numbers. These adoption numbers are also important when one would like to evaluate more aggregate poverty impacts of technology interventions. Poverty impacts of IRRC technologies across more aggregate areas have not been emphasized in the existing literature and having an idea of the geographical spread and number of adopters would likely allow one to better assess the poverty effects of technologies. We recognize that availability of resources is critical in the monitoring of adoption numbers, but perhaps local NARES (and funding support from national sources) could be utilized to help track these figures. Adoption number by itself is also a good measure that indicates acceptance of the technologies on the ground.

Lastly, most of the economic impact evaluation studies have not been published in peer-reviewed academic journals. But we acknowledge that there are a few that have already been published in high-level agricultural and development journals. We also acknowledge that impact studies take some time to get to a stage where it is ready to be submitted for publication. Nevertheless, it should be an objective of IRRC to publish the existing (and future) impact studies in peer-reviewed journals. Utilizing the more current assessment methods that account for selection (as mentioned above) would likely make it easier to publish the impact evaluations. Publishing the impact results in peer-reviewed journals increases their credibility and makes them more convincing to donors and policymakers.

3.2 Aggregate economic surplus analysis

3.2.1 Conceptual framework: stylized economic surplus model

The empirical approach used in the economic impact assessment of IRRC is conceptually based on a stylized economic surplus model that has been widely used to evaluate the welfare effects of new agricultural technologies and research programs within a partial equilibrium framework. Recent studies that have used this framework to evaluate the economic impact of rice technologies/research programs are (among others) Hareau et al. (2006), Alpuerto et al. (2009), and Brennan and Malabayabas (2011). Basically, the model measures a technology/research-induced supply shift and evaluates the net welfare effects through the resulting changes in producer and consumer surplus.

In the stylized framework discussed below, several important simplifying assumptions are used: (1) supply and demand curves are assumed to be linear, (2) research-induced supply shifts are assumed parallel, (3) a static model is assumed (i.e., dynamics are put aside), (4) competitive market clearing is imposed, and (5) a closed-economy context is assumed. A closed economy assumption implies that commodity prices are determined within the country (or region of interest) and that the commodity is not typically traded. Some of these assumptions are adjusted (i.e., relaxed/strengthened/changed) in the empirical implementation in order to facilitate the estimation of results.

Figure 3.1 presents the stylized economic surplus model of a technology/research-induced supply shift. An IRRC technological innovation disseminated in a particular country (or region) presumably increases rice yields and/or lowers production cost, such that the market supply

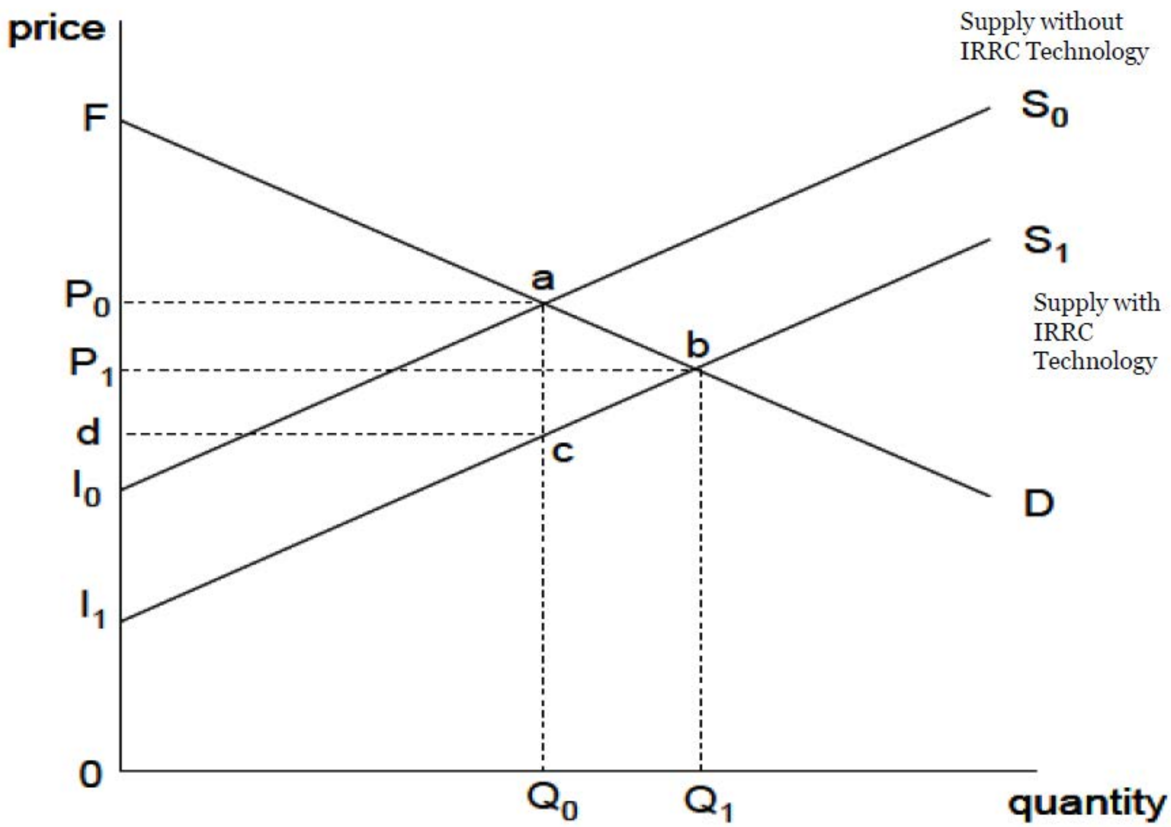


Fig. 3.1. Stylized economic surplus model: closed economy
(adapted from Alston et al. 1998).

curve will shift from S_0 to S_1. The equilibrium price decreases from P_0 to P_1, while equilibrium quantity increases from Q_0 to Q_1. In this case, consumers gain because they can buy more goods at a lower price. Producers, on the other hand, gain from the lower cost if they are able to sell enough additional quantity to offset the lower price. As can be seen later (Section 3.2.2), if an open economy context is assumed such that the demand curve is perfectly elastic (i.e., flat), then all the gains from the technological innovation accrues to the producers.

The change in consumer surplus is represented by the area P_0abP_1 and the change in producer surplus is denoted by the area P_1bI_1 less P_0aI_0. The total net surplus is the area I_0abI_1, which represents the sum of the changes in consumer and producer surplus. As described in Alston et al. (1998), this area can be viewed as the sum of two parts: (a) the cost saving on the original quantity (i.e., the area between the two supply curves to the left of Q_0 – area I_0acI_1), and (b) the economic surplus due to the incremental increase in quantity to Q_0 (i.e., the triangular area abc, the total value of the increment in consumption (Q_0abQ_1) less the total cost of the increment in production (Q_0cbQ_1)). The total net economic surplus can then be considered as the "benefits" due to the technological/research intervention that can then be compared with the research investment "costs" of the donors. Hence, the financial net present value (NPV), BCR, and internal rate of return (IRR) measures can be calculated from this framework.

3.2.2 Empirical approach

3.2.2.1 Empirical implementation of the surplus framework

The economic surplus model in Figure 3.1 only serves as the conceptual basis for the actual economic surplus approach implemented in this study. To facilitate estimation of the economic surplus measures in a spreadsheet framework (see Alston et al. 1998), we make further assumptions with regards to the within-country economy/trade contexts and the elasticity of rice demand. First, we assume a small open economy context (in contrast to the closed economy context in Figure 3.1) for the four countries of main interest in this study: Bangladesh, Indonesia, Philippines, and Vietnam (see TOR). This assumption also suggests that the countries are "small" enough such that changes in production within each country do not influence world rice prices (i.e., prices remain constant). This further implies that the demand curve within each country is perfectly elastic (i.e., flat) and welfare benefits due to a technology/research-induced supply shift accrues to producers (i.e., increases producer surplus but does not affect consumer surplus).

Figure 3.2 presents a graphical representation of this economic surplus model assumption. The initial equilibrium is defined at the following point: consumption at C_0, domestic production at Q_0, world rice price at P_w, and net imports (i.e., the difference between Q_0 and C_0) equal to QT_0. Consistent with the assumptions in Figure 3.1, an IRRC technology/research intervention is assumed to result in a parallel shift of the supply curve from S_0 to S_1, which results in lower rice importation QT_1. With a small open economy assumption (and constant P_w), the total change in economic surplus I_0abI_1 is all producer surplus. The corresponding algebraic formulas to calculate changes in the total economic surplus (which is equivalent to the change in producer surplus in this case) are as follows:

(1) $\Delta CS=0$,

(2) $\Delta PS=\Delta TS=P_w Q_0 K(1+0.5K\varepsilon)$,

where ΔCS is the change in consumer surplus, ΔPS is the change in producer surplus, ΔTS is the change in total surplus, P_w is the constant rice price, Q_0 is the pre-intervention production level, K is the so-called K-shift parameter that represents the vertical shift in supply (and expressed as a proportionate cost reduction per ton due to the intervention), and ε is the supply elasticity of rice in the country. The K-shift parameter is calculated as

(3)
$$K_1=\left[\frac{E(Y)}{\varepsilon}-\frac{E(C)}{1+E(Y)}\right]pA_1(1-\delta_1)$$

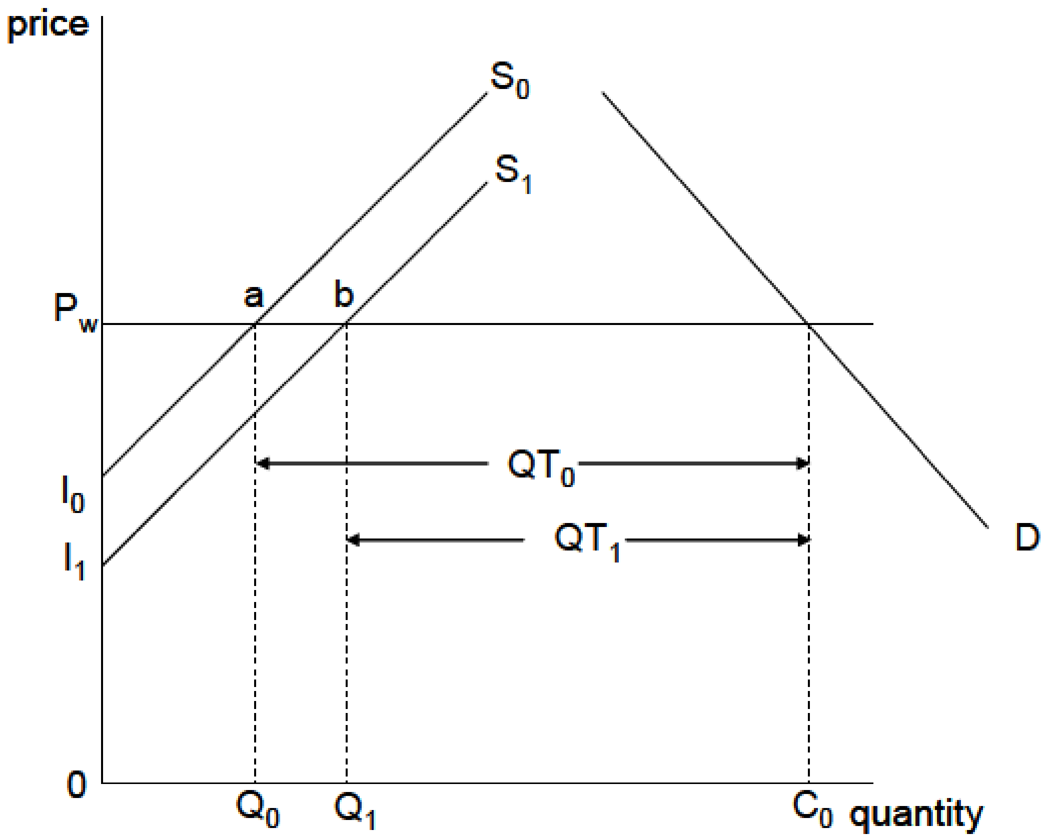


Fig. 3.2. Economic surplus model for small open economy.

where $E(Y)$ is the expected proportionate yield change per hectare due to the IRRC technology, ε is the supply elasticity of rice in the country, $E(C)$ is the proportionate change in input costs per hectare (if any), ρ is the probability that the new technology will fully achieve the yield change $E(Y)$, A_t is the rate of adoption in year t, and, δ_t is the rate of annual depreciation of the new variety.

The economic surplus calculations above are operationalized in a spreadsheet where the welfare changes are first calculated for particular IRRC technology and country combinations (e.g., EBRM technology in Vietnam, SSNM in the Philippines, etc.). The surplus measures are then aggregated up (i.e., summed up for the all technology-country combinations considered), discounted (using a 5% discount rate), and then compared with the pertinent total discounted IRRC research investment costs. This allows for calculation of the different financial indicators of interest.

3.2.2.2 Technology-country combinations evaluated: best evidence approach

Given the number of IRRC technologies that can be evaluated and the limited time to complete the meta-impact assessments, the review team made judgments on the technology-country combinations evaluated for this study. In making these judgments, a "best evidence" approach similar to the one developed by Raitzer and Kelley (2008) was utilized.

First, only major IRRC technologies disseminated in the four countries of interest were considered in the analysis. For example, the market information board and quality tools developed and disseminated by the PP Work Group in Cambodia were considered relatively "minor" (compared with, say, HSS - hermetic storage bags) and, therefore, these were not included in the economic surplus evaluation. Cambodia was also not one of the focus countries of the meta-impact assessment (see TOR). Second, we categorized the different technology-country combinations evaluated based on the quantity and quality of the impact evidence for a particular combination (i.e., if there were adequate, good-quality impact studies that document the yield/cost change from the technology in a particular country) and whether data to conduct the surplus analysis are available for a particular technology-country combination (e.g., for example, adoption figures). Consideration was also given to the length of time the technology has been disseminated in a particular country of interest. Notwithstanding the major considerations above, we strived to include at least one technology from each work group in the economic surplus analysis.

Based on the criteria described above, we considered four technology-country aggregation groups: (1) Aggregation Group 1 that includes AWD in the Philippines and EBRM in Vietnam, (2) Aggregation Group 2 that includes AWD in the Philippines, EBRM in Vietnam, SSNM (particularly the LCC) in Bangladesh, and DSR in Bangladesh, (3) Aggregation Group 3 that includes AWD in the Philippines, EBRM in Vietnam, SSNM/LCC in Bangladesh, DSR in Bangladesh, AR in the Philippines, and HSS in the Philippines, and (4) Aggregation Group 4 that includes AWD in the Philippines, EBRM in Vietnam, SSNM/LCC in Bangladesh, DSR in Bangladesh, AR in the Philippines, HSS in the Philippines, 3R3G/1M5R in Vietnam, and ICM in Indonesia. In light of these groupings, we view AWD in the Philippines and EBRM in Vietnam (Aggregation Group 1) as the two technology-country combinations that have several quality impact studies conducted in the particular focus country and where adoption data/figures are fairly reliable. Moreover, these two technologies are relatively "mature" inasmuch as they have been disseminated more than 5 years ago. Thus, this group has the "best evidence" (and data) available to allow us to make relatively reliable inferences on the returns to IRRC research expenditures. In addition, these two technologies serve as good candidates to demonstrate whether a couple of "high-potential" technologies can already cover the total research outlays of IRRC.

In Aggregation Group 2, we added SSNM/LCC and DSR (both for Bangladesh) to the economic surplus assessment. Based on the impact evidence, there had been some good-quality impact studies for SSNM/LCC for Vietnam but not in Bangladesh. It should be noted though that there are some adoption figures we could use based on LCCs released in Bangladesh (Flor 2011). For DSR, there are several impact studies of DSR (together with SDV) in Bangladesh, but the adoption data are not as reliable. These are some of the reasons the SSNM/LCC and DSR were included only in the second aggregation group.

For Aggregation Group 3, AR and HSS were added to the four technologies included in Aggregation Group 2. Fewer impact studies have been conducted for AR and HSS compared with the other technologies included in the first two groups. In addition, HSS has only been recently released and so adoption figures are not yet available. The last aggregation group (Aggregation Group 4) further includes two "integrated technologies" – 3R3G/1M5R in Vietnam and ICM in Indonesia. These integrated technologies were added last primarily because they encompass all the work groups and we cannot directly compare benefits from these integrated technologies to the expenditures for a particular work group. But note that there have been several impact studies conducted for these technologies (especially 3R3G/1M5R in Vietnam); adoption data for these integrated technologies are still somewhat limited.

3.2.2.3 Limitations of the empirical approach

Given the assumptions made to facilitate the empirical impact estimation within a coherent economic framework (and with the time and resource constraints of the assessment team), there are some important limitations of the surplus analysis that need to be recognized and discussed. First, we used a small open economy assumption for all four countries of interest in this assessment. This assumption is reasonable for Bangladesh, Indonesia, and the Philippines, given that they are all small country rice importers whose domestic supply changes are not typically expected to influence world prices. Our small open economy assumption is consistent with Alpuerto et al. (2009) who also considered these countries as small open economies in their economic surplus analysis. However, Vietnam is a major rice exporter in the world market and some would argue that the small open economy assumption does not fit in this case. But, in the context of this study, we still maintained a small open economy assumption for Vietnam for consistency in calculating IRRC benefits across countries and in order to facilitate the aggregation of benefits across various IRRC technology-country combinations. The spreadsheet approach to the economic surplus calculations (for each technology-country combination) also makes it difficult to link the resulting world price changes to the small open economies considered in this study. Note that Brennan and Malabayabas (2011) have also made the assumption that Vietnam is a small open economy in the context of an economic surplus analysis for rice technologies. In light of the limited time frame to complete the meta-impact assessment, the review team was not able to explore the implications of assuming a large open economy structure for Vietnam. Hence, we leave this for future work.

The second limitation to take note of is that, in aggregating the economic benefits of the various technology-country combinations, we implicitly made the assumption that these benefits are additive. It could be that some technologies are complementary such that the additive assumption effectively overestimates the benefits. Notwithstanding this limitation, this additivity assumption has been used in previous economic surplus studies and is typically considered a reasonable assumption in evaluating economic impact of research programs (see Brennan and Malabayabas 2011).

Third, we assumed that the research/technology-induced supply shift is parallel (i.e., the parallel shift assumption) rather than pivotal (i.e., the pivotal shift assumption). Note that the parallel shift assumption is consistent with the recommendation of Alston et al. (1998) and this assumption has been used in a number of economic surplus studies for rice technologies to date (see Alpuerto et al. [2009] and Brennan and Malabayabas [2011]). However, Alston et al. (1998) also pointed out that, with a linear supply curve, total benefits from a parallel shift are almost twice the size of total benefits from a pivotal shift (of equal size at the pre-research equilibrium). Given this insight, a pivotal shift effect–calculated as half of the parallel shift effect–may serve as a lower bound of the benefits of technology intervention and gives a range of benefits against which investment costs are assessed.

The fourth limitation of the empirical approach used in this study is the timeframe considered. As noted in previous sections, the actual time period where IRRC operated was 1997–2012. For the purpose of accountability, the actual "ex post" timeframe (i.e., 1997 to 2012) is pertinent because this is the actual timeline for the existence of IRRC. However, it may also be important to "project" the potential benefits of IRRC technologies beyond 2012 because the benefits of the IRRC technologies disseminated may not have matured during the 1997–2012 period. Making "ex ante" projections requires making further assumptions on the path of model variables (such as adoption rates). Hence, to strike a balance, we decided to consider a 1997–2016 timeframe in the analysis but report benefit figures both for the strictly "ex post" period of 1997–2012 and the full 1997–2016 period. Moreover, for this assessment, we assumed a logistic adoption path for all IRRC technologies evaluated, where we empirically fit this curve based on available adoption information. The logistic adoption path has been used in previous surplus studies as well (see Alston et al. 1998).

Lastly, in economic surplus modeling, it is quite common to have impact estimates (i.e., NPVs) that are in the hundreds of millions (and sometimes in billions) of dollars. Based on this common finding, we made every effort to guard against "overestimating" the impact figures by making conservative (but reasonable) assumptions with regard to some of the parameters in the surplus model. For example, we assumed that the yield and cost change effects used in the analysis only has a 50% probability of being achieved (i.e., ρ=0.5). This value accounts for the uncertainty in the yield and cost effect estimates used, given the inherent limitations in the farm-level impact studies previously conducted (i.e., selection issues not being adequately addressed, limited or nonrepresentative sample sizes, etc.). However, it also needs to be emphasized here that our economic surplus analysis only focused on four of the 11 countries where IRRC operates and only a subset of technologies within a country was addressed. Therefore, there are other surplus impacts of IRRC (for other countries/technologies) that were not considered here.

Overall, all the limitations above should always be kept in mind when interpreting and utilizing the impact estimates produced from the economic surplus models.

3.2.3 Empirical results from the surplus models

In this section, we present the results from the economic surplus models of the various IRRC technology-country combinations evaluated. It is important to note that the assumptions and parameter values used in these models were primarily based on what is found in existing literature, and these were also complemented by the review team's field visits (and interactions) with major stakeholders (i.e., researchers, extension personnel) involved in the research and dissemination activities of the various technologies. The research costs per work group (and for IRRC as a whole) were collected from available IRRI project materials (see Table 3.1).[4]

[4]Specifically, we used research cost data from project proposal materials since these are the most complete data spanning all phases of the IRRC. We also tried to collect actual expenditure data from the finance unit of IRRI but were not able to find a complete data set that includes

Table 3.1. Research investment costs (US$) for IRRC.

Work Group	Research investments from all sources (SDC plus all sources)	Research investments from SDC only
LPCE	1,710,141	1,160,941
PP	967,416	217,416
PS	6,583,524	5,314,174
WS	2,094,850	1,150,850
CH	3,113,791	283,791
CU	4,015,843	3,825,843
Total	18,485,565	11,953,015

3.2.3.1 Economic surplus analysis of AWD in the Philippines

The spreadsheet that serves as the basis for calculating the economic surplus benefits for AWD in the Philippines is presented in Table 3.2. As mentioned above, the period of analysis was the 20-year period from 1997 to 2016. The rice supply elasticity (εA) for the Philippines was assumed to be 0.28, which was the mean value based on three supply elasticities: 0.152, 0.40., and 0.30 as reported in Mohanty et al. (2010), Alpuerto et al. (2009), and Mamaril (2002), respectively.

The yield change due to AWD was assumed to be 1.5%. As seen in Section 3.3.4.1, the existing evidence on the yield impact of AWD has been mixed. For pump irrigation systems, there does not seem to be any significant difference in the yields of AWD farmers and non-AWD farmers. However, recent studies that examined AWD in canal/gravity systems suggest about a 10% increase in yields (on average), although most of this benefit is more strongly felt by downstream users. It could be that the more efficient allocation of and improved access to water allow downstream users to have better yields than before. Since about 90% of the irrigated rice area is using gravity systems, approximately one-third of the irrigated area is downstream, and the effect of AWD is mostly felt in the dry season (half of the full season), then a 1.5% aggregate yield increase would be reasonable (i.e., 0.9 × 0.33 × 0.5 × 10% =1.5%). The input cost change from AWD was assumed to be -1.0%. The existing impact studies suggest that AWD producers in pump systems have lower costs (fuel, pump, and opportunity costs), but this is not evident in more common gravity irrigation systems. Nevertheless, we assumed a 1% reduction in costs due to the reduced time that AWD farmers use for gravity irrigation (i.e., reduced opportunity costs) and the observed cost reduction of AWD farmers in pump irrigation systems. Given the uncertainty and limitations in estimating these yield and cost effects, a very conservative 50% probability of success for these changes was assumed (as mentioned above).

One of the key reasons for categorizing AWD in Aggregation Group 1 is the availability of good adoption numbers from the WS Work Group. As mentioned in the economic impact evidence section, approximately 93,000 ha (83,000 farmers) were estimated to have adopted AWD in the Philippines. This is approximately 2% of the total 4.5 million ha rice area in the country. Based on this adoption percentage and assuming that AWD adoption started in 2002, a logistic adoption path was traced where 2% adoption rate is reached in 2011 and about 10% adoption rate is reached in 2016 (i.e., approximately 450,000 ha or ~500,000 farmers). A 1%/year linear disadoption in the last 2 years and technology depreciation of 2% $year^{-1}$ in the last 5 years were also assumed to further account for unforeseen factors that may affect the effectiveness of the technology in the future.

Paddy rice price and production were gathered from IRRI's World Rice Statistics online database for all technology-country combinations included in the analysis. The total research costs presented in Table 3.2 are based on existing IRRI financial data collected for the WS Work Group, amounting to about US$2.09 million (see Table 3.1). This amount was divided equally over the 2001–12 period because the WS Work Group was first established in 2001. The rice prices and research costs were then deflated/inflated based on the consumer price index (CPI) in the Philippines where the base year used is 2010 (i.e., normalized to 2010 common currency). The CPI data used are available from the World Rice Statistics database.

Given a discount rate of 5% (which is the rate commonly used in surplus analysis), we find that the present value (PV) of the total benefits of AWD in the Philippines for the 1997–2012 period is around US$14.2 million. If we consider the longer 1997–2016 period, the benefits of the technology

expenditures for all IRRC project phases. In comparing these two sources, it appears that, in general, the research investment cost data from the proposal materials are higher than the expenditure data from the finance unit. This should be kept in mind when interpreting our surplus model results.

Table 3.2. Economic surplus spreadsheet calculation: AWD in the Philippines.

Year	εA	Max Yield Change	Gross Cost Change Per Ton	Input cost Change per ha	Input Cost change per ton	Net cost change	Prob of success of yld/cost change	Adoption rate	depreciation rate	deprn factor	K shift	Paddy Rice Price ($/ton) normalized to 2010	Paddy Rice Prodn (tons)	Total Benefits or Change in Total Surplus ($)	Total Costs WS Workgroup ($) normalized to 2010	Net Benefits ($)	Discounted Total Benefits (5%; t=0 at 2010)	Discounted Total Costs (5% t=0 at 2010)	Discounted net benefits (5% t=0 at 2010)
1997	0.28	0.02	0.05	-0.01	-0.010	0.06	0.50	0.0000	0.000	1.00	0.000000	142.14	11268000	0.00	0.00	0.00	0.00	0.00	0.00
1998	0.28	0.02	0.05	-0.01	-0.010	0.06	0.50	0.0000	0.000	1.00	0.000000	117.31	8554000	0.00	0.00	0.00	0.00	0.00	0.00
1999	0.28	0.02	0.05	-0.01	-0.010	0.06	0.50	0.0000	0.000	1.00	0.000000	123.28	11786600	0.00	0.00	0.00	0.00	0.00	0.00
2000	0.28	0.02	0.05	-0.01	-0.010	0.06	0.50	0.0000	0.000	1.00	0.000000	121.29	12389400	0.00	0.00	0.00	0.00	0.00	0.00
2001	0.28	0.02	0.05	-0.01	-0.010	0.06	0.50	0.0000	0.000	1.00	0.000000	107.44	12954900	0.00	117053.51	-117053.51	0.00	181588.42	-181588.42
2002	0.28	0.02	0.05	-0.01	-0.010	0.06	0.50	0.0012	0.000	1.00	0.000037	117.73	13270700	57930.01	120239.76	-62309.76	85589.00	177648.89	-92059.89
2003	0.28	0.02	0.05	-0.01	-0.010	0.06	0.50	0.0016	0.000	1.00	0.000051	114.92	13499900	78962.59	123000.27	-44037.68	111108.29	173073.73	-61965.44
2004	0.28	0.02	0.05	-0.01	-0.010	0.06	0.50	0.0022	0.000	1.00	0.000070	124.55	14496800	126120.74	128933.28	-2812.54	169013.86	172782.93	-3769.07
2005	0.28	0.02	0.05	-0.01	-0.010	0.06	0.50	0.0030	0.000	1.00	0.000096	148.95	14603000	208449.53	137338.39	71111.14	266040.30	175282.46	90757.84
2006	0.28	0.02	0.05	-0.01	-0.010	0.06	0.50	0.0041	0.000	1.00	0.000131	169.18	15326700	340783.89	144878.27	195905.62	414224.95	176100.45	238124.51
2007	0.28	0.02	0.05	-0.01	-0.010	0.06	0.50	0.0057	0.000	1.00	0.000180	207.60	16240200	607244.35	149067.09	458177.26	702961.24	172563.79	530397.45
2008	0.28	0.02	0.05	-0.01	-0.010	0.06	0.50	0.0078	0.000	1.00	0.000247	294.74	16815500	1222334.67	161386.35	1060948.32	1347623.97	177928.45	1169695.52
2009	0.28	0.02	0.05	-0.01	-0.010	0.06	0.50	0.0106	0.000	1.00	0.000337	295.37	16266400	1620688.17	168047.26	1452640.91	1701722.58	176449.62	1525272.96
2010	0.28	0.02	0.05	-0.01	-0.010	0.06	0.50	0.0145	0.000	1.00	0.000461	329.64	15771700	2394788.42	174570.83	2220217.59	2394788.42	174570.83	2220217.59
2011	0.28	0.02	0.05	-0.01	-0.010	0.06	0.50	0.0198	0.000	1.00	0.000628	329.64	15771700	3263210.15	182687.53	3080522.62	3107819.19	173988.13	2933831.06
2012	0.28	0.02	0.05	-0.01	-0.010	0.06	0.50	0.0269	0.020	0.98	0.000836	329.64	15771700	4344983.04	182687.53	4162295.50	3941027.70	165702.98	3775324.72
2013	0.28	0.02	0.05	-0.01	-0.010	0.06	0.50	0.0364	0.040	0.96	0.001108	329.64	15771700	5760459.94		5760459.94	4976101.88	0.00	4976101.88
2014	0.28	0.02	0.05	-0.01	-0.010	0.06	0.50	0.0490	0.060	0.94	0.001460	329.64	15771700	7594189.59		7594189.59	6247758.57	0.00	6247758.57
2015	0.28	0.02	0.05	-0.01	-0.010	0.06	0.50	0.0649	0.080	0.92	0.001892	329.64	15771700	9839383.00		9839383.00	7709414.04	0.00	7709414.04
2016	0.28	0.02	0.05	-0.01	-0.010	0.06	0.50	0.0851	0.100	0.90	0.002428	329.64	15771700	12628008.94		12628008.94	9423214.70	0.00	9423214.70
																Total Discounted Benefits (1997-2012):	14,241,919.50	2,097,680.68	12,144,238.82
																Total Discounted Benefits (1997-2016):	42,598,408.70	2,097,680.68	40,500,728.02
																		BCR (1997-2012):	6.79
																		BCR (1997-2016):	20.31
																		IRR (1997-2012):	0.646
																		IRR (1997-2016):	0.691

increase to US$42.6 million. If we only consider the available investment cost data for the WS Work Group (discounted at 5% as well), the NPV of AWD benefits in the Philippines is approximately US$12.1 million for the 1997–2012 period and US$40.5 million for the 1997–2016 period. The corresponding BCRs are approximately 7:1 and 20:1 for the 1997–2012 and the 1997–2016 periods, respectively. The IRRs for the 1997–2012 and the 1997–2016 periods are 0.646 and 0.691, respectively. As noted above, one limitation of the analysis is a parallel shift assumption. If a pivotal shift is assumed, the surplus measures will be cut in half and can serve as a lower bound estimate. Considering this calculation, the IRRs for the 1997–2012 period and 1997–2016 period, for example, would still be about 0.323 and 0.345, respectively.

Note that the investment costs considered above are total investments to the WS Work Group from all donor sources (not just SDC). Of the US$2.09 million total expenditures of the WS Work Group, about US$1.15 million is from SDC. When considering only the SDC costs for the WS Work Group, the NPV of AWD benefits in the Philippines is approximately US$13.1 million for the 1997–2012 period and US$41.4 million for the 1997–2016 period (see Appendix 2). The corresponding BCRs are approximately 12:1 and 37:1 for the 1997–2012 and the 1997–2016 periods, respectively. The IRRs for the 1997–2012 and the 1997–2016 periods are 0.915 and 0.971, respectively.

3.2.3.2 Economic surplus analysis of EBRM in Vietnam

The economic surplus calculation spreadsheet for EBRM in Vietnam (1997-2016) is presented in Table 3.3. Several studies have reported Vietnamese rice supply elasticities (εA) ranging from 0.10 to 0.37 (see Mohanty et al. 2010 and Yu and Fan 2009), but values in the 0.3–0.37 range are more predominant in this literature. Given the reported range of elasticities, we assumed a rice supply elasticity of 0.31 (second column in Table 3.3).

Yield increase due to EBRM was assumed to be 2.5%. This figure is based on recent studies by Palis et al. (2010b) and Brown (2010) that estimate yield effect of EBRM from about 1% to 10% and also feedback from IRRI scientists suggesting a 2.5% reduction in chronic yield losses due to rats. The cost change was assumed to be 5% (i.e., 5% increase in cost). This value is based mainly on the cost analysis in Palis et al (2004) where a cost increase was observed. Most of the existing evidence showed significant reduction in rodenticide costs by EBRM farmers. But these studies typically do not investigate the full, total cost effects of EBRM (except for Palis et al. 2004). It is likely that, even with the reduced rodenticide cost of EBRM, the increased labor cost, the cost of the trap materials, and the transaction costs (i.e., for making farmers work together plus establishing institutions to facilitate community action) would likely be higher than the reduction in rodenticide use alone.

A logistic adoption path was assumed with initial EBRM dissemination and diffusion starting in 2006. Huan et al. (2010) suggest that, on average, about 100,000 ha of rice each year are severely affected by rodents in the Mekong Delta. This represents approximately 1.3% of total rice area planted in Vietnam (i.e., total rice area is approximately 7.6 million ha). However, based on our interactions with IRRI scientists, the area referenced in Huan et al. (2010) is only where severe damage usually occurs and that approximately 1 million ha have chronic losses due to rats. Hence, we conservatively assumed that this 13% (1 million/7.6million) is the target maximum adoption rate for EBRM. These areas would be the ones likely to adopt EBRM because they are affected by rodent problems. Based on the EBRM data in Palis et al. (2010b), we assumed that about 1000 ha was the initial area (0.01% of total rice area) where EBRM was adopted in 2006 and that, by 2016, half of the 13% area affected by rodent problems would have adopted EBRM. To be conservative, we also make a 1% $year^{-1}$ disadoption assumption for the last 2

Table 3.3. Economic surplus spreadsheet calculation: EBRM in Vietnam.

Year	εA	Max Yield Change	Gross Cost Change Per Ton	Input cost Change per ha	Input Cost change per ton	Net cost change	Prob of success of yld/cost change	Adoption rate	depreciation rate	deprn factor	K shift	Paddy Rice Price ($/ton) normalized 2010	Paddy Rice Prodn (tons)	Total Benefits or Change in Total Surplus ($)	Total Costs LPCE Workgroup ($) normalized to 2010	Net Benefits ($)	Discounted Total Benefits (5%; t=0 at 2010)	Discounted Total Costs (5% t=0 at 2010)	Discounted net benefits (5% t=0 at 2010)
1997	0.31	0.025	0.08	0.05	0.049	0.03	0.50	0.0000000	0.000	1.00	0.000000	66.57	27523900	0.00	0.00	0.00	0.00	0.00	0.00
1998	0.31	0.025	0.08	0.05	0.049	0.03	0.50	0.0000000	0.000	1.00	0.000000	77.91	29145500	0.00	0.00	0.00	0.00	0.00	0.00
1999	0.31	0.025	0.08	0.05	0.049	0.03	0.50	0.0000000	0.000	1.00	0.000000	65.74	31393800	0.00	0.00	0.00	0.00	0.00	0.00
2000	0.31	0.025	0.08	0.05	0.049	0.03	0.50	0.0000000	0.000	1.00	0.000000	58.02	32529500	0.00	0.00	0.00	0.00	0.00	0.00
2001	0.31	0.025	0.08	0.05	0.049	0.03	0.50	0.0000000	0.000	1.00	0.000000	48.76	32108400	0.00	95557.21	-95557.21	0.00	148240.59	-148240.59
2002	0.31	0.025	0.08	0.05	0.049	0.03	0.50	0.0000000	0.000	1.00	0.000000	62.61	34447200	0.00	98158.32	-98158.32	0.00	145024.54	-145024.54
2003	0.31	0.025	0.08	0.05	0.049	0.03	0.50	0.0000000	0.000	1.00	0.000000	59.76	34568800	0.00	100411.87	-100411.87	0.00	141289.58	-141289.58
2004	0.31	0.025	0.08	0.05	0.049	0.03	0.50	0.0000000	0.000	1.00	0.000000	76.24	36148900	0.00	105255.32	-105255.32	0.00	141052.19	-141052.19
2005	0.31	0.025	0.08	0.05	0.049	0.03	0.50	0.0000000	0.000	1.00	0.000000	87.20	35832900	0.00	112116.87	-112116.87	0.00	143092.69	-143092.69
2006	0.31	0.025	0.08	0.05	0.049	0.03	0.50	0.0001562	0.000	1.00	0.000002	96.61	35849500	8621.41	118272.08	-109650.68	10479.37	143760.46	-133281.08
2007	0.31	0.025	0.08	0.05	0.049	0.03	0.50	0.0003615	0.000	1.00	0.000006	140.07	35942700	28993.03	121691.65	-92698.62	33563.06	140873.29	-107310.24
2008	0.31	0.025	0.08	0.05	0.049	0.03	0.50	0.0008345	0.000	1.00	0.000013	228.53	38729800	117678.13	131748.53	-14070.40	129740.14	145252.76	-15512.62
2009	0.31	0.025	0.08	0.05	0.049	0.03	0.50	0.0019174	0.000	1.00	0.000031	228.53	38950200	271930.65	137186.20	134744.45	285527.18	144045.51	141481.67
2010	0.31	0.025	0.08	0.05	0.049	0.03	0.50	0.0043583	0.000	1.00	0.000069	228.53	39988900	634581.79	142511.75	492070.04	634581.79	142511.75	492070.04
2011	0.31	0.025	0.08	0.05	0.049	0.03	0.50	0.0096718	0.000	1.00	0.000154	228.53	39988900	1408251.97	149137.86	1259114.12	1341192.36	142036.05	1199156.30
2012	0.31	0.025	0.08	0.05	0.049	0.03	0.50	0.0204108	0.020	0.98	0.000319	228.53	39988900	2912534.30	149137.86	2763396.45	2641754.47	135272.43	2506482.04
2013	0.31	0.025	0.08	0.05	0.049	0.03	0.50	0.0391903	0.040	0.96	0.000599	228.53	39988900	5478390.73		5478390.73	4732439.89	0.00	4732439.89
2014	0.31	0.025	0.08	0.05	0.049	0.03	0.50	0.0650000	0.060	0.94	0.000973	228.53	39988900	8897527.82		8897527.82	7320018.16	0.00	7320018.16
2015	0.31	0.025	0.08	0.05	0.049	0.03	0.50	0.0899016	0.080	0.92	0.001318	228.53	39988900	12044991.19		12044991.19	9437565.77	0.00	9437565.77
2016	0.31	0.025	0.08	0.05	0.049	0.03	0.50	0.1073974	0.100	0.90	0.001540	228.53	39988900	14076751.73		14076751.73	10504288.88	0.00	10504288.88
																Total Discounted Benefits (1997-2012):	5,076,838.36	1,712,451.84	3,364,386.52
																Total Discounted Benefits (1997-2016):	37,071,151.06	1,712,451.84	35,358,699.22
																		BCR (1997-2012):	2.96
																		BCR (1997-2016):	21.65
																		IRR (1997-2012):	0.272
																		IRR (1997-2016):	0.474

years of analysis. A 2% year^{-1} technology depreciation assumption was also assumed starting in 2012.

The total research costs used in Table 3.3 are for the LPCE Work Group, amounting to about US$1.7 million (see Table 3.1).[5] This amount was divided equally over the 2001–12 period because the LPCE Work Group was first established in 2001. The rice prices and research costs were then deflated/ inflated based on the relevant CPI to normalize at 2010 values.

Based on a discount rate of 5%, we find that the PV of the total benefits of EBRM in Vietnam is around US$5.0 million for 1997–2012. If we consider the longer 1997–2016 period, the discounted benefits of the technology increase to US$37 million. Based on the available investment cost data for the LPCE Work Group (discounted at 5% as well), the NPV of EBRM benefits in Vietnam is approximately US$3.3 million for the 1997–2012 period and US$35.3 million for the 1997–2016 period. The corresponding BCRs are 3:1 and 21:1 for the 1997–2012 and the 1997–2016 periods, respectively. The IRRs for the 1997–2012 period and the 1997–2016 period are 0.272 and 0.474, respectively. Again, if we consider a pivotal shift instead of a parallel shift assumption, the impact estimates should be approximately half of the values reported above.

If we consider SDC investments to the LPCE Work Group alone, the total investment cost for the 2001–12 was US$1.16 million. Based only on this SDC investment value, the NPV of EBRM in Vietnam is approximately US$3.9 million for the 1997–2012 period and $US35.9 million for the 1997–2016 period (see Appendix 2). The corresponding BCRs are approximately 4:1 and 32:1 for the 1997–2012 and the 1997–2016 periods, respectively. The IRRs for the 1997–2012 and the 1997–2016 periods are 0.347 and 0.533, respectively.[6]

3.2.3.3 Economic surplus analysis of SSNM/LCC in Bangladesh

The economic surplus calculation spreadsheet for SSNM/LCC in Bangladesh (1997–2016) is presented in Table 3.4. Note that the specific technology evaluated here is the LCC that was initially disseminated in Bangladesh in 2008. The *Nutrient Manager* for smartphones and computer (software in CDs) are not evaluated here primarily because adoption and impact information on these two more recent SSNM tools have not been formally studied and documented.

Rice supply elasticities for Bangladesh reported in the literature typically range from 0.2 to 0.3 (Rahman 1986, Ahmed 1997, Kamal 2007, Dorosh and Rashid 2012). Based on this reported range of rice supply elasticities, we assumed a 0.25 rice supply elasticity value in our surplus model for SSNM/ LCC in Bangladesh. The assumed yield increase due to LCC was 8%. In Flor (2011), the observed mean yield increase from a rapid rural assessment with limited number of sites was around 12–31%. But the observed mean yield effect of SSNM/LCC in Vietnam was around 3–11% using more advanced statistical techniques. Hence, to be conservative, we chose an 8% yield change value. We assumed that there is no cost change because the impact evidence suggests that even though most LCC farmers reduced N fertilizer use, there were subsequent increases in some other inputs (P & K).

Based on Flor (2011), we assumed that adoption and dissemination of LCC in Bangladesh started in 2008. A logistic adoption path is fitted where we assumed that about 15% of farmers who received LCC are adopters by 2012. This is based on the LCC dissemination numbers in Flor (2011) where she estimated that 2–31% of farmers who receive LCC are users. Paddy rice prices and production for Bangladesh are again gathered from the World Rice Statistics database (as was done for the other technology-country combinations). The total research costs for the PS Work Group were assumed

[5]Based on feedback from IRRC scientists, we learned that the rodent research work in IRRC received fairly minimal support from SDC. This was noted in the Phase III external review. However, there was a significant investment by ACIAR in the Phase II period for rodent research in Vietnam, which makes the cost estimate here reasonable.

[6]It is important to note here that the returns to EBRM (and the estimated returns on investments (ROI) for the other technology combinations) only pertain to the specific country combination studied. For the EBRM work, for example, a similar surplus impact may have been experienced in Indonesia where the technology was also disseminated. This effectively suggests that ROI dollars would be effectively larger if we consider the Indonesia experience together with the Vietnam experience.

Table 3.4. Economic surplus spreadsheet calculation: SSNM/LCC in Bangladesh.

Year	εA	Max Yield Change	Gross Cost Change Per Ton	Input cost Change per ha	Input Cost change per ton	Net cost change	Prob of success of yld/cost change	Adoption rate	depreciati on rate	deprn factor	K shift	Paddy Rice Price ($/ton) normalize d 2010	Paddy Rice Prodn (tons)	Total Benefits or Change in Total Surplus ($)	Total Costs PS Workgroup ($) normalized to 2010	Net Benefits ($)	Discounted Total Benefits (5%; t=0 at 2010)	Discounted Total Costs (5% t=0 at 2010)	Discounted net benefits (5% t=0 at 2010)
1997	0.25	0.08	0.32	0.00	0.000	0.32	0.50	0.0000	0.000	1.00	0.000000	54.98	28152000	0.00	217631.54	-217631.54	0.00	410376.72	-410376.72
1998	0.25	0.08	0.32	0.00	0.000	0.32	0.50	0.0000	0.000	1.00	0.000000	66.62	29710000	0.00	237798.79	-237798.79	0.00	427052.47	-427052.47
1999	0.25	0.08	0.32	0.00	0.000	0.32	0.50	0.0000	0.000	1.00	0.000000	68.62	34430000	0.00	251945.00	-251945.00	0.00	430911.46	-430911.46
2000	0.25	0.08	0.32	0.00	0.000	0.32	0.50	0.0000	0.000	1.00	0.000000	62.97	37627500	0.00	261915.33	-261915.33	0.00	426632.48	-426632.48
2001	0.25	0.08	0.32	0.00	0.000	0.32	0.50	0.0000	0.000	1.00	0.000000	58.55	36269000	0.00	275899.69	-275899.69	0.00	428010.97	-428010.97
2002	0.25	0.08	0.32	0.00	0.000	0.32	0.50	0.0000	0.000	1.00	0.000000	63.84	37593000	0.00	283409.81	-283409.81	0.00	418725.36	-418725.36
2003	0.25	0.08	0.32	0.00	0.000	0.32	0.50	0.0000	0.000	1.00	0.000000	61.06	38361400	0.00	289916.42	-289916.42	0.00	407941.51	-407941.51
2004	0.25	0.08	0.32	0.00	0.000	0.32	0.50	0.0000	0.000	1.00	0.000000	92.27	36236000	0.00	303900.77	-303900.77	0.00	407256.10	-407256.10
2005	0.25	0.08	0.32	0.00	0.000	0.32	0.50	0.0000	0.000	1.00	0.000000	99.43	39795600	0.00	323711.94	-323711.94	0.00	413147.58	-413147.58
2006	0.25	0.08	0.32	0.00	0.000	0.32	0.50	0.0000	0.000	1.00	0.000000	102.61	40773000	0.00	341483.73	-341483.73	0.00	415075.61	-415075.61
2007	0.25	0.08	0.32	0.00	0.000	0.32	0.50	0.0000	0.000	1.00	0.000000	123.28	43181000	0.00	351356.94	-351356.94	0.00	406739.58	-406739.58
2008	0.25	0.08	0.32	0.00	0.000	0.32	0.50	0.0019	0.000	1.00	0.000308	152.68	46742000	2200068.17	380393.90	1819674.26	2425575.15	419384.28	2006190.87
2009	0.25	0.08	0.32	0.00	0.000	0.32	0.50	0.0026	0.000	1.00	0.000421	152.68	47724000	3068188.10	396093.93	2672094.16	3221597.50	415898.63	2805698.87
2010	0.25	0.08	0.32	0.00	0.000	0.32	0.50	0.0036	0.000	1.00	0.000575	152.68	49355000	4332939.40	411470.25	3921469.15	4332939.40	411470.25	3921469.15
2011	0.25	0.08	0.32	0.00	0.000	0.32	0.50	0.0049	0.000	1.00	0.000785	152.68	49355000	5914784.06	430601.63	5484182.44	5633127.68	410096.79	5223030.89
2012	0.25	0.08	0.32	0.00	0.000	0.32	0.50	0.0067	0.020	0.98	0.001049	152.68	49355000	7908890.28	430601.63	7478288.66	7173596.63	390568.37	6783028.26
2013	0.25	0.08	0.32	0.00	0.000	0.32	0.50	0.0091	0.040	0.96	0.001402	152.68	49355000	10564084.94		10564084.94	9125653.76	0.00	9125653.76
2014	0.25	0.08	0.32	0.00	0.000	0.32	0.50	0.0124	0.060	0.94	0.001870	152.68	49355000	14092222.89		14092222.89	11593706.65	0.00	11593706.65
2015	0.25	0.08	0.32	0.00	0.000	0.32	0.50	0.0167	0.080	0.92	0.002465	152.68	49355000	18580095.79		18580095.79	14557991.22	0.00	14557991.22
2016	0.25	0.08	0.32	0.00	0.000	0.32	0.50	0.0225	0.100	0.90	0.003243	152.68	49355000	24443660.91		24443660.91	18240236.12	0.00	18240236.12

	Discounted Total Benefits	Discounted Total Costs	Discounted net benefits
Total Discounted Benefits (1997-2012):	22,786,836.36	6,639,288.15	16,147,548.21
Total Discounted Benefits (1997-2016):	76,304,424.11	6,639,288.15	69,665,135.96

BCR (1997-2012):	3.43
BCR (1997-2016):	11.49
IRR (1997-2012):	0.236
IRR (1997-2016):	0.322

to have been incurred starting in 1997 (when it was established) and amounted to about US$6.6 million (see Table 3.1). This research investment was then divided equally for the period 1997–2012 and deflated/inflated based on the relevant CPI values.

We find that the PV of the total benefits of SSNM/LCC in Bangladesh is around US$22.8 million for the 1997–2012 period, using a discount rate of 5%. If we consider the longer 1997–2016 period, the discounted benefits of the technology increase to US$76.3 million. Based on the available investment cost data for the PS Work Group (discounted at 5% as well), the NPV of SSNM/LCC in Bangladesh is approximately US$16.1 million for the 1997–2012 period and US$69.6 million for the 1997–2016 period. The corresponding BCRs are 3:1 and 11:1 for the 1997–2012 and the 1997–2016 periods, respectively. The IRRs for the 1997–2012 and the 1997–2016 periods are 0.236 and 0.322, respectively. Again, if we consider a pivotal shift instead of a parallel shift assumption, the impact estimates should be approximately half of the values reported above.

If we only consider SDC investments to the PS Work Group alone, the total investment cost for 2001–12 was US$5.3 million. Based only on this SDC investment value, the NPV of SSNM/LCC in Bangladesh is approximately US$17.4 million for the 1997–2012 period and US$71.4 million for the 1997–2016 period (see Appendix 2). The corresponding BCRs are approximately 4:1 and 14:1 for the 1997–2012 and the 1997–2016 periods, respectively. The IRRs for the 1997–2012 and the 1997–2016 periods are 0.265 and 0.346, respectively.

3.2.3.4 Economics surplus analysis of DSR in Bangladesh

The spreadsheet to show the economic surplus effects of DSR (and short-duration varieties [SDVs]) in Bangladesh is presented in Table 3.5. The surplus model here evaluates DSR together with SDV and weed management using herbicides (versus the practice of transplanting [TP] using long-duration varieties [LDVs]). The rice supply elasticity used here was the same as in the SSNM/LCC surplus model above and it was assumed to be 0.25.

We assumed that DSR and SDV provide a 1.5% increase in yield relative to producers who use TP and/or LDVs. The range of yield increases from the previous literature is from -3% to 25%. But previous studies (especially in India) also provide cases where DSR have yields that are not significantly different or are even lower than TP/LDVs. Information gathered from the field visits also suggest that farmers generally observe that DSR/SDV tends to produce lower yields than TP/LDV. Thus, to be conservative, only a 1.5% yield increase was assumed. Previous studies and our field visits suggest that one major advantage of DSR/SDV in Bangladesh is the labor cost savings (8–20% lower). However, there were observations that herbicide costs for DSR and SDV increase as well. Therefore, a 1% cost reduction is assumed in the DSR surplus model for Bangladesh (Table 3.5).

From the discussion in Palis et al. (2012a), we assumed that the adoption of DSR/SDV started in 2004. The main target for this technology was presumed to be the northern districts in Bangladesh, particularly the medium/highland types (where Mazid and Johnson [2010] indicate that it is most suitable). Given the information above and the discussion in Palis et al. (2012a), a logistic adoption path was assumed where approximately 1% of total rice area in Bangladesh had utilized SDV/DSR. In the target area, a 50% adoption rate after 20 years was conservatively assumed as well (given some of the concerns regarding the possibly lower yields of DSR vis-à-vis transplanted LDVs). As with the previous surplus models discussed above, paddy rice prices and production for Bangladesh were gathered from the World Rice Statistics database. The total research costs for the LPCE Work Group were assumed to have been incurred starting in 2004 (when it was established) and amounted to about US$1.7 million (see Table 3.1). This research investment was then divided equally for the period 2004–12 and deflated/inflated based on relevant CPI values.

Table 3.5. Economic surplus spreadsheet calculation: DSR/SDV in Bangladesh.

Year	εA	Max Yield Change	Gross Cost Change Per Ton	Input cost Change per ha	Input Cost change per ton	Net cost change	Prob of success of yld/cost change	Adoption rate	depreciation rate	deprn factor	K shift	Paddy Rice Price ($/ton) normalized 2010	Paddy Rice Prodn (tons)	Total Benefits or Change in Total Surplus ($)	Total Costs LPCE Workgroup ($) normalized to 2010	Net Benefits ($)	Discounted Total Benefits (5%; t=0 at 2010)	Discounted Total Costs (5% t=0 at 2010)	Discounted net benefits (5% t=0 at 2010)
1997	0.25	0.02	0.06	-0.01	-0.010	0.07	0.50	0.0000	0.000	1.00	0.000000	54.98	28152000	0.00	0.00	0.00	0.00	0.00	0.00
1998	0.25	0.02	0.06	-0.01	-0.010	0.07	0.50	0.0000	0.000	1.00	0.000000	66.62	29710000	0.00	0.00	0.00	0.00	0.00	0.00
1999	0.25	0.02	0.06	-0.01	-0.010	0.07	0.50	0.0000	0.000	1.00	0.000000	68.62	34430000	0.00	0.00	0.00	0.00	0.00	0.00
2000	0.25	0.02	0.06	-0.01	-0.010	0.07	0.50	0.0000	0.000	1.00	0.000000	62.97	37627500	0.00	0.00	0.00	0.00	0.00	0.00
2001	0.25	0.02	0.06	-0.01	-0.010	0.07	0.50	0.0000	0.000	1.00	0.000000	58.55	36269000	0.00	95557.21	-95557.21	0.00	148240.59	-148240.59
2002	0.25	0.02	0.06	-0.01	-0.010	0.07	0.50	0.0000	0.000	1.00	0.000000	63.84	37593000	0.00	98158.32	-98158.32	0.00	145024.54	-145024.54
2003	0.25	0.02	0.06	-0.01	-0.010	0.07	0.50	0.0000	0.000	1.00	0.000000	61.06	38361400	0.00	100411.87	-100411.87	0.00	141289.58	-141289.58
2004	0.25	0.02	0.06	-0.01	-0.010	0.07	0.50	0.0008	0.000	1.00	0.000028	92.27	36236000	92890.89	105255.32	-12364.42	124482.68	141052.19	-16569.51
2005	0.25	0.02	0.06	-0.01	-0.010	0.07	0.50	0.0011	0.000	1.00	0.000037	99.43	39795600	146374.46	112116.87	34257.59	186815.02	143092.69	43722.33
2006	0.25	0.02	0.06	-0.01	-0.010	0.07	0.50	0.0014	0.000	1.00	0.000049	102.61	40773000	205999.92	118272.08	87727.84	250394.19	143760.46	106633.74
2007	0.25	0.02	0.06	-0.01	-0.010	0.07	0.50	0.0019	0.000	1.00	0.000066	123.28	43181000	348709.23	121691.65	227017.59	403674.53	140873.29	262801.23
2008	0.25	0.02	0.06	-0.01	-0.010	0.07	0.50	0.0025	0.000	1.00	0.000087	152.68	46742000	621530.71	131748.53	489782.18	685237.61	145252.76	539984.86
2009	0.25	0.02	0.06	-0.01	-0.010	0.07	0.50	0.0033	0.000	1.00	0.000116	152.68	47724000	843046.01	137186.20	705859.81	885198.31	144045.51	741152.80
2010	0.25	0.02	0.06	-0.01	-0.010	0.07	0.50	0.0044	0.000	0.95	0.000146	152.68	49355000	1099148.92	142511.75	956637.17	1099148.92	142511.75	956637.17
2011	0.25	0.02	0.06	-0.01	-0.010	0.07	0.50	0.0058	0.000	0.90	0.000183	152.68	49355000	1379875.24	149137.86	1230737.38	1314166.90	142036.05	1172130.84
2012	0.25	0.02	0.06	-0.01	-0.010	0.07	0.50	0.0074	0.020	0.85	0.000220	152.68	49355000	1654743.87	149137.86	1505606.01	1500901.47	135272.43	1365629.04
2013	0.25	0.02	0.06	-0.01	-0.010	0.07	0.50	0.0094	0.040	0.80	0.000261	152.68	49355000	1969177.14		1969177.14	1701049.25	0.00	1701049.25
2014	0.25	0.02	0.06	-0.01	-0.010	0.07	0.50	0.0118	0.060	0.75	0.000308	152.68	49355000	2322262.03		2322262.03	1910530.72	0.00	1910530.72
2015	0.25	0.02	0.06	-0.01	-0.010	0.07	0.50	0.0147	0.080	0.70	0.000360	152.68	49355000	2709451.11		2709451.11	2122925.84	0.00	2122925.84
2016	0.25	0.02	0.06	-0.01	-0.010	0.07	0.50	0.0182	0.100	0.65	0.000414	152.68	49355000	3121036.93		3121036.93	2328965.81	0.00	2328965.81

	Discounted Total Benefits	Discounted Total Costs	Discounted net benefits
Total Discounted Benefits (1997-2012):	6,450,019.63	1,712,451.84	4,737,567.79
Total Discounted Benefits (1997-2016):	14,513,491.25	1,712,451.84	12,801,039.41

BCR (1997-2012):	3.77
BCR (1997-2016):	8.48
IRR (1997-2012):	0.443
IRR (1997-2016):	0.493

Assuming a discount rate of 5%, we find that the PV of the total benefits of DSR/SDV in Bangladesh is around US$6.5 million for the 1997–2012 period. If we consider the longer 1997–2016 period, the discounted benefits of the technology increase to US$14.5 million. Based on the available investment cost data for the LPCE Work Group (discounted at 5% as well), the NPV of DSR/SDV in Bangladesh is approximately US$4.7 million for the 1997–2012 period and US$12.8 million for the 1997–2016 period. The corresponding BCRs are 4:1 and 8:1 for 1997–2012 and the 1997–2016, respectively. The IRRs for the 1997–2012 and the 1997–2016 periods are 0.443 and 0.493, respectively. Again, if we consider a pivotal shift instead of a parallel shift assumption, the impact estimates should be approximately half of the values reported above.

The total SDC investment to the LPCE Work Group for the 2001–12 period was US$1.2 million. Based only on this SDC investment value to the LPCE Work Group, the NPV of DSR/LDV in Bangladesh is approximately US$5.2 million for the 1997–2012 and US$13.3 million for 1997–2016 (see Appendix 2). The corresponding BCRs are approximately 5:1 and 12:1 for the 1997–2012 and the 1997–2016 periods, respectively. The IRRs for the 1997–2012 and the 1997–2016 periods are 0.567 and 0.603, respectively.

3.2.3.5 Economic surplus analysis of AR in the Philippines

In Table 3.6, we present the spreadsheet that shows the changes in economic surplus due to adoption of AR in the Philippines. The rice supply elasticity used here was the same as in the AWD surplus model and it was assumed to be 0.28. Based on the studies of Lampayan et al. (2012b) and Templeton and Bayot (2011), producers who use AR in the Philippines tend to have 11–25% lower yields compared with those who use transplanting. Hence, we assumed that the yield increase in the economic surplus model for AR is -15%. But note that these previous studies also showed a substantial benefit from AR due to cost reductions ranging from 21% to 62% (primarily from reduced irrigation costs). Based on this figure, we assumed a 50% reduction in input cost in the AR economic surplus model for the Philippines.

Based on information gathered from our field visits, as well as in Lampayan et al. (2012b), AR adoption in the Philippines was assumed to have started in 2006. A logistic adoption path was fitted based on adoption figures provided in Soriano (2012) where he stated that there were about 5000 AR adopters in 2011, approximately 1.8% of the area where AR is suited (Templeton and Bayot 2011). Paddy rice prices and production figures for the Philippines were the same as the ones used in the AWD surplus model for the Philippines. The total research costs for the WS work group were assumed to have been incurred starting in 2004 (when it was established) and amounted to about US$2.09 million (see Table 3.1). This research investment was then divided equally for the period 2004–12 and deflated/inflated based on relevant CPI values.

Given a discount rate of 5%, we find that the PV of the total benefits of AWD in the Philippines for the 1997–2012 period is around US$403,000. If we consider the longer 1997–2016 period, the benefits of the technology increase to US$1.15 million. Weighing these benefits against the total discounted investment costs of the WS Work Group, the NPV of AWD benefits in the Philippines is approximately -US$1.6 million for the 1997–2012 period and -US$939,000 for the 1997–2016 period. The corresponding BCRs are approximately 0.2:1 and 0.55:1 for the 1997–2012 and the 1997–2016, respectively. These NPV and BCR figures suggest that the economic surplus change due to AR adoption in the Philippines does not fully cover the total investment cost for the WS Work Group. The IRRs for the 1997–2012 and the 1997–2016 periods are less than zero in this case.

Note that the investment costs considered above are total investments to the WS Work Group from all donor sources (not just SDC). Of the US$2.09 million total expenditures of the WS Work Group, about US$1.15 million is from SDC. When considering only the SDC costs for the WS working group, the NPV of AWD benefits in the Philippines

Table 3.6. Economic surplus spreadsheet calculation: AR in the Philippines.

Year	εA	Max Yield Change	Gross Cost Change Per Ton	Input cost Change per ha	Input Cost change per ton	Net cost change	Prob of success of yld/cost change	Adoption rate	depreciation rate	deprn factor	K shift	Paddy Rice Price ($/ton) normalized to 2010	Paddy Rice Prodn (tons)	Total Benefits or Change in Total Surplus ($)	Total Costs WS Workgroup ($) normalized to 2010	Net Benefits ($)	Discounted Total Benefits (5%; t=0 at 2010)	Discounted Total Costs (5% t=0 at 2010)	Discounted net benefits (5% t=0 at 2010)
1997	0.28	-0.15	-0.54	-0.50	-0.588	0.05	0.50	0.0000	0.000	1.00	0.000000	142.14	11268000	0.00	0.00	0.00	0.00	0.00	0.00
1998	0.28	-0.15	-0.54	-0.50	-0.588	0.05	0.50	0.0000	0.000	1.00	0.000000	117.31	8554000	0.00	0.00	0.00	0.00	0.00	0.00
1999	0.28	-0.15	-0.54	-0.50	-0.588	0.05	0.50	0.0000	0.000	1.00	0.000000	123.28	11786600	0.00	0.00	0.00	0.00	0.00	0.00
2000	0.28	-0.15	-0.54	-0.50	-0.588	0.05	0.50	0.0000	0.000	1.00	0.000000	121.29	12389400	0.00	0.00	0.00	0.00	0.00	0.00
2001	0.28	-0.15	-0.54	-0.50	-0.588	0.05	0.50	0.0000	0.000	1.00	0.000000	107.44	12954900	0.00	117053.51	-117053.51	0.00	181588.42	-181588.42
2002	0.28	-0.15	-0.54	-0.50	-0.588	0.05	0.50	0.0000	0.000	1.00	0.000000	117.73	13270700	0.00	120239.76	-120239.76	0.00	177648.89	-177648.89
2003	0.28	-0.15	-0.54	-0.50	-0.588	0.05	0.50	0.0000	0.000	1.00	0.000000	114.92	13499900	0.00	123000.27	-123000.27	0.00	173073.73	-173073.73
2004	0.28	-0.15	-0.54	-0.50	-0.588	0.05	0.50	0.0000	0.000	1.00	0.000000	124.55	14496800	0.00	128933.28	-128933.28	0.00	172782.93	-172782.93
2005	0.28	-0.15	-0.54	-0.50	-0.588	0.05	0.50	0.0000	0.000	1.00	0.000000	148.95	14603000	0.00	137338.39	-137338.39	0.00	175282.46	-175282.46
2006	0.28	-0.15	-0.54	-0.50	-0.588	0.05	0.50	0.0002	0.000	1.00	0.000004	169.18	15326700	11450.50	144878.27	-133427.77	13918.16	176100.45	-162182.29
2007	0.28	-0.15	-0.54	-0.50	-0.588	0.05	0.50	0.0002	0.000	1.00	0.000006	207.60	16240200	19767.27	149067.09	-129299.83	22883.08	172563.79	-149680.71
2008	0.28	-0.15	-0.54	-0.50	-0.588	0.05	0.50	0.0003	0.000	1.00	0.000008	294.74	16815500	38567.66	161386.35	-122818.69	42520.85	177928.45	-135407.60
2009	0.28	-0.15	-0.54	-0.50	-0.588	0.05	0.50	0.0004	0.000	1.00	0.000010	295.37	16266400	49599.66	168047.26	-118447.60	52079.65	176449.62	-124369.98
2010	0.28	-0.15	-0.54	-0.50	-0.588	0.05	0.50	0.0005	0.000	1.00	0.000014	329.64	15771700	71154.68	174570.83	-103416.15	71154.68	174570.83	-103416.15
2011	0.28	-0.15	-0.54	-0.50	-0.588	0.05	0.50	0.0007	0.000	1.00	0.000018	329.64	15771700	94255.31	182687.53	-88432.22	89766.96	173988.13	-84221.16
2012	0.28	-0.15	-0.54	-0.50	-0.588	0.05	0.50	0.0009	0.020	0.98	0.000024	329.64	15771700	122222.86	182687.53	-60464.67	110859.74	165702.98	-54843.24
2013	0.28	-0.15	-0.54	-0.50	-0.588	0.05	0.50	0.0012	0.040	0.96	0.000030	329.64	15771700	158191.67		158191.67	136651.91	0.00	136651.91
2014	0.28	-0.15	-0.54	-0.50	-0.588	0.05	0.50	0.0016	0.060	0.94	0.000039	329.64	15771700	204264.57		204264.57	168048.96	0.00	168048.96
2015	0.28	-0.15	-0.54	-0.50	-0.588	0.05	0.50	0.0021	0.080	0.92	0.000050	329.64	15771700	260346.19		260346.19	203988.06	0.00	203988.06
2016	0.28	-0.15	-0.54	-0.50	-0.588	0.05	0.50	0.0027	0.100	0.90	0.000064	329.64	15771700	330553.47		330553.47	246664.09	0.00	246664.09

Total Discounted Benefits (1997-2012): 403,183.11 2,097,680.68 (1,694,497.57)
Total Discounted Benefits (1997-2016): 1,158,536.13 2,097,680.68 (939,144.55)

BCR (1997-2012): 0.19
BCR (1997-2016): 0.55
IRR (1997-2012): negative
IRR (1997-2016): negative

is approximately -US$749,000 for the 1997–2012 period and US$6,000 for the 1997–2016 period (see Appendix 2). The corresponding BCRs are approximately 0.35:1 and 1:1 for the 1997–2012 and the 1997–2016 periods, respectively. These economic surplus figures suggest that the total SDC investment to the WS Work Group will only be covered by AR adoption if we consider the expected benefits until 2016. The IRRs for the 1997–2012 is negative and the IRR is around 0.05 for the period 1997–2016.

3.2.3.6 Economics Surplus Analysis of HSS in the Philippines

The spreadsheet showing the economic surplus effects of HSS in the Philippines is presented in Table 3.7. Based on our field visits in the Philippines and interactions with Dr. Cesar Tado (PhilRice) and Martin Gummert (PP Work Group leader), we decided to model the economic impact of HSS based on adoption of certified rice seed producers (rather than paddy rice farmers). As pointed out in Section 3.1.2.1, HSS in the Philippines may be better suited for seed farmers (rather than rice producers themselves) and that industry partners (manufacturers like GrainPro© and distributors like Pacifica Agrivet©) will have to play important roles in the wider dissemination of HSS.

The rice supply elasticity used in the surplus analysis of HSS was the same as in the AWD and AR surplus models, and it was assumed to be 0.28. From Gummert (2012a), farmers who used HSS tend to have lower storage losses from pests by about 2–10%. Hence, we assumed a 6% increase in the yield of rice seed producers when they use HSS. We further assumed that there is no input cost change due to HSS because we presumed that the higher cost of HSS is compensated for by the typically higher prices received for the seed (i.e., since they are good quality).

HSS adoption in the Philippines was assumed to have started in 2011. A logistic adoption path was also used where we assumed that 5% of certified rice seed producers would have adopted the technology by 2016 and 50% would adopt HSS 20 years from initial adoption. The data for rice seed prices and rice seed production were collected from the Bureau of Agricultural Statistics (BAS) in the Philippines. The total research costs for the PP Work Group were assumed to have been incurred starting in 2003 (when it was established) and amounted to about US$967,416 (see Table 3.1). This research investment was then divided equally for the period 2003–2012 and deflated/inflated based on the relevant CPI values.

We find that the PV of the total benefits of HSS adoption by rice seed producers in the Philippines is around US$458,543 for the 1997–2012 period, using a discount rate of 5%. If we consider the longer 1997–2016 period, the discounted benefits of the technology increase to about US$1.8 million. Based on the available investment cost data for the PP Work Group (discounted at 5% as well), the NPV of HSS in the Philippines is approximately -US$504,846 for the 1997–2012 period and US$809,406 for the 1997–2016 period. The negative NPV for the 1997–2012 period is mainly because the HSS technology was assumed to have only been adopted in 2011 and, for the 1997–2012 period, not enough time has passed to capture the benefits of the technology. The corresponding BCRs are 0.48:1 and 1.84:1 for the 1997–2012 and the 1997–2016 periods, respectively. The IRR for the 1997–2012 period is negative and the IRR for the 1997–2016 period is 0.152. Again, if we consider a pivotal shift instead of a parallel shift assumption, the impact estimates should be approximately half of the values reported above.

If we only consider SDC investments to the PP Work Group alone, the total investment cost for 2003–12 was US$217,416. Based only on SDC investment value, the NPV of HSS in the Philippines is approximately US$242,032 for the 1997–2012 period and US$1.55 million for the 1997–2016 period (see Appendix 2). The corresponding BCRs are approximately 2:1 and 8:1 for the 1997–2012 and the 1997–2016 periods, respectively. The IRRs for the 1997–2012 and the 1997–2016 periods are 0.233 and 0.414, respectively.

Table 3.7. Economic surplus spreadsheet calculation: HSS in the Philippines.

Year	εA	Max Yield Change	Gross Cost Change Per Ton	Input cost Change per ha	Input Cost change per ton	Net cost change	Prob of success of yld/cost change	Adoption rate	depreciation rate	deprn factor	K shift	Seed Rice Price ($/ton) normalized to 2010	Seed Rice Prodn (tons)	Total Benefits or Change in Total Surplus ($)	Total Costs WS Workgroup ($) normalized to 2010	Net Benefits ($)	Discounted Total Benefits (5%; t=0 at 2010)	Discounted Total Costs (5% t=0 at 2010)	Discounted net benefits (5% t=0 at 2010)
1997	0.28	0.06	0.21	0.00	0.000	0.21	0.50	0.0000	0.000	1.00	0.000000	430.74	171000	0.00	0.00	0.00	0.00	0.00	0.00
1998	0.28	0.06	0.21	0.00	0.000	0.21	0.50	0.0000	0.000	1.00	0.000000	339.21	191000	0.00	0.00	0.00	0.00	0.00	0.00
1999	0.28	0.06	0.21	0.00	0.000	0.21	0.50	0.0000	0.000	1.00	0.000000	375.94	191000	0.00	0.00	0.00	0.00	0.00	0.00
2000	0.28	0.06	0.21	0.00	0.000	0.21	0.50	0.0000	0.000	1.00	0.000000	345.71	193000	0.00	0.00	0.00	0.00	0.00	0.00
2001	0.28	0.06	0.21	0.00	0.000	0.21	0.50	0.0000	0.000	1.00	0.000000	315.60	195000	0.00	0.00	0.00	0.00	0.00	0.00
2002	0.28	0.06	0.21	0.00	0.000	0.21	0.50	0.0000	0.000	1.00	0.000000	320.36	192000	0.00	0.00	0.00	0.00	0.00	0.00
2003	0.28	0.06	0.21	0.00	0.000	0.21	0.50	0.0000	0.000	1.00	0.000000	311.99	201000	0.00	68162.83	-68162.83	0.00	95911.95	-95911.95
2004	0.28	0.06	0.21	0.00	0.000	0.21	0.50	0.0000	0.000	1.00	0.000000	316.31	206000	0.00	71450.72	-71450.72	0.00	95750.80	-95750.80
2005	0.28	0.06	0.21	0.00	0.000	0.21	0.50	0.0000	0.000	1.00	0.000000	342.74	204000	0.00	76108.57	-76108.57	0.00	97135.96	-97135.96
2006	0.28	0.06	0.21	0.00	0.000	0.21	0.50	0.0000	0.000	1.00	0.000000	388.19	204000	0.00	80286.93	-80286.93	0.00	97589.26	-97589.26
2007	0.28	0.06	0.21	0.00	0.000	0.21	0.50	0.0000	0.000	1.00	0.000000	444.07	204000	0.00	82608.24	-82608.24	0.00	95629.36	-95629.36
2008	0.28	0.06	0.21	0.00	0.000	0.21	0.50	0.0000	0.000	1.00	0.000000	500.62	204000	0.00	89435.18	-89435.18	0.00	98602.28	-98602.28
2009	0.28	0.06	0.21	0.00	0.000	0.21	0.50	0.0000	0.000	1.00	0.000000	484.55	204000	0.00	93126.44	-93126.44	0.00	97782.77	-97782.77
2010	0.28	0.06	0.21	0.00	0.000	0.21	0.50	0.0000	0.000	1.00	0.000000	532.03	204000	0.00	96741.60	-96741.60	0.00	96741.60	-96741.60
2011	0.28	0.06	0.21	0.00	0.000	0.21	0.50	0.0194	0.000	1.00	0.002081	532.03	204000	225955.78	101239.62	124716.16	215195.98	96418.68	118777.30
2012	0.28	0.06	0.21	0.00	0.000	0.21	0.50	0.0235	0.020	0.98	0.002471	532.03	204000	268290.54	101239.62	167050.92	243347.43	91827.32	151520.11
2013	0.28	0.06	0.21	0.00	0.000	0.21	0.50	0.0285	0.040	0.96	0.002930	532.03	204000	318145.50		318145.50	274826.04	0.00	274826.04
2014	0.28	0.06	0.21	0.00	0.000	0.21	0.50	0.0344	0.060	0.94	0.003469	532.03	204000	376703.10		376703.10	309914.57	0.00	309914.57
2015	0.28	0.06	0.21	0.00	0.000	0.21	0.50	0.0412	0.080	0.92	0.004059	532.03	204000	440816.15		440816.15	345390.99	0.00	345390.99
2016	0.28	0.06	0.21	0.00	0.000	0.21	0.50	0.0492	0.100	0.90	0.004740	532.03	204000	514759.55		514759.55	384121.50	0.00	384121.50

	Discounted Total Benefits	Discounted Total Costs	Discounted net benefits
Total Discounted Benefits (1997-2012):	458,543.40	963,389.99	(504,846.58)
Total Discounted Benefits (1997-2016):	1,772,796.51	963,389.99	809,406.52

BCR (1997-2012):	0.48
BCR (1997-2016):	1.84
IRR (1997-2012):	negative
IRR (1997-2016):	0.152

3.2.3.7 Economic surplus analysis of 3R3G/1M5R in Vietnam

The economic surplus effect of 3R3G/1M5R adoption in Vietnam is presented in Table 3.8. The rice supply elasticity used in the surplus calculation for 3R3G/1M5R was 0.3, which is similar to that used for EBRM in Vietnam.

In this analysis, we assumed that the 1M5R program is a simple continuation of the 3R3G program. The 3R3G program was disseminated and adopted from 2003 to 2009 and we assumed that further adoption occurred after 2009, but it is now the 1M5R approach. The implicit assumption is that the producers who used 3R3G before 2009 simply continued using the 1M5R approach afterward (i.e., they just followed the additional two reductions and one must-do practice). Based on this scenario, farm-level impact of 3R3G (2003–09) was assumed to be different from the farm-level impact of 1M5R (2009 onward). The yield effect of 3R3G/1M5R is assumed to be zero, given that most previous studies of 3R3G did not find any statistically significant difference in the yields of adopters vis-à-vis nonadopters (see Section 3.3.5).[7] The impact of 3R3G/1M5R mainly comes from the input cost reduction of this management approach. For 2003–09, we assumed that the 3R3G program reduces input cost by about 4%. Cost function regressions in Huelgas and Templeton (2010) suggest that unit costs of 3R3G adopters were approximately 7–8% than nonadopters. But the study by Lang et al. (2008) did not find any significant difference in input costs. Thus, we settled on the 4% cost reduction assumption for the 3R3G period. For the period after 2009 (when 1M5R is now assumed to be more predominant), a 5% input cost reduction is assumed based on the study of Chi et al. (2012).

For the logistic adoption path, the start of 3R3G/1M5R adoption was assumed to be in 2003. The major target area for these technology approaches was assumed to be the Mekong Delta of Vietnam, which accounts for approximately half of the country's total production. The logistic adoption path was traced such that approximately 11,000 ha used 3R3G in 2003 and, by 2016, about 425,000 ha utilizes 3R3G/1M5R. Paddy rice prices and production figures for Vietnam were the same as the ones used in the model for EBRM in Vietnam. The prices were deflated/inflated based on relevant CPI values.

Given that 3R3G/1M5R is an integrated technology, it essentially encompasses all the work groups and no "work-group-specific" investment cost can reasonably be associated with it. The benefits of 3R3G/1M5R cannot be compared with "work-group-specific" investment costs such that no meaningful NPV, BCR, and IRR can be computed. Hence, only the discounted surplus benefits are reported here. Using a 5% discount rate, we find that the PV of the total benefits of 3R3G/1M5R in Vietnam is around US$14 million for the 1997–2012 period. If we consider the longer 1997–2016 period, the discounted benefits of the technology increase to about US$41 million.

3.2.3.8 Economics surplus analysis of ICM in Indonesia

The spreadsheet showing the economic surplus effects of ICM in Indonesia is presented in Table 3.9. Several studies have reported Indonesian rice supply elasticities (εA) ranging from 0.10 to 1.25. Mohanty et al. (2010) reports a rice supply elasticity of 0.103, while Yu and Fan (2009) reports short-run and long-run rice supply elasticities with median values of around 0.32 and 0.698, respectively. Taking the average of these values, we assumed a rice supply elasticity of 0.37 for the ICM economic surplus model.

Based on findings in Dikitanan et al. (2012), the yield effect of ICM was assumed to be 20% and no input cost effect was applied. ICM dissemination

[7]The preponderance of evidence from Section 3.3.5 suggests no significant difference in the yields of 3R3G/1M5R adopters versus nonadopters. However, after we conducted the surplus analysis, IRRC scientists informed us of a study conducted by economists from the Institute of Policy and Strategy for Agricultural and Rural Development (IPSARD) and that they found that mean yields of 1M5R adopters in An Giang province are 0.2–0.4 t ha^{-1} higher than those of nonadopters. However, this is a preliminary result with no published documentation yet. Hence, a zero yield effect assumption here still seems reasonable. It is clear that further research on this topic is needed.

Table 3.8. Economic surplus spreadsheet calculation: 3R3G/1M5R in Vietnam.

Year	εA	Max Yield Change	Gross Cost Change Per Ton	Input cost Change per ha	Input Cost change per ton	Net cost change	Prob of success of yld/cost change	Adoption rate	depreciati on rate	deprn factor	K shift	Paddy Rice Price ($/ton) normalized to 2010	Paddy Rice Prodn (tons)	Total Benefits or Change in Total Surplus ($)	Total Costs ($) normalized to 2010	Net Benefits ($)	Discounted Total Benefits (5%; t=0 at 2010)
1997	0.31	0.00	0.00	-0.04	-0.040	0.04	0.50	0.0000	0.000	1.00	0.000000	66.57	27523900	0.00			0.00
1998	0.31	0.00	0.00	-0.04	-0.040	0.04	0.50	0.0000	0.000	1.00	0.000000	77.91	29145500	0.00			0.00
1999	0.31	0.00	0.00	-0.04	-0.040	0.04	0.50	0.0000	0.000	1.00	0.000000	65.74	31393800	0.00			0.00
2000	0.31	0.00	0.00	-0.04	-0.040	0.04	0.50	0.0000	0.000	1.00	0.000000	58.02	32529500	0.00			0.00
2001	0.31	0.00	0.00	-0.04	-0.040	0.04	0.50	0.0000	0.000	1.00	0.000000	48.76	32108400	0.00			0.00
2002	0.31	0.00	0.00	-0.04	-0.040	0.04	0.50	0.0000	0.000	1.00	0.000000	62.61	34447200	0.00			0.00
2003	0.31	0.00	0.00	-0.04	-0.040	0.04	0.50	0.0015	0.000	1.00	0.000030	59.76	34568800	62531.55			87988.16
2004	0.31	0.00	0.00	-0.04	-0.040	0.04	0.50	0.0020	0.000	1.00	0.000040	76.24	36148900	111363.94			149238.33
2005	0.31	0.00	0.00	-0.04	-0.040	0.04	0.50	0.0027	0.000	1.00	0.000054	87.20	35832900	168486.69			215036.46
2006	0.31	0.00	0.00	-0.04	-0.040	0.04	0.50	0.0036	0.000	1.00	0.000072	96.61	35849500	249099.24			302781.69
2007	0.31	0.00	0.00	-0.04	-0.040	0.04	0.50	0.0048	0.000	1.00	0.000096	140.07	35942700	482676.72			558758.64
2008	0.31	0.00	0.00	-0.04	-0.040	0.04	0.50	0.0064	0.000	1.00	0.000128	228.53	38729800	1130261.99			1246113.84
2009	0.31	0.00	0.00	-0.04	-0.040	0.04	0.50	0.0085	0.000	1.00	0.000170	228.53	38950200	1512405.19			1588025.45
2010	0.31	0.00	0.00	-0.05	-0.050	0.05	0.50	0.0113	0.000	1.00	0.000282	228.53	39988900	2578837.64			2578837.64
2011	0.31	0.00	0.00	-0.05	-0.050	0.05	0.50	0.0150	0.000	1.00	0.000374	228.53	39988900	3420020.57			3257162.45
2012	0.31	0.00	0.00	-0.05	-0.050	0.05	0.50	0.0198	0.020	0.98	0.000485	228.53	39988900	4433993.17			4021762.51
2013	0.31	0.00	0.00	-0.05	-0.050	0.05	0.50	0.0261	0.040	0.96	0.000627	228.53	39988900	5727790.46			4947880.76
2014	0.31	0.00	0.00	-0.05	-0.050	0.05	0.50	0.0343	0.060	0.94	0.000806	228.53	39988900	7365093.68			6059280.79
2015	0.31	0.00	0.00	-0.05	-0.050	0.05	0.50	0.0443	0.080	0.92	0.001020	228.53	39988900	9321150.81			7303365.56
2016	0.31	0.00	0.00	-0.05	-0.050	0.05	0.50	0.0569	0.100	0.90	0.001281	228.53	39988900	11709225.30			8737604.20

Total Discounted Benefits (1997-2012): 14,005,705.17
Total Discounted Benefits (1997-2016): 41,053,836.48

Table 3.9. Economic surplus spreadsheet calculation: ICM in Indonesia.

Year	εA	Max Yield Change	Gross Cost Change Per Ton	Input cost Change per ha	Input Cost change per ton	Net cost change	Prob of success of yld/cost change	Adoption rate	depreciation rate	deprn factor	K shift	Paddy Rice Price ($/ton) normalized to 2010	Paddy Rice Prodn (tons)	Total Benefits or Change in Total Surplus ($)	Total Costs ($) normalized to 2010	Net Benefits ($)	Discounted Total Benefits (5%; t=0 at 2010)
1997	0.37	0.20	0.54	0.00	0.000	0.54	0.50	0.0000	0.000	1.00	0.000000	36.10	49377100	0.00			0.00
1998	0.37	0.20	0.54	0.00	0.000	0.54	0.50	0.0000	0.000	1.00	0.000000	28.84	49236700	0.00			0.00
1999	0.37	0.20	0.54	0.00	0.000	0.54	0.50	0.0000	0.000	1.00	0.000000	57.25	50866400	0.00			0.00
2000	0.37	0.20	0.54	0.00	0.000	0.54	0.50	0.0000	0.000	1.00	0.000000	48.80	51898000	0.00			0.00
2001	0.37	0.20	0.54	0.00	0.000	0.54	0.50	0.0000	0.000	1.00	0.000000	48.11	50460800	0.00			0.00
2002	0.37	0.20	0.54	0.00	0.000	0.54	0.50	0.0000	0.000	1.00	0.000000	64.14	51489700	0.00			0.00
2003	0.37	0.20	0.54	0.00	0.000	0.54	0.50	0.0000	0.000	1.00	0.000000	71.74	52137600	0.00			0.00
2004	0.37	0.20	0.54	0.00	0.000	0.54	0.50	0.0000	0.000	1.00	0.000000	95.45	54088500	0.00			0.00
2005	0.37	0.20	0.54	0.00	0.000	0.54	0.50	0.0000	0.000	1.00	0.000000	125.89	54151100	0.00			0.00
2006	0.37	0.20	0.54	0.00	0.000	0.54	0.50	0.0000	0.000	1.00	0.000000	157.07	54454900	0.00			0.00
2007	0.37	0.20	0.54	0.00	0.000	0.54	0.50	0.0000	0.000	1.00	0.000000	199.91	57157400	0.00			0.00
2008	0.37	0.20	0.54	0.00	0.000	0.54	0.50	0.0000	0.000	1.00	0.000013	222.15	60251100	174195.06			192050.05
2009	0.37	0.20	0.54	0.00	0.000	0.54	0.50	0.0001	0.000	1.00	0.000026	175.28	64398900	293896.99			308591.84
2010	0.37	0.20	0.54	0.00	0.000	0.54	0.50	0.0002	0.000	1.00	0.000052	299.31	66411500	1034447.90			1034447.90
2011	0.37	0.20	0.54	0.00	0.000	0.54	0.50	0.0004	0.000	1.00	0.000104	299.31	66411500	2063633.54			1965365.27
2012	0.37	0.20	0.54	0.00	0.000	0.54	0.50	0.0008	0.020	0.98	0.000202	299.31	66411500	4019089.49			3645432.64
2013	0.37	0.20	0.54	0.00	0.000	0.54	0.50	0.0015	0.040	0.96	0.000391	299.31	66411500	7765761.97			6708357.17
2014	0.37	0.20	0.54	0.00	0.000	0.54	0.50	0.0029	0.060	0.94	0.000744	299.31	66411500	14782388.29			12161507.43
2015	0.37	0.20	0.54	0.00	0.000	0.54	0.50	0.0055	0.080	0.92	0.001363	299.31	66411500	27096584.95			21230883.33
2016	0.37	0.20	0.54	0.00	0.000	0.54	0.50	0.0098	0.100	0.90	0.002379	299.31	66411500	47305896.12			35300388.04

Total Discounted Benefits (1997-2012): 7,145,887.70

Total Discounted Benefits (1997-2016): 82,547,023.67

and adoption were assumed to have started in 2008. The main target area for adoption was South and Southeast Sulawesi, which only accounts for about 5% of total rice production in Indonesia. A logistic adoption path is traced such that a 20% adoption rate in the target area is expected by 2016. Paddy rice prices and production figures for Indonesia were gathered from IRRI's World Rice Statistics database. The prices were deflated/inflated based on the relevant CPI values.

As with the 3R3G/1M5R analysis above, the ICM approach encompasses several work groups such that there is no "work-group-specific" cost that can be compared with the surplus benefits of the technology. Thus, only the discounted surplus benefits are reported here (i.e., NPV, BCR, and IRR are not reported). Using a 5% discount rate, we find that the PV of the total benefits of ICM in Indonesia is around US$7.1 million for the 1997–2012 period. If we consider the longer 1997–2016 period, the discounted benefits of the technology increase to about US$82 million.

3.2.3.9 Results of the surplus analysis, by aggregation group

Table 3.10 and Table 3.11 summarize all the benefits/costs and surplus measures for each technology-country combination discussed in Sections 3.2.3.1–3.2.3.8. The figures in Table 3.10 reflect the surplus results when the full IRRC research costs (from all sources) are taken into consideration. Table 3.11, on the other hand, shows the surplus results only when SDC investments are considered.

In terms of total discounted benefits, the IRRC technology that provides the largest benefit value is SSNM/LCC in Bangladesh. However, if one considers IRRC (or SDC) research investments, then the IRRC technology that provides the highest net benefit is AWD. The combined yield improvements/cost reductions from AWD and the lower research investment costs (relative to the other work groups) allowed for AWD to have the highest return on investment. A similar pattern is observed when only SDC costs are considered, albeit with larger surplus measure magnitudes (because of the lower SDC investment value compared with the full research expenditures from all funding sources).

The figures in Tables 3.10 and 3.11 show the surplus measures on a "per work group" basis. In the succeeding subsections, we discuss returns to investment in IRRC based on the "best evidence" aggregation criteria presented in Section 3.2.2.2. Again, note that Aggregation Group 1 consists of AWD and EBRM, which we feel have the best and most reliable figures/data used in the surplus model (i.e., good adoption numbers and yield/cost impact measures coming from several good quality studies). The other aggregation groups add up the benefits from additional technology-country combinations with lower quality figures/data. Using several levels of benefit aggregation allows one to see how the surplus measures vary with the different technology-country combinations included in the analysis. Table 3.12 presents the summary surplus measures (by aggregation group) when we consider total IRRC research investments from all donor sources. Table 3.13, on the other hand, shows the summary surplus measures (by aggregation group) when we only consider the SDC research investments in IRRC.

3.2.3.9.1 Results of the surplus analysis for Aggregation Group 1

The total aggregate benefits from AWD and EBRM for the 1997–2012 period amounted to US$19.3 million, which is enough to cover the full IRRC research investment of about US$18.5 million. Hence, even just considering the 16-year span from 1997 to 2012, the economic surplus generated by the dissemination of AWD in the Philippines and EBRM in Vietnam already offset the total research investment in IRRC. If we consider the longer 1997–2016 period, total economic surplus due to AWD and EBRM is about US$79.7 million.

The NPVs of AWD and EBRM combined are approximately US$776,000 for the 1997–2012 period, and about US$61.8 million for the 1997–2016 period (where an additional 4 years of projected benefits is considered). The corresponding BCRs for Aggregation Group 1 are 1.04:1 and 4.3:1,

Table 3.10. Summary of economic surplus measures,[a] by technology-country combination (considering total IRRC cost from all sources).

IRRC technology	Total discounted benefits ('000 US$)	Total discounted IRRC cost ('000 US$)	NPV ('000 US$)	BCR	IRR
		----------------1997–2012----------------			
AWD	14,241	2,097	12,144	6.79	0.646
EBRM	5,076	1,712	3,364	2.96	0.272
SSNM/LCC	22,786	6,639	16,147	3.43	0.236
DSR/SDV	6,450	1,712	4,737	3.77	0.443
AR	403	2,097	-1,694	0.19	-
HSS	458	963	-504	0.48	-
3R3G/1M5R	14,005	N/A	N/A	N/A	N/A
ICM	7,145	N/A	N/A	N/A	N/A
		----------------1997–2016----------------			
AWD	42,598	2,097	40,500	20.31	0.691
EBRM	37,071	1,712	35,606	21.65	0.474
SSNM/LCC	76,304	6,639	69,665	11.49	0.322
DSR/SDV	14,513	1,712	12,801	8.48	0.493
AR	1,158	2,097	-999	0.55	-
HSS	1,772	963	809	1.84	0.152
3R3G/1M5R	41,053	N/A	N/A	N/A	N/A
ICM	82,547	N/A	N/A	N/A	N/A

[a]-, negative value; N/A, not applicable.

Table 3.11. Summary of economic surplus measures,[a] by technology-country combination (considering SDC cost only).

IRRC technology	Total discounted benefits ('000 US$)	Total discounted SDC cost ('000 US$)	NPV ('000 US$)	BCR	IRR
		----------------1997–2012----------------			
AWD	14,241	1,152	13,089	12.36	0.951
EBRM	5,076	1,162	3,914	4.37	0.347
SSNM/LCC	22,786	5,359	17,427	4.25	0.265
DSR/SDV	6,450	1,162	5,287	5.55	0.567
AR	403	1,152	-749	0.35	-
HSS	458	216	242	2.12	0.233
3R3G/1M5R	14,005	N/A	N/A	N/A	N/A
ICM	7,145	N/A	N/A	N/A	N/A
		----------------1997–2016----------------			
AWD	42,598	1,152	41,446	36.96	0.971
EBRM	37,071	1,162	35,358	31.89	0.533
SSNM/LCC	76,304	5,359	71,464	14.33	0.346
DSR/SDV	14,513	1,162	13,350	12.48	0.603
AR	1,158	1,152	6	1.01	0.050
HSS	1,772	216	1,556	8.19	0.414
3R3G/1M5R	41,053	N/A	N/A	N/A	N/A
ICM	82,547	N/A	N/A	N/A	N/A

[a]-, negative value; N/A, not applicable.

Table 3.12. Summary of economic surplus measures, by aggregation group[a] (considering total IRRC cost from all sources).

IRRC technology	Total discounted benefits ('000 US$)	Total discounted IRRC Cost ('000 US$)	NPV ('000 US$)	BCR	IRR
		----------------1997–2012----------------			
Agg. Group 1	19,319	18,543	776	1.04	0.060
Agg. Group 2	48,556	18,543	30,012	2.62	0.241
Agg. Group 3	49,417	18,543	30,874	2.67	0.243
Agg. Group 4	70,569	18,543	52,026	3.81	0.302
		----------------1997–2016----------------			
Agg. Group 1	79,669	18,543	61,787	4.30	0.255
Agg. Group 2	170,487	18,543	152,605	9.19	0.366
Agg. Group 3	173,419	18,543	155,536	9.35	0.368
Agg. Group 4	297,019	18,543	279,137	16.02	0.430

[a]Agg. Group 1: AWD & EBRM; Agg. Group 2: AWD, EBRM, SSNM, & DSR; Agg. Group 3: AWD, EBRM, SSNM, DSR, AR, & HSS; Agg. Group 4: AWD, EBRM, SSNM, DSR, AR, HSS, 3R3G/1M5R, & ICM.

Table 3.13. Summary of economic surplus measures, by aggregation group[a] (considering SDC cost only).

IRRC technology	Total discounted benefits ('000 US$)	Total discounted SDC cost ('000 US$)	NPV ('000 US$)	BCR	IRR
		----------------1997–2012----------------			
Agg. Group 1	19,319	12,029	7,289	1.61	0.138
Agg. Group 2	48,556	12,029	36,526	4.04	0.285
Agg. Group 3	49,417	12,029	37,388	4.11	0.288
Agg. Group 4	70,569	12,029	58,539	5.87	0.341
		----------------1997–2016----------------			
Agg. Group 1	79,669	12,029	68,210	6.62	0.293
Agg. Group 2	170,487	12,029	159,028	14.17	0.400
Agg. Group 3	173,419	12,029	161,959	14.42	0.403
Agg. Group 4	297,019	12,029	285,560	24.69	0.463

[a]Agg. Group 1: AWD & EBRM; Agg. Group 2: AWD, EBRM, SSNM, & DSR; Agg. Group 3: AWD, EBRM, SSNM, DSR, AR, & HSS; Agg. Group 4: AWD, EBRM, SSNM, DSR, AR, HSS, 3R3G/1M5R, & ICM.

respectively, for the 1997–2012 and the 1997–2016 periods. Moreover, IRRs for the 1997–2012 and 1997–2016 periods are 0.060 and 0.255, respectively. The surplus measures are even higher when one considers SDC investments alone (see Table 3.13).

3.2.3.9.2 Results of the surplus analysis for Aggregation Group 2

In Aggregation Group 2, the surplus benefits from SSNM/LCC and DSR/SDV are added on top of the surplus from the technology-country combination in Aggregation Group 1. From both the 1997–2012 and 1997–2016 periods, the amount of benefits for Aggregation Group 2 (i.e., US$48.5 million and US$170.5 million) is more than double the one in Aggregation Group 1. But note that the data used for the added technologies in Aggregation Group 2 (and above) are not as reliable as those used in Aggregation Group 1. Hence, more caution is needed in interpreting these results.

The NPVs for the technology-country combinations in Aggregation Group 2 are approximately US$30 million for the 1997–2012 period and about US152.6 million for the 1997–2016 period. The corresponding BCR for the technologies in Aggregation Group 2 are 2.62:1 and 9.2:1, respectively, for 1997–2012 and 1997–2016. In addition, IRRs for the 1997–2012 and 1997–2016 periods are 0.241 and 0.366, respectively. Table 3.13 also presents the surplus measures for Aggregation Group 2 for the case where only SDC research investments are considered.

3.2.3.9.3 Results of the surplus analysis for Aggregation Group 3

Aggregation Group 3 adds the change in economic surplus from AR and HSS to the aggregate surplus values calculated in Aggregation Group 2. Especially for the case of HSS where it has only been recently disseminated and released, the figures/data used for these two additional technologies in Aggregation Group 3 are not as reliable compared with the ones used in the prior aggregation groups. Total aggregated benefits for Aggregation Group 3 are US$49.4 million for the 1997–2012 period and US$173.4 million for the 1997–2016 period.

The NPVs for the technology-country combinations in Aggregation Group 3 are approximately US$30.8 million for the 1997–2012 period and about US$155.5 million for the 1997–2016 period. The corresponding BCRs for the technologies in Aggregation Group 2 are 2.67:1 and 9.35:1, respectively, for the 1997–2012 and the 1997–2016 periods. In addition, IRRs for the 1997–2012 and 199–72016 periods are 0.243 and 0.368, respectively. Note that these surplus values are only slightly higher than those in Aggregation Group 2 since the additional surplus change from AR and HSS are not as substantial as the other technology-country combinations (see Tables 3.10 and 3.11). Table 3.13 also presents the surplus measures for Aggregation Group 3 for the case where only SDC research investments are considered.

3.2.3.9.4 Results of the surplus analysis for Aggregation Group 4

For Aggregation Group 4, the surplus benefits from the 3R3G/1M5R technology approach in Vietnam and the ICM package in Indonesia are added to the benefits from all technologies in the prior groups. This provides the most comprehensive aggregation of the benefits based on all the surplus models in Tables 3.2–3.9. However, as mentioned above, the data quality in some instances may not be as high as in AWD and EBRM in Aggregation Group 1. The total discounted benefits for Aggregation Group 4 are US$70.5 million for the 1997–2012 period and US$297 million for the 1997–2016 period.

If we consider all the IRRC technology-country combinations modeled in this meta-impact assessment, the NPVs for all these technologies are about US$52 million for the 1997–2012 period, and US$279 million for the 1997–2016 period. The corresponding BCRs for the technologies in Aggregation Group 4 are 3.81:1 and 16:1, respectively, for the 1997–2012 and the 1997–2016 periods. In addition, IRRs for the 1997–2012 and 1997–2016 periods are 0.302 and 0.430, respectively.

Table 3.13 also presents the surplus measures for Aggregation Group 4 for the case where only SDC research investments are considered.

3.2.3.10 Sensitivity analysis

The economic surplus results in Tables 3.2–3.13 crucially depend on the assumptions made and the parameter values used in the modeling exercise. Hence, studies that use the economic surplus framework to evaluate agricultural technology and/or research program impacts also typically investigate the sensitivity of results when key parameter values are changed (see, for example, Alpuerto et al. 2009). In this study, we examine how the surplus results would change if we increase or decrease the following parameters by 10%: yield effect, cost effect, adoption rate, probability of success, and supply elasticity. However, due to time and resource constraints, we only undertake this sensitivity analysis on the surplus models for AWD in the Philippines, EBRM in Vietnam, and the combined results for Aggregation Group 1 (i.e., the case with the best evidence).

Results of the sensitivity analysis are presented in Table 3.14. Overall, it seems that surplus results tend to be more sensitive to the parameter representing the probability of success. In all three surplus models, the surplus results increase by 20–26% or more with a 10% change in the probability value. Changes in the assumed yield effect and the supply elasticity value are the next two parameters that tend to influence the resulting surplus results the most. In two of the three surplus models examined, the effect of a 10% adjustment in the yield effect or the supply elasticity changes the NPVs by about 20%. These sensitivity results should always be kept in mind when interpreting the surplus results reported in Tables 3.2–3.13. If the assumed yield effects in the surplus models are 10% higher (or lower) than the ones used, for example, then the expected benefits from the IRRC technologies may be 20% higher (or lower) than the ones reported. Note, however, that the magnitudes of these sensitivity analysis results seem reasonable based on similar findings from previous studies (see Alpuerto et al. 2009).

3.2.4 Synthesis/lessons learned from the economic surplus models

The economic surplus analyses of selected IRRC technologies overwhelmingly show that the improved economic welfare of farmers from adoption of these technologies more than compensates for the research investments made to develop and disseminate it. Even only considering the period that covers the four phases of the project (1997–2012), the rate of returns to total research investment in IRRC ranges from 6% to 30% (depending on how the economic surplus benefits from the different technologies are aggregated). If a longer 1997–2016 period is considered (where we project benefits 4 more years to the future), rate of returns to total IRRC research investments have a larger magnitude ranging from 25% to 43%. Given that the economic surplus generated by IRRC technologies is more than the total research investments (from all sources), the rate of return of SDC's research investment, in particular, have even higher values (e.g., 14–34% for the 1997–2012 period, and 29–46% for the 1997–2016 period).

These rates of return figures are consistent with findings from existing studies that evaluate different NRM technologies (see Renkow and Byerlee 2010). Moreover, the corresponding NPVs of the economic benefits from IRRC are relatively smaller than NPVs observed from genetic improvement research. The NPVs for the IRRC technologies are in the hundreds of million dollar (US$) range, while most genetic research NPVs typically goes well above the billion dollar (US$) range. But note that the surplus analysis conducted in this meta-impact assessment only covers a subset of countries and a subset of NRM technologies developed and disseminated by IRRC. It is possible that the return on investment measures for IRRC can come close to genetic research values when other possible

Table 3.14. Sensitivity analysis for AWD, EBRM, and Aggregation Group 2 surplus models (1997–2016).

Assumption/parameter change	----- AWD -----		----- EBRM -----		--- Agg. Group 1 ---	
	Change in NPV[a] ('000 US$)	% Change	Change in NPV ('000 US$)	% Change	Change in NPV ('000 US$)	% Change
±10% yield change	3,589	8.86	9,522	26.93	13,111	21.22
±10% cost change	662	1.63	5,676	16.05	6,338	10.26
±10% adoption rate	4,261	10.52	3,708	10.48	7,969	12.89
±10% prob. of success	8,522	21.04	7,416	20.97	15,937	25.79
±10% supply elasticity[b]	3,271	8.07	8,530	24.12	11,801	19.09

[a]Change in NPV – the difference between the reported NPV here and the "base" NPV (1997-2016) reported in Table 2 for AWD, Table 3 for EBRM, and Table 12 for Agg. Group 1; [b]Note that an increase (decrease) in supply elasticity decreases (increases) the NPV.

technology-country combinations are considered.

In terms of the "work-group-specific" surplus measures, the IRRC technology that tends to have the highest economic surplus value is AWD (for both 1997–2012 and 1997–2016). This may be due to the fact that this is a more mature technology that provides both yield-enhancing (at least for downstream producers) and cost-reducing effects. On the other hand, the "least mature" technologies such as HSS and AR have the lowest surplus values more likely because their target recipients are fairly specific (i.e., rainfed/water-short areas for AR and seed producers for HSS) and they have not been disseminated for a long time relative to the other IRRC technologies.

Even with the economic surplus evidence provided here, it should be noted that several key assumptions and parameter values were used to calculate the surplus figures. Our sensitivity analysis shows that changing some of the parameter values (i.e., the probability of success and the assumed yield effects) could influence the magnitude of the surplus estimates. Hence, as emphasized above, the assumptions made and the limitations of the surplus framework should always be kept in mind when interpreting the results of these quantitative models. Even with this in mind, we still believe that the quantitative evidence supports the conclusion that the benefits from the IRRC technologies is well worth the research investments made.

3.3. Poverty impact assessment: a case study approach

In this section, we discuss the possible poverty impacts of particular IRRC technologies in selected countries. Due to time and resource constraints, we only focus on the following IRRC technologies: AWD in the Philippines, EBRM in Vietnam, SSNM/LCC in Bangladesh, and DSR/SDV in Bangladesh. The analysis here is more of a "case study" approach where poverty impacts are essentially based on income effects found in previous impact studies of IRRC technologies. Data from publicly available sources were also used (mainly for the poverty thresholds). Per capita incomes were computed and compared with poverty thresholds for specific areas where the IRRC studies were conducted (Huelgas and Templeton 2010).[8] This will allow one to see how per capita income improves relative to the poverty threshold. Note that this is like a "back-of-the-envelope" calculation approach that attempts to provide a rough estimate of the quantitative effect of selected IRRC technologies on poverty. A more comprehensive poverty analysis in the context of an overall livelihood assessment (which is probably a more preferred approach) is not covered here and is left for future work. Results of the poverty assessment are reported in Table 3.15.

3.3.1 Poverty impact: AWD in the Philippines

To evaluate the possible poverty impact of AWD in the Philippines, we used the net income impacts from Sumalde et al. (2012) in Bohol province, Lampayan et al. (2004) in Nueva Ecija, and studies by Lampayan et al. (2004), Palis et al. (2004b), Lampayan et al. (2012a), and Rejesus et al. (2011) in Tarlac province. Note that the Bohol site is primarily a gravity-based irrigation system, while the other AWD sites are pump irrigation systems. Poverty threshold data were taken from the National Statistical Coordination Board of the Philippines.

For the Bohol site, the AWD impact study is a "before-after" framework: net income was compared before AWD adoption in 2005 and then after AWD adoption in 2010. The 2010 income values were deflated to base year 2005, so that these figures would be comparable. Based on Table 3.15, it can be seen that the Bohol farmers in the AWD study site had per capita incomes well below the poverty threshold for rural areas in the province. AWD income increased (by >80%), but not enough to be higher than the poverty line. The AWD impact study in Nueva Ecija, on the other hand, is a "with-without"

[8]Using the approach in Huelgas and Templeton (2010), we calculate per capita income as follows: per capita income = (net farm income (in \$ ha^{-1}) × average farm size (in ha))/average household size (in number of persons).

Table 3.15. Poverty impact assessment of selected IRRC technologies.

Technology/location	Year(s)	Poverty threshold[a] (US$ yr^{-1})	Per capita income without IRRC technology (US$ yr^{-1})	Per capita income with IRRC technology (US$ yr^{-1})
AWD in the Philippines				
Bohol[b]	2005/2010	333	89	167
Nueva Ecija[b]	2002	275	180	203
Tarlac site A[b]	2002/2003	240	254	265
Tarlac site B[b]	2005	240	261	300
EBRM in Vietnam				
Han Nam	2005/2009	181	103	84
South Vietnam[c]	2000/2001	128	166	163
SSNM/LCC in Bangladesh	2010	456	59	69
DSR/SDV in Bangladesh[d]	2008	456	71	100

[a]Poverty thresholds reported here correspond to the rural areas of the location, unless data are not available and a more aggregate threshold (for both urban and rural) is reported. [b]The Bohol AWD site is primarily a gravity-based irrigation system, while the other AWD sites are pump irrigation systems. [c]South Vietnam here includes Tien Giang and Soc Trang provinces. [d]The DSR/SDV technology is compared with traditional transplanting with long-duration varieties here.

framework that compares farmers who adopted AWD and those who did not (in 2002). Similar to the results in the Bohol site, there was improvement in income from AWD use but not enough to go over the poverty threshold.

The studies that focused on the Tarlac sites used “with-without” comparisons of AWD adopters and nonadopters. Tarlac Site A results were based on the average income effects from Palis et al. (2004b) and Lampayan et al. (2004). Tarlac Site B results were based on the average income effects from Lamapayan et al. (2012a) and Rejesus et al. (2011). In contrast to results from Bohol and Nueva Ecija, farmers studied in Tarlac generally had per capita income above the poverty line even without the AWD technology (Table 3.15) and impact evidence suggest that incomes were further enhanced with AWD adoption.

3.3.2 Poverty impact: EBRM in Vietnam

The poverty impact assessment for EBRM in Vietnam focuses on study sites in Han Nam province (Palis et al. 2010b) and in South Vietnam, particularly in Tien Giang and Soc Trang provinces (Palis et al. 2004b, Palis et al. 2005). The study in Han Nam province used the “before-after” framework such that net income was compared before EBRM adoption in 2005 and then after EBRM adoption in 2009. The 2009 income values were deflated to base year 2005, so that these figures would be comparable. Poverty line values used in this analysis were gathered from the General Statistics Office of Vietnam and these reflect the poverty level for rural areas at the national level (i.e., we utilized the average threshold value from 2005 to 2009).

Per capita income of farmers in Han Nam was well below the rural area poverty threshold in Vietnam (Table 3.15). In Palis et al. (2010b), the nominal income values actually increased after EBRM adoption (from data collected in 2009). However, when income values were deflated here, the real value of per capita income after EBRM adoption decreased (Table 3.15). Hence, in real terms, EBRM did not improve the poverty status of the farmers studied in Han Nam.

In contrast, per capita income levels in the provinces studied in South Vietnam were well above the poverty thresholds (see Table 3.15). These studies used a “with-without” framework in analyzing the income effects of EBRM (see Palis et al. 2004b, Palis et al. 2005). Moreover, the impact evidence from these studies showed an increase in per capita income when EBRM technology is used. Thus, EBRM adoption in South Vietnam shows potential for improving per capita income and the poverty status of farmers in the area.

3.3.3 Poverty impact: SSNM/LCC in Bangladesh

The potential impact of SSNM/LCC on per capita income and poverty status of rice farmers in Bangladesh was primarily based on the income figures reported in Flor (2011). Flor (2011) conducted a rapid rural assessment of SSNM/LCC in 2010, focusing on six Bangladesh districts: Mymensingh, Gazipur, Bogra, Sirajganj, Rajshai, and Kushtia. Hence, the analysis here pertains to these areas in Bangladesh. The poverty line figure used in this poverty analysis was computed based on the $1.25 per day requirement ($456 per year) of the World Bank for a person to be able to procure 2,100 calories a day for human health.

Based on boro-season data that compared incomes of farmers who used SSNM/LCC and those who did not (i.e., a “with-without” comparison in Flor [2011]), per capita income of farmers who used SSNM/LCC in Bangladesh was found to be about $10 higher than those who did not use the technology (see Table 3.15). However, note that the magnitudes of the per capita income levels of farmers in the study area, regardless of whether they used SSNM/LCC or not, were well below the calculated poverty line. This suggests that, even though SSNM/LCC improves per capita income of Bangladesh rice farmers, the increase in income by itself may not be enough to pull them above the poverty line.

3.3.4 Poverty impact: DSR/SDV in Bangladesh

The analysis of the potential poverty effect of DSR/SDV mainly pertains to the study of Palis et al. (2012b) that concentrated on rice farmers in Rangpur and Nilphamari districts of Bangladesh. This study utilized cross-sectional survey data that compared rice farmers who adopted DSR/SDV and those who used the more traditional seed establishment method of transplanting with long-duration varieties (TP/LDV). As with the poverty analysis for SSNM/LCC above, the poverty line in the poverty analysis of DSR/SDV is based on the World Bank figure of $1.25 per day ($456 per year) needed for a person to be able to procure 2,100 calories a day for human health.

From Table 3.15, it can be seen that rice farmers in Rangpur and Nilphamari districts who used DSR/SDV generally had higher income than those who used TP/LDV. This indicates that the DSR/SDV approach has the potential to improve income and consequently the poverty status of Bangladeshi rice farmers. However, even with the positive income effects of DSR/SDV, the per capita income of farmers in the study area still tend to be below the computed poverty threshold (Table 3.15).

3.3.5 Synthesis/lessons learned from the poverty impact assessment

The poverty impact assessment above generally indicates that selected IRRC technologies do have the potential to improve the income of farmers (i.e., mainly through higher yield or lower cost). However, the evidence in Table 3.15 shows that, in areas where the IRRC technology users are well below the poverty threshold, the income effect of the technology alone may not provide a sufficient income boost that will allow poor rice farmers to go above the poverty line. Admittedly, the poverty impact assessment here is very limited and only considers selected IRRC technologies in particular study sites. Overall, more in-depth research needs to be conducted to provide further evidence about the potential poverty effects of the different IRRC technologies. Perhaps a rigorous analysis of the poverty maps developed at IRRI can be utilized in the future to determine whether the geographical dispersion of the IRRC technologies (and its consequent yield/cost effects) is consistent with high poverty regions. The impact of IRRC technologies on poverty levels is a research topic where more effort and resources are needed in the future.

4. Sociocultural, gender, institutional, and policy impacts

This section summarizes the available evidence on the social, cultural, gender (and diversity), institutional, and policy impacts of several IRRC technologies (by work group). It examines the impacts on different dimensions of livelihood, particularly household and community assets (human, social and cultural, physical, natural, and financial), on household vulnerability and resilience, food security, and gender-related impacts. Policy and institutional impacts are also considered. The analysis is presented by work group and technology; however, the available evidence on sociocultural, gender, institutional, and policy impacts for some of the areas are limited and hence the discussion is more restricted in scope.

4.1 Labor Productivity and Community Ecology (LPCE) Work Group

4.1.1 Direct-seeded rice (DSR)

Evidence of the sociocultural, gender, institutional, and policy impacts associated with direct seeded rice (DSR), usually in combination with other technologies, including short-duration varieties and herbicide, is mainly from studies conducted in Bangladesh and India.

DSR and associated technologies have an important influence on labor demand and the timing of labor opportunities. In Bangladesh, one of the main pathways from adoption of DSR to social impact is related to labor availability during the *monga* period the yearly seasonal hunger gap from October to November before harvest of the *aman* rice crop and before the planting of the long-duration rice varieties (Palis et al. 2012a, Mazid and Johnson 2010). Reducing vulnerability in this period can make an important contribution to household well-being and child and maternal health. In particular, food insecurity and food shortages impact on women and children, contributing to high levels of malnutrition. Gender-related norms in family food consumption assign priority in consumption to men first, then children, and lastly, women (Palis et al. 2012a). Marginal farmers (typically owning farmlands between 0.02 and 0.2 ha) and landless laborer families lack the means to purchase food during the *monga* period as there are few opportunities for agricultural employment and few nonagricultural sources of employment. It affects an estimated 12.6 million people in northwest Bangladesh. This situation gives rise to various coping strategies, including taking loans at high interest rates resulting in indebtedness, forward selling of crops, taking advances on future wages, borrowing food, reducing food consumption, selling assets, or seeking work outside the village (adults and older children) (Mazid and Johnson 2010, Palis et al. 2012a).

An assessment of on-farm trials conducted with five farmers' groups in Rangpur from 2005 to 2007 found that marginal farmers applying DSR and weed control options were able to harvest *aman* rice early and experienced improved income and household food security during *monga* (Mazid and Johnson 2010). The combination of short-duration variety, direct seeding using a drum seeder or lithao, and weed management brings the harvest period forward, thus creating opportunities for employment (Mazid and Johnson 2010). The earlier harvest of the shorter duration crop provides an earlier food supply; the agricultural wages enable laborers to buy food, and crop intensity can be increased by cultivation of post-rice crops such as potato and vegetable.

Studies conducted from 2006 to 2008 assessed sociocultural and economic impacts of DSR and SDVs on rural communities in Rangpur and Nilphamari districts (Palis et al. 2012a) through household surveys, key informant interviews, thematic analysis, and focus group discussions with men and women farmers and landless laborers. Perceptions and experiences with the technologies were explored and narratives about the technology impacts in intervention villages were collected. In terms of the methodology, more details could have been provided on the numbers and distribution of focus group discussions, the use of thematic analysis and the degree of consensus within and across the focus groups.

Findings from the household survey showed that adoption of DSR resulted in earlier harvest of grain and rice straw, providing food for households and feed for livestock. More opportunities for employment of agricultural labor were created in the *monga* months and beyond, as the new technologies, SDV (with DSR or TPR) or DSR and LDV increased the likelihood of planting three crops per year by 3-4.5 times, compared with LDV and TPR.This increases cropping intensity and diversification (Palis et al. 2012a). Focus group discussions revealed that rice farmers perceived that the *monga* technologies had positive economic benefits: higher rice yield, higher income from rice and rice straw and from crop intensification and diversification. This has enabled some investment, for example, in livestock and irrigation and in trading activities, contributing to enhancement of livelihoods.

Social and cultural impacts reported by farmers and laborers included the greater likelihood of sustaining the daily basic needs of their family; food security, health and children's education and in meeting repayments of loans. The narratives revealed a reduction in psychological stress since they were no longer worried about securing the family food supply in the *monga* period. Further impacts identified were the improvement of marital and family relations with the reduction of conflict associated with food scarcity, and the enhanced financial capacity of husbands to give gifts and clothing to their wives. At community level, participants identified the contribution of the *monga* technologies to community peace and order, by enabling access to food during the hungry period, enhancing income and employment which have contributed to the reduction of crime in the community, particularly theft of money, movable property, and food (Palis et al. 2012a).

However, in the wider context of the rural economy in Bangladesh, reduced agricultural labor supply and increasing labor cost are associated with the growth of the nonfarm economy (Orr et al. 2008). DSR is seen as an important strategy for reducing labor costs for transplanting and weeding. An economic evaluation of on-farm trials (OFTs) was conducted in 2003 and 2005, including a sample from outside the project area (Jabbar et al. 2008). Farmers identified important advantages in earlier sowing and labor saving for transplanting and seedbed preparation, but they mentioned a range of disadvantages in DSR, including more weeds.

In terms of gender impacts of the DSR technologies, studies in the High Barind Tract identified potential negative effects on hired labor for transplanting and weeding, particularly among tribal women and male seasonal agricultural migrant laborers (Jabbar et al. 2008; Orr et al. 2008). Although nonfarm employment was growing rapidly, women were less mobile. However, the point was made that additional labor requirements for *rabi* crops on land otherwise unused might compensate for it.

The studies in Rangpur and Nilphamari districts (Palis et al. 2012a) collected sex-disaggregated details of labor inputs on different variety (SDV and LDV) and seeding (DSR and TPR) combinations, specifying whether family or hired labor. There was an overall increase in harvest labor requirement with DSR compared with TPR, including a significant increase in female harvesting labor, both family and hired, attributed to the higher yield of DSR. There was no statistical difference in total female weeding labor between TPR and DSR farmers. For both TPR and DSR practices, 87% of weeding labor was done by men and only 13% by women.

Palis et al. (2012a) reported that 85% of harvesting labor being provided by men. However, early harvest would benefit men and women farmers equally. There were wage differentials between male and female laborers; women's wages were between 40% and 60% lower than men's (Palis et al. 2012a), although this may be associated with a shorter agricultural working day (Orr et al. 2008). A household survey in 2009 found that 38% of the female-headed households were food-insecure compared with 23% of male-headed ones (Palis et al. 2012a).

The Bangladesh *monga* studies included analysis of gender roles and household decision making (Palis et al. 2013). An important observation was that the full employment of women does not mean that they are better off; it is rather indicative of poverty. DSR can free up women's labor from transplanting for other economic tasks while providing employment for harvesting in the *monga* period.

The impacts of DSR in India were less linked to issues of seasonal employment, income, and food security. However, the lower demand for transplanting and weeding labor reduced reliance on migrant labor. As in Bangladesh, early harvest provided new opportunities for *rabi* cropping. Adoption of DSR tended to be by larger farmers with access to machinery, infrastructure, and who are less risk averse. Risk aversion was an important factor influencing adoption (Singh et al. 2010). The study did not provide further quantitative or qualitative information on livelihood benefits or gender impacts.

Assessing the impacts of DSR and SDVs is challenging as the technologies are better understood, as noted by Orr et al. (2008) not as '*prescriptive recommendations, but as choices that allow timely rice establishment with variable monsoon rainfall'. They provide a flexible repertoire of choices from which farmers select for their 'performance*' (Richards 1997) according to conditions in a specific season. These include unpredictable conditions of rainfall timing and amount, as well as land topography and soil type. Mazid and Johnson (2010) note the conditions in which different options perform better. Hence, measures of adoption versus non-adoption in a single year do not capture all the benefits brought about by the enhanced knowledge and options available to farmers. The approach taken in the development of DSR, based on participatory research, demonstration, and farmer evaluation helped to create the experiential learning necessary for farmers' decisionmaking. The DSR work in India also acknowledges the complexity of rice production systems and the emphasis placed on farmers acquiring the knowledge to decide and apply the best technology, through problem analysis, on-farm trials, demonstrations, field days, and training (Singh et al. 2010). In both countries, working with farmers was vital in identifying the constraints to the adoption of DSR.

A social and institutional factor influencing uptake of the DSR and associated technologies (and hence impact) is the incentive structure facing sharecroppers in Bangladesh. Farmer evaluation of on-farm trials in Rajshahi district (Jabbar et al. 2008) raised concerns by sharecroppers that if DSR resulted in lower yields, it might risk their tenancy, since it would reduce the amount of crop going to the landowner. Orr et al. (2008) indicate that sharecroppers have adopted elements of the new technologies such as herbicides but would be unwilling to adopt other practices if they reduced yields or created higher risk.

Outscaling of the technologies and approaches was promoted through the creation of a multistakeholder grouping, which also provided a platform for institutional learning and sharing of experiences and activities of each of the partners (Palis et al. 2012a). NGOs in five districts linked with CBOs, farmer groups, and research institutions in the validation and dissemination of the *monga* technologies (Palis et al. 2012a). This group then linked with an alliance of government and NGOs called the Northwest Area Focal Forum (Mazid and Johnson 2010).

In India, the DSR work (2000–2007) was conducted by IRRC in partnership with universities of agriculture and technology, ICAR, extension organizations, and NGOs across the three states, Uttarakhand, Bihar, and Uttar Pradesh for the development and validation of technologies for direct seeding. Subsequently, the NGOs were funded by the DFID Poverty Alleviation through Rice Innovation Systems (PARIS) project to further extend the reach. There was an initiative to promote links between universities and NGOs for cross-country learning between eastern India and western Bangladesh (Singh et al. 2010). Members of NGOs based in India (Neford, Ramakrishna Mission, and Pradan) visited areas in northwest Bangladesh to see how DSR was used to combat *monga* (RIU 2009). Learning points included the importance of a local champion, the significance of policy and government support, the important role played by NGOs in promoting DSR for *monga,* and the need for the technology to be constantly refined through farmer and researcher collaboration. Subsequent funding from IRRC supported further promotion and innovative communication methods, such the use of farmer videos in extension. This project involved more than 200 farmer groups and claimed to have "informed" over 2 million farmers about DSR and other technologies promoted by the PARIS project. Based on our communication with IRRC scientists (in the LPCE Work Group), DSR outreach efforts by the Indian NGOs continued through 2013, with funding by IRRC.

In terms of policy impacts, in Bangladesh, the technologies were adopted into a national program for *monga* mitigation with a 3-year action plan from 2008 to 2010, including DSR, SDVs and other cropping options (Mazid and Johnson 2010, Palis et al. 2012a).

4.1.2 Ecologically based rodent management (EBRM)

The potential pathways for social, cultural, and institutional impacts of EBRM are i) through reduced rodent damage to the rice crop, enhancing yields, food security and income; ii) through improvements to the environment and reduction in disease transmission and contamination from rats and rodenticides, leading to benefits for human and animal health; and iii) through the social processes of participatory learning and community action. Evidence from Vietnam, Philippines, and Indonesia was examined in relation to these issues, as well as the policy impacts of EBRM research and development. Some observations are made on the spillover effects of this research in Cambodia[9] and Lao PDR.

The early studies (1998–2002) on integrated rodent management at the village level (IRM-V) combine a focus on understanding rodent ecology and implementation of the CTBS (Palis et al. 2004; Palis et al. 2005, Palis et al. 2007). Later approaches are based on more holistic technologies and a greater emphasis on community action that used farmers' traditional rodent control practices, combined with CTBS (Brown 2010, Johnson et al. 2012). Community actions include synchronous cropping, rat campaigns before and after transplanting, reducing width of irrigation banks to less than 30 cm to prevent nesting, improving general hygiene, and promoting synchronous fallow.

An assessment of the adoption and impact of rodent control in Vietnam (Palis et al. 2004) outlines the outcomes of projects in north, south central, and south Vietnam. In all three areas, farmers in the 'treatment' villages reported a reduction in crop losses to rodents (0.7–1 t ha^{-1}) and a reduction in the use of rodenticides (by 66% in Binh Thuan), plastic fences, and electrocutions. Farmers also had access to chemical-free rat meat. The studies identified conditions necessary for adoption of CTBS, which vary according to location. In north Vietnam, CTBS was considered less suitable for a mixed cropping system with scattered rice farms. In south and south central Vietnam, farmers considered the traps effective but expensive in time and money. The sustainability of CTBS would depend on finding a mechanism for financing them, either through government or farmer contributions. The reports indicate that farmers tend to look at the overall cost of CTBS rather than the per hectare cost (one trap covers 15–20 ha). Problems with 'free riders' were also identified (Palis et al. 2011b).

Community action for rodent control was not new to Vietnam (Palis et al. 2005), but preexisting social norms and social relationships make a difference to the scale of community actions for rodent control. In north Vietnam, well-organized community participation was attributed to the history of strong cooperatives born out of past experience of collective farming. In the south and south central regions, where there was less of a community culture, coordination and joint action (for synchronous planting and field sanitation) was encouraged by the project, reportedly giving rise to an increase in social cohesion and interaction among community members.

Palis et al. (2007) noted that the conceptual framework of common property resources (CPR) is appropriate for the analysis of EBRM. However, the studies do not examine the relative importance of economic motivation (participation in community rodent control activities influenced by the degree of benefits received and costs of participation) compared with social motivation (norms of social cooperation). Nevertheless, it appears that social motivation is encouraged when there is greater economic motivation (more benefits).

The existing reports give a good picture of the enabling and constraining factors for successful EBRM adoption, but they are less detailed on the actual impacts beyond estimates of loss reduction.

A later phase of EBRM from 2006 to 2009 was active in two districts of Ha Nam province in the Red River Delta and in An Giang province in the Mekong delta (Palis et al. 2010b, Brown 2010). Knowledge, attitude, and practice and socioeconomic surveys were conducted before and after the interventions. The approach in Ha Nam compared EBRM based on

[9]The IRRC did not explicitly conduct EBRM work in Cambodia but results of impact studies from this country are presented here as evidence of "spillover" research from IRRC efforts in other Asian countries.

community action alone, with community action with CTBS, whereas that in An Giang province, there were three comparisons: CTBS and community action, community action without CTBS, and control sites.

In Ha Nam, there was an increased involvement in community actions (36% in 2006 to 62% in 2009), an increase in rice yield (9.4%), and a reduction in rodenticide use (62–90%) which were partly attributed to better rodent management practices (Palis et al. 2010b). Community actions for rodent control involved both men and women. As with the earlier phases of IRM-V, adoption of the CTBS was low, related to cost and the specific farm circumstances in north Vietnam. In An Giang, involvement in community actions increased from 17% to 46% and rodenticide use was reduced by 37% (Brown 2010). Farmers' knowledge about rat biology and management significantly improved. However, there was little adoption of CTBS for reasons similar to those found in earlier studies.

There were community-level outcomes arising from increased participation of community members in actions to manage rats at village level (Brown 2010). These included improved management of rats and other pests in the farming system arising from synchronized cropping and field sanitation. In both areas, there were reports of enhanced social cohesion; evidence that collective action for rodent management had enhanced 'bonding' social capital, defined as social cohesion within groups or communities resulting from relationships between people of similar ethnicity, social status, and location, based on local ties, trust, and shared moral values, reinforced by working together (Pretty 2003, Sanginga et al. 2007). Farmers in Ha Nam reported a strengthened sense of community and social cohesion through working together. There were also indications that 'bridging' social capital had also been strengthened; building relationships across social groupings, communities, and external agencies. Farmers reported more cohesive interaction with different sectors in the community and beyond–with political leaders, youth, women, and involvement with neighboring villages.

These studies have identified a number of sociocultural factors influencing adoption (Palis et al. 2010b, Palis et al. 2011b). Effective actions were built on active engagement of farmers in development and validation, including the incorporation of local knowledge and indigenous practices such as synchronous planting, digging burrows, and hunting with dogs. EBRM is a knowledge-intensive technology, but experiential learning can help to generate a common understanding and consensus in farmers' groups as the basis for joint action. The Vietnamese political system, history, and culture and its associated social norms, values, and organization create the cultural context in which action takes place. Social capital as manifested in the degree of trust, interconnectedness, and community orientation influences the levels of collective action. Rats have important cultural beliefs associated with them which influence behavior (Huan et al. 2010) and are often perceived to be consistently outsmarting humans (Palis et al. 2011a). Experiential learning through collective actions can help to influence such beliefs.

The more successful cases of EBRM implementation and adoption were characterized by multistakeholder partnerships involving a network of organizations at different levels and active linkages among village-based farmers' organizations, People's committees, agricultural extension and research institutions and NGOs. In particular, the strong linkages between extension and political organizations helped to generate diffusion of EBRM into neighboring provinces (Palis et al. 2011a, Palis et al. 2011b).

The EBRM work has been influential at policy level. Efforts were made during the project to engage directors of provincial and national agencies at an early stage. The early work in Vietnam on CTBS and IRM-V technologies influenced government policy at national and provincial levels, stimulating a policy directive (no 09-1998/CT/TTG, 1998 and subsequent telegram and letter in 2010) and an information campaign (1999–2000) on rat control. These directed farmers to adopt integrated rodent management and organize groups for rodent control and limit the use of rodenticides. At the provincial level, money was allocated for CTBS demonstrations. The NGO World Vision incorporated EBRM into their development projects covering 12 provinces. EBRM has been mainstreamed into national training programs for 3R3G and into IPM FFS.

Promotion of these techniques in the Philippines took off in 2007, led by PhilRice in partnership with IRRC/IRRI (Palis et al. 2008). As in Vietnam, indigenous practices and the interconnection of rodents with culture and beliefs influenced the strategies to manage them (Palis et al. 2008, Singleton et al. 2008).

Two studies report on the impacts of an extension campaign in 2006–07 to introduce EBRM in Zaragosa in Nueva Ecija, Central Luzon, Philippines (Flor and Singleton 2010, Flor and Singleton 2011). The evaluation study compared different levels of intervention: 1) intensive campaigns, 2) media and consultations, 3) media only, and 4) no facilitated intervention (not heard of campaign). There was no significant difference in yield between treatment groups in the seasons before the campaign. Farmers who had heard of the EBRM campaign had higher mean yields of rice by 0.7 t ha^{-1} in the 2007–08 dry season. There was more coordinated community control in the intensive campaign village. Effects in non-intensive villages were less than the intensive, but they had better management practices and yields than in non-intervention villages. As in Vietnam, farmers emphasized that a stronger social cohesion was created because of EBRM activities introduced in the campaign.

An important finding concerned the importance of personal interaction of EBRM 'champions' in influencing behavioral change. The media campaign was more effective in reaching farmers when it was combined with visits from extension technicians, officials, and PhilRice staff. The authors suggest that personal interaction provides norms or motivating conditions that encourage farmers to practice what they have heard. They conclude that communication campaigns with follow-up support from extension are an effective way to change attitudes and practices of smallholder farmers and disseminate EBRM. The involvement of local government officials helped influence higher level policymakers to promote EBRM over a wider area.

In Indonesia, from 1999 to 2002, collaboration between the Indonesian Center for Rice Research (ICRR), the Indonesian Centre for Agricultural Technology Assessment and Development (ICATAD), and IRRC/IRRI introduced community action and CTBS in West Java. Comparing treatment and nontreatment villages, studies found a 6% rice yield increase, reduced costs of rodent control, and 49% less chemical use (Singleton et al. 2005). This led to further outscaling in South Sulawesi and South Sumatra (Singleton et al. 2005, Palis et al. 2008, Sudarmadji et al. 2010a), a process assisted by a presidential decree in 2001 and training and demonstration plots with the involvement of staff of the Assessment Institutes for Agricultural Technology (AIATs).

Further work on EBRM was conducted in West Java and South Sulawesi between 2006 and 2009 (Brown 2010), focusing on organization and promotion of community action for rodent control (Sudarmadji et al. 2010a). The research design and methods were similar to the studies described for Vietnam. There was increased involvement of the community in rodent management, resulting in less damage to rice crops and increased yields (5% in treatment sites) and reduced use of rodenticides (from 98% to 46% compared with 88% in control villages), and reduced electrocution. The study concluded that there were significant social benefits of applying EBRM though a community-based approach to rodent management. Rodent control was less expensive and more effective, leading to higher yields and improvements in livelihoods and food security. Community actions on rodent management also provided the catalyst for discussions on a range of other issues, e.g., management of brown planthoppers (Brown 2010).

Conclusions reached on the sustainability of CTBS were similar to those observed in Vietnam. They were considered more appropriate when rodent densities are high and losses are greater than 10%, making the investment of time and money worthwhile. However, farmers regarded them as expensive and were reluctant to invest in the early trap crop. Therefore cheaper, simpler versions (linear trap barrier system) were developed. CTBS were used to protect nursery beds in West Java. Participation in rodent control activities is influenced by incentives share-cropping farmers may lack the motivation to engage. Furthermore, community-based rodent management is dependent on strong, effective leadership of farmer groups; disjointed governance undermines farmer cooperation (Sudarmaji et al. 2010a).

Cultural beliefs also affected the response to rodent control approaches. In South Sulawesi, there was a belief, based on a legend, that it is forbidden to kill rats (Baco et al. 2010, Sudarmadji 2010b). Aspects of traditional culture, such as 'sitting together' (*Tudang Sipulung*), have led to a modern variant of this practice, whereby diverse stakeholders meet annually at village, subdistrict, district, and provincial levels to discuss planting times and technology applications.

Effective communications and relationships among partners were important for scaling out and scaling up the technology and practices (Sudarmadji et al. 2010a). ICRR provided a range of extension materials and media outputs, including contribution to the Indonesian rice knowledge bank. Technical knowledge on EBRM was included in the new curriculum of the Faculty of Biology, Gadjah Mada University.

Efforts were made to inform and influence policymakers, for example, in national rice week 2008. The national 2020 vision for rice production encourages three or four rice crops in one year, which has the side effect of providing a continuous source of food for rodents. Improvement on traditional controls is therefore essential. EBRM, CTBS, synchronized cropping, community campaigns, and field hygiene were integrated into a range of national level programs e.g., the P2BN Peningkatan Beras National Rice Production Increase Program, which trained 60, 000 farmers in 2008, and the Prima Tani Program, which promoted best agricultural practices and business models (Sudarmaji et al. 2010b).

A comparison of the implementation and uptake of EBRM in Vietnam, the Philippines, and Indonesia with that in Cambodia (where IRRC was not directly involved, although its work was influential), provides an interesting illustration of the influence of social and cultural factors in influencing the outcomes from similar interventions. As mentioned in footnote 1 earlier, the EBRM work in Cambodia is not directly conducted by IRRC, but it is an example of spillovers from IRRC research conducted elsewhere. In Cambodia, farmers at the EBRM project sites were found to have comparatively greater knowledge about effective rodent management. However, they were reluctant to continue to use the TBS due to the high cost of materials. The concept of community action was relatively new and they had some difficulty working as a group. Both CARDI and OAE staff were trained on TBS site extension and efforts were made to replicate this in other districts. But, in 2011, there was no evidence of upscaling of the technology at farmer and community levels in Cambodia. Reasons relate to negative experiences of cooperative action in the recent history of Cambodia, the short 3-year time frame, and belief systems that discourage the practice of harming animals.

The situation in Lao PDR was similar to that in Cambodia (Brown and Khamphoukeo 2010). Interventions in northern areas showed technical success and increased farmers' knowledge and awareness, but there was little evidence of upscaling of rat management technology (Palis et al. 2011b). The nature of the farming system shifting cultivation and small farm size contributed to the difficulties of getting farmers to work together for rodent control (Palis et al. 2011) and the high degree of social, ethnic, and linguistic heterogeneity has not been conducive to community action. However, agencies such as World Vision and GTZ have integrated the practices into their programs (Palis et al. 2011b). The institutional landscape in Laos was also challenging, requiring closer coordination and partnership between extension and research institutions.

Overall, the evidence of social impacts contained within available reports is drawn from key informant interviews and FGDs following EBRM interventions and from household surveys comparing pre- and post-project survey results from locations where EBRM was introduced, with control locations. They provide qualitative assessments of the benefits of joint action, communication, and learning. Analysis of social capital and group cohesion was covered in the initial surveys mainly through exploring individual and collective actions for rodent control. However, the reporting and analysis of these dimensions lacked detail, so it is difficult to understand the degree to which community action for rodent management is using existing social capital or has helped to strengthen or build cohesion and trust. The surveys provide quantitative evidence of reduced rodent damage and enhanced yields in areas where EBRM has been adopted.

The studies show differences in knowledge and practice and the immediate outcomes, but less in terms of the impacts of these changes. Other dimensions of impact, e.g., on health and the environment are not specified in any detail. There is little discussion of women's involvement in rodent control (except for Vietnam) or gender-disaggregated outcomes and impacts.

EBRM has become influential as the national policy for rodent management in rice-based agriculture in Vietnam and Indonesia and has had limited local policy influence in the Philippines and Lao PDR, but less influence in Cambodia.

4.2 Post Production (PP) Work Group

Benefits from post-production technologies relate to the reduction in postharvest losses and improvement in food grain and seed quality from harvesting through drying and storage and through the marketing stages. The reduction in losses effectively provides a yield increase, with associated benefits from the higher quality rice produced and its higher market value. A relatively small reduction in losses of, for example, 5% can make a difference in the region of 2.1 million tons in Southeast Asia (Gummert 2012a). With better market information, farmers would be better informed about appropriate price levels for their products and able to defend themselves from underselling. Because this work group is based mainly on agricultural engineering expertise, laser leveling is also included. The work area is differentiated by country and target group for the technologies and hence there are different patterns of benefits from post production technologies in the rice value chain accruing to farmers (both small-scale and commercial), millers, and traders. The PP Work Group, formed in 2003, has been working in Cambodia, Indonesia, Lao PDR, Myanmar, Philippines, and Vietnam.

IRRC's approach has been to create the necessary linkages and partnerships spanning the public and private sector, to introduce, test, manufacture, train, maintain, and support post-production technologies. The specific partnerships vary across country, but all involve a range of different stakeholders and mechanisms of dissemination. Participatory impact pathway analysis at an early stage of the work helped to raise awareness and guide strategies for promotion and dissemination. An important mechanism to foster this multistakeholder exchange has been the creation of learning alliances (LAs) as platforms for joint learning and action. At the same time, the program has emphasized the development of viable business models to assist outscaling and to guide decisionmaking (Gummert 2012b).

4.2.1 Hermetic seed storage (HSS)

IRRC introduced and evaluated improved storage technologies in the Philippines, Cambodia, Indonesia, Laos, Myanmar, and Vietnam. The anticipated benefits of hermetic storage of rice for home consumption/sale and for seed are reduced storage losses and improved quality and value of stored seed (Gummert 2012a, Yi et al. 2010). Improved storage (especially in combination with improved drying technology) can reduce the risk of aflatoxin contamination and hence also has beneficial consequences for health.

In the Philippines, hermetic storage was introduced through IRRC partnerships and the LA (Tado 2012). Trials showed an improvement in germination rate, allowing a reduced seed rate (65.6 kg ha^{-1} reduced from 80 kg ha^{-1}). LA members promoted training on storage management for their networks in different regions.

In Cambodia, surveys of adoption at eight project sites and two control sites in Battambang and Prey Veng provinces, provide insight into the benefits and constraints experienced by farmers. The storage interventions were hermetic super bags, 5-ton cube or cocoon storage, and granary improvement (Flor and Maligalig 2009). There were high levels of uptake of the super bag at project sites (91.7%) and 96.7% of farmers interviewed said they were willing to pay an average of USS0.50 per bag. There were significant changes in farmers' knowledge on how they can improve their postharvest practices. Seed rates among super bag adopters were significantly lower (by 22 kg ha^{-1}) than farmers in control sites (Maligalig et al. 2010).

Uptake of the super bag in Cambodia, Vietnam, and the Philippines has been mainly for seed storage rather than for storing paddy rice for household consumption or future sale (Ryan 2007). While local production and distribution has taken off in the Philippines and Indonesia, there is little information available on the supply systems in other countries. There is little evidence of the extent of uptake by farmers or seed growers in Vietnam, Myanmar, and Lao PDR. The social and gender impacts of the storage technology are largely unexplored. There does not appear to be any analysis of household decisionmaking and gender dimensions of knowledge attitudes and practices with respect to postharvest storage. The documentation of the briefing and training sessions include photographs showing both men and women participants, but the respective numbers are not reported nor were survey data on farmers disaggregated to show participation and results for men and women.

4.2.2 Flat bed dryers (FBD)

The development and dissemination of the FBD technology in the region has a long history. FBDs were developed by Nong Lam University (NLU), Vietnam, in 1982 based on an IRRI design (Nguyen Le Hung et al. 2012). Further technical developments continued through the 1990s, with IRRI collaboration, and the production of FBDs was commercialized. Some countries (Philippines, Indonesia) had made earlier efforts to introduce FBDs, but rates of utilization were low. Others had very few or no FBDs (Cambodia, Myanmar, Lao PDR), (Gummert 2012a). The IRRC worked in partnership with NLU, national partners, and private sector stakeholders to test different sizes and models of dryers and to share this knowledge and provide training across the region (Gummert 2012a). As a result, dryers were installed in Cambodia, Lao PDR, and Myanmar and were upgraded in Philippines and Indonesia.

It is estimated that, by 2012, around 45% of the summer/autumn crop of the Mekong Delta would be mechanically dried (Gummert 2012a). There were about 7,500 FBDs in Vietnam by 2011, where the PP Work Group was involved in the installation of four dryers, and the rest typically spearheaded by other institutions and the private sector. In the Philippines, the Department of Agriculture funded installation of 15 reversible dryer units at PhilRice provincial stations and interest in the technology was promoted to other organizations through the LA. In 2006, FBDs in Myanmar were promoted by the Myanma Rice and Paddy Traders Association, which had strong links to IRRC and Vietnam. The number increased to 152 in 2012, with a further 200–300 copied from the design. Arrangements were in place for sustainable production and marketing of FBDs through public-private partnerships (Gummert et al. 2012a, Myo 2012). The extent of uptake in Cambodia is not clear. In Lao PDR, there are reported to be 20–30 FBDs. In South Sumatra, Indonesia, there were 200 dryers by 2010 and an additional 70 with an improved blower by 2012, mainly owned by rice millers (Gummert 2012a).

Information on the adoption proportion of FBDs by different types is only available for Myanmar where 71% of the dryers were owned by rice millers, 6% by private seed farms, 15% by farmer community, and the remainder by bean processors, government seed farms, a cooperative, and a paddy contractor (Myo 2012). There is no further breakdown on the mode of ownership among the 'farmer community' and no discussion of gender issues in access to drying technology. A similar set of characteristics was found in Cambodia, but the proportions were not specified. Village adopters include private individual owners and individual owners linked to a cooperative, providing services to members. Actual cooperative ownership seems to be rare.

Overall, there was some ambiguity as to the type of users for whom the different dryer technologies were intended and through what type of management arrangements. While there were successful efforts in technical training for farmers; there still seems to be some challenges in farmer group ownership of dryer technologies, especially with respect to the level of social capital required for a joint enterprise and the governance structure required for its operational and financial management. Promotion to private individuals and rice milling enterprises appears to have had more success. The success (or otherwise) of government service provision of FBDs in the Philippines and Lao PDR is less documented.

There is evidence that the dryers can reduce physical losses and improve the quality of rice grains, resulting in higher prices (Kyaw and Gummert 2010; Gummert 2012a,b). In Cambodia, traders pay 20% higher for dry paddy and 10–12% higher for FBD dried paddy (Flor 2011).

Gender impacts of mechanized drying have not been addressed in the available reports. Without an analysis of women's postharvest roles, it is difficult to know whether the replacement of manual drying has had positive or negative impacts for women in terms of freeing their time for alternative activities or by reducing income-earning opportunities for particular categories of women.

An important benefit of mechanical drying is the reduction of risk for smallholders faced with heavy rainfall during the summer harvest. Mechanical drying enables farmers to dry their rice on time by using local services or to sell to millers for drying without a price penalty (Myo 2012, Flor 2012). From the policy perspective, improved rice quality supports an emphasis on rice self-sufficiency (Philippines), an export strategy (Cambodia and Myanmar), and ability to participate in certification schemes (Vietnam).

4.2.3 Combine harvester (CH)

Combine harvesting can reduce harvest losses compared with traditional harvesting and improve grain quality. IRRC's role in support of CH was to facilitate technology improvement and transfer. In 2004, a multisector partnership/collaboration among NLU Vietnam, Briggs and Stratton, and PhilRice led to the development of a mini CH (Nguyen Le Hung et al. 2012). This was transferred to manufacturers in the Philippines and Vietnam, and business models were developed. The Philippines had 800 units by 2009 and, in Vietnam, the number of combines reached 8000 by April 2012. The CH was introduced into Cambodia from Vietnam, with IRRC support for training and demonstration. Numbers increased from zero to 2000 by 2012 (Gummert 2012a). A demo mini CH was imported into Laos and also several larger combines. Myanmar requested assistance for importation of six units.

The main social and cultural impacts associated with CH use are linked to reduction in demand for labor and reduction of labor cost. However, there is not much documented evidence of what type of farmers are using these services, whose labor has been replaced, and with what consequences for example, whether the labor replaced has been mainly hired or household labor, male or female labor, local or migrant. Without knowing the pre-CH arrangements and division of labor, it is hard to assess impacts.

The majority of CHs are owned by private individuals who contract harvesting services to farmers. The main channels of benefit have therefore been for the owners of CHs through profitable operations and farmers through labor savings and improved grain yield and quality from renting CH services. Combine ownership by farmer groups or cooperatives, although assessed as viable (Ryan, 2007), does not appear to have been taken up.

Combine harvesters are being promoted in government programs, for example, in Vietnam, it is part of the 1M5R program (Gummert 2012a). There is a strong emphasis on mechanization as a complement to the large-scale field model program (Gummert 2012 b).

4.2.4 Laser leveling

The development and utilization of laser leveling is most advanced in India where IRRI supported development and training, research, and on-farm trials in four states in 2001/2002 (Gummert et al. 2012b). Laser leveling has been adopted on approximately 200,000 ha (Jat et al. 2009). The benefits of laser-assisted leveling for farmers in India are well documented, including better crop establishment, reduction in water and energy use, reduced pesticide and herbicide use, increased yield, reduced labor time in tillage, increased profitability and farm income, and employment creation (Jat et al. 2006, 2009; Gummert 2012a). The private-sector model of technology development and commercialization was effective, with 11 suppliers of laser-leveling equipment supplying around 10,000 units, which have been bought by contract service providers who have average net returns of US$3,593 per year. The direct employment creation effects were estimated at 350 person-days per unit per year.

The social impacts were not scale-neutral. Adopters of laser leveling were mainly larger farmers, even though custom hiring of equipment was generally available. Larger plot size appears to matter for operational efficiency and to realize the full potential of the technology. Other factors, such as risk and vulnerability associated with possible yield impacts in the first season after leveling, are not discussed.

IRRC has made efforts to transfer the technology to Southeast Asia, through pilots in Vietnam, Cambodia, and Laos and promotion in Vietnam, including training, on-farm trials, and demonstrations. Starting in 2003, two laser-leveling kits were transferred from IRRI to Bac Lieu Seed Centre and NLU; and scientists were trained by IRRI staff (Hien 2012). NLU acted as intermediary to establish a private sector distributor for Vietnam, Cambodia, and Laos; extension staff members were trained in laser leveling. Information was widely disseminated, including those given to agricultural policymakers, and laser leveling was certified by the Vietnamese government for use in extension. Laser-leveling units were demonstrated in Cambodia in 2012, Myanmar, and Lao PDR, along with training.

In Vietnam, 14 farmers interviewed in November 2011 reported benefits from laser leveling, including higher yields. However, it appears that farmers with larger fields are in a more favorable position to hire laser leveling contractors (Hien 2012). The reasons for this are not elaborated but are likely to relate to the difficulties of operating laser-leveling machinery on small fields.

4.2.5 Rice mill improvement, market boards, quality tools, and integrated technologies

IRRC has provided technical support to millers to improve recovery rates, improve efficiency, hygiene, and overall product quality. This has involved evaluation of mills and training of operators in Vietnam, Lao PDR, Indonesia, and Myanmar (Gummert 2012a, Nguyen Le Hung et al. 2012). Technical upgrading and business support to a noncertified organic value chain in Lao PDR enabled the pre- and post-organic certification of four mills, giving them access to a 20% higher price. In Cambodia, constraints identified were villagers lacking awareness of the importance of efficient milling and village-level mill operators being mostly untrained. The introduction of scales to villagers was a key aspect of bringing about change and building awareness of milling efficiency and expected recovery rate (Ryan 2007). As with the other postproduction technologies above, the gender aspects are unreported. It is unclear whose responsibility it is to arrange milling for household consumption and hence how awareness building is being targeted.

In Cambodia and Vietnam, market information boards in villages aimed to empower farmers by providing better information to assist farmers make decisions about where and when to sell their rice and what quantity to produce. The belief was that transparency of information would make it harder for traders to manipulate farmers and would enable farmers to negotiate (Gummert 2012a). In Cambodia, access to price information gave farmers more confidence when dealing with rice traders. The introduction of scales also ensured that farmers were paid for the volumes sold. However, it was found that market information sets the floor price rather than empowers farmers to negotiate higher prices. Nevertheless, farmers were able to get 15–17% higher paddy price (Flor 2011). The market board appeared less relevant than the use of radio at appropriate times (early morning) to disseminate market price data.

Awareness of rice quality was considered an important farmer attribute because it influences decisionmaking in postharvest management. Hence, development of rice quality test kits and promotion of moisture meters in Cambodia, Myanmar, Lao PDR, and the Philippines were undertaken. However, there is very little information on the scale of uptake of these tools or on the outcomes from their use. The major limitation to moisture meter uptake seems to be the unavailability or lack of a supply chain.

The preceding discussion relates to single postharvest technologies. However, it is important to consider the level of impacts when these technologies are applied at the relevant part of the post-production value chain. The Flor and Maligalig (2009) study of postproduction technologies in Cambodia compared farmers at project intervention sites with a similar group (in terms of socioeconomic and farm characteristics) of control site farmers. The main post-production technologies adopted in the project sites were the super bags (91.7% compared with 16.7% of control farmers), market information boards (87.1%) and moisture meters (61.3%). Drying technology was only available in one village and CHs were not used by the sampled farmers (i.e., combine harvesting was not yet available in the project villages), so the comparisons did not include the effects of these technologies. Farmers in the project villages got a significantly higher per-hectare yield than the control group and scored significantly higher in terms of their knowledge on ensuring good grain quality. Control farmers also used lower seed rates by 22 kg ha^{-1}. There were no significant differences in postharvest costs or in labor use. Male labor and female labor were compared separately across project and control sites, but no such comparison was included within sites (which, if monitored over time, could indicate changes in the gender division of labor with technology introduction). Project site farmers received significantly higher prices than did the control farmers. Given the higher yields and higher prices received, they had significantly higher returns US$515 ha^{-1} gross and US$146 ha^{-1} net compared with US$393.8 gross and -US$14.47 net for the control group.

4.3 Productivity and Sustainability (PS) Work Group

The PS Work Group aimed to increase profitability of rice farming by developing and disseminating sustainable nutrient and crop management practices (Banks et al. 2011). Starting with research and on-farm experimentation from 1997 to 1999 in six countries in Asia, an approach for identifying appropriate nutrient management in specific situations (site-specific nutrient management [SSNM]) was developed to improve yield and nutrient efficiency in irrigated rice (Dobermann et al. 2002). Additional information on the technical and economic achievements of SSNM is given in Pampolino et al. (2007). In IRRC Phase IV, the emphasis was on the development and dissemination of sustainable nutrient and crop management practices to increase the profitability of rice farming (Nga et al. 2010). A key tool in SSNM is the leaf color chart (LCC).

There is limited information available on the social, cultural, gender, and policy impacts arising from the work of the PS group. However, impacts on livelihoods, income, and food security can be partly extrapolated from the extent of adoption of the technologies and the measurable gains in terms of additional yield and reduced costs (previously discussed in the economic impact evidence section). Livelihood benefits mainly arise from the improved yields associated with SSNM, contributing to enhanced food security and increased incomes. However, the latter would depend on paddy prices lower prices could reduce the incentive to adopt SSNM (Dobermann et al. 2002). The earlier on-farm trials found differences in the contribution made by SSNM across countries and domains within countries, mainly explained by climate and differences in crop management practices (Dobermann et al. 2002). Increased net benefits were reported by Dobermann et al. (2002) and Pampolino et al. (2007) particularly from year 2; attributed to increased yield rather than to reduced cost of inputs. These findings were supported by a survey of SSNM adopters and nonadopters in northern Vietnam (Nga et al. 2010).

Dobermann et al. (2002) notes that SSNM might increase yields more for farmers whose yields, because of poor nutrient management, are usually lower than those of other members of the group; but it may not work for certain groups of small farmers, particularly those with poor general crop management. Investment requirements are not considered a serious constraint as SSNM requires, on average, an additional 5% increase in paid-out costs in the first year and lower subsequently. Dobermann quotes an earlier survey that showed only 7% of farmers identifying availability of finance as influencing their fertilizer management decision.

Pampolino et al. (2007) found that SSNM did not reduce input costs overall. There was an increase in labor costs in India and Philippines with SSNM. Nevertheless, this was compensated for by increased revenues from higher yields.

SSNM is characterized as a knowledge-intensive and site-specific technology (Dobermann et al. 2002). This implies the importance of farmer learning and participation in the technology dissemination process and the need to minimize the complexity of the tools. Nga et al. (2010) provides some evidence of improvement in farmers' knowledge, attitudes, and skills as a result of SSNM work in Vietnam. His survey found that almost 100% of respondents had an understanding of the role of fertilizers, but adopters reported that, before SSNM, they were not aware of the nutrient needs of rice at different growth stages or the relationship among nutrients, pest and diseases, and rice yield. Previously, they tried to maintain green leaves across the whole growth cycle, believing that rice plants needed to be fed on fixed schedules. With SSNM, they observed plants in different growth stages, paying attention to crop health and nutrient requirements, which encouraged them to adapt the timing and rate of fertilizer application. Nonadopters applied fertilizer earlier and across a wider range of growth stages. A third of respondents had seen the LCC. Some used the LCC for two seasons, then applied their own knowledge and experience. Others felt they had insufficient training on how to use it. In other cases, village leaders and extension workers took the LCC reading and provided farmers with the recommendation.

Nga et al. (2010) notes that the spread of SSNM in Vietnam was concentrated among farmers and communities at project sites, and that it was more difficult to promote the technology province- and countrywide. This was because SSNM had not been approved by the Scientific Committee, which would allow its official dissemination through the country's extension network.

The LCC was introduced and tested in Bangladesh in 2001 under the PETRRA project (Alam 2005), as a simple tool for improving the timing and rate of N fertilizer use in farmers' fields with no limitation in water supply. It was designed to address the problem of farmers applying excess fertilizer at times that did not match crop needs. Experimental data over three wet and dry seasons suggested that the use of LCC for N management increased grain yield and profit compared with farmers' conventional fertilizer practice (Alam 2005).

The LCC was modified and disseminated by BRRI and partner organizations. By August 2011, more than 600,000 LCCs had been distributed in Bangladesh with around a similar estimated number of users (Flor 2011) and 985,600 over all countries. IRRC provided technical backstopping, contributed inputs for extension materials, and facilitated the importation of LCCs. An estimated 220,000 farmers were trained. The study conducted by Flor (2011) of LCC adoption and impacts in Bangladesh was based on interviews with dissemination partners and FGDs with farmers in seven sites over six districts. Responses suggested savings from reduced expenditure on fertilizer (a 50% savings of around US$25 ha^{-1}), consistent with a study by PKSF (a reduction of 52% and savings of US$21 ha^{-1}). Farmers using LCC said their yields had increased. However, the study notes methodological limitations relating to sample selection and controls for other variables affecting yield (e.g. improved weed and water management). Nevertheless, farmers perceived advantages in using the LCC and experienced less pressure in finding money to pay for fertilizer. Labor requirements for repeated readings of the LCC were raised as an issue by some groups. Generally, opportunity cost for labor was low in the study areas, but this is subject to change as labor markets develop (Alam, 2005).

An interesting observation in the FGDs was that more farmers were able to use the LCCs when they were given to groups rather than to individuals (Flor 2011). Groups were also the focus for training, experimentation, and adaptation in using the LCCs.

4.4 Water Savings (WS) Work Group

4.4.1 Alternate wetting and drying (AWD)

The AWD is a technology intended to bring about greater efficiency of water use and result in water savings in water-scarce areas. It requires a change of practice from continuous flooding of the rice crop to irrigating at intervals according to the level of water in the soil. The social, cultural, gender, and institutional impacts are assessed in relation to the differences the changed practices make to household food security and income, labor allocation, and cost. Irrigated rice production is often based on management and allocation of shared water resources and therefore changes in these management practices are likely to have social and community-level implications. Incentives for reducing water use are linked to the structures of payment embedded in the relationships between farmers, landowners, pump owners, or irrigation scheme management. Large irrigation schemes are important components of national agricultural-sector strategy and policy, and hence changes will have implications for these institutions and for policies.

4.4.1.1 AWD in the Philippines

There are different contexts of AWD in Philippines, the deep-well-irrigated systems in central Philippines and the large-scale gravity-/canal-irrigated schemes such as those in Bohol. Important differences in management exist; these relate to the nature of water resources and entitlements and arrangements for their use. Large-scale schemes come under government control and are managed by the National Irrigation Administration (NIA), although management is increasingly being transferred to the irrigators' associations (IAs). The long-standing problem with such schemes is that distribution of water is not equitable; often the upstream and middlestream farmers get a higher share of the water while downstream farmers receive less or none (Sibayan et al. 2010).

Collaborative work among PhilRice, IRRI, and NIA on AWD started in 2001 with demonstrations in pump irrigation schemes and then to large gravity irrigation schemes. AWD has been further promoted in the Philippines as part of the Country Outreach Program under IRRC (ICOP). The ICOP has taken an integrated approach to AWD, consistent with policy directions, including the Philippine Rice Self-Sufficiency Program (PRSSP), now called the Food Staple Self-Sufficiency Program (FSSSP).

The social, cultural, and institutional impacts can be traced at individual-farmer, community, and national levels. However, there is some difficulty in attributing changes to AWD alone because, particularly under ICOP, a holistic technology development approach was followed, combining a number of improved practices, including aerobic rice, SSNM, synchronized planting in addition to AWD. Data from pre-adoption/baseline studies compared with follow-up studies show no significant impact of AWD on yields but some evidence of reduction in costs and increased net returns (Lampayan et al. 2004, Lampayan 2012). This can be regarded as contributing to improved incomes and livelihoods. Savings in water (of 21–26%) and fuel costs (of 25 and 21%) are also beneficial to the national economy and environment (Palis et al. 2012c). In some areas, the efficient use of water has enabled an improvement in access to domestic water supplies (Palis et al. 2004b).

There were similar findings for the large-scale gravity schemes. Comparison of data from a 2006 baseline study for Malinao dam in Bohol with a post-implementation survey in 2010 showed a 31–76% increase in profits for farmers and no significant impact on average yields. There was a reduction in yield differences between upstream and downstream farmers (Sumalde et al. 2012). For the Upper Pampanga River Integrated Irrigation System (UPRIIS) scheme, AWD did not significantly affect yield. There were no data differentiating yields and income for upstream and downstream users, but reports and discussions with leaders from IAs indicate that yields of downstream users are now at levels similar to those of upstream users (field visit discussion in: UPRIIS 25/6/12 and Pilar, Bohol 27/6/2012)[10].

The main contribution to individual and national food security has been the expansion of the schemes, both in area, cropping intensity, and number of farmers, increasing rice production for the same amount of water. The irrigated area expanded by 20–30% in Central Luzon (Lampayan et al. 2012a). In the gravity irrigation schemes in Bohol, improved water availability after AWD and improved delivery to farmers at the end of irrigation channels resulted in an increase in average farm size of about 17% (Sumalde et al. 2012) to 38% (Valdivia 2012). LA members reported that Bohol region has a rice self-sufficiency score of 103% and there is an increase in per capita rice consumption (field visit discussion in: LA, Bohol 27/6/12; see Appendix 3). In the UPRIIS scheme, cropping intensity increased from 159.45% to 197.84% (Sibayan et al. 2010). Yield increases were reported in areas where there had been adoption of a range of improvements; for example, the Upper

[10]The list and description of field visit discussions are presented in Appendix 3. The standard questions asked in all of the field visits (for different stakeholders) are also presented in Appendix 3.

Sinyawan Farmers IA in Davao increased their yields from 100–110 bags per hectare to 130 bags per hectare (field visit discussion in: Upper Sinyawan, 29/6/12).

Palis et al. (2004b) showed a very small reduction in labor cost with AWD. However, Palis et al. (2012c) estimated savings in labor time between 21% and 25%. Lampayan et al. (2012a) found a 49% reduction in average hours spent in irrigation between 2003 and 2004 and a 48% reduction between 2003 with 2005. Frequency of irrigation was reduced and there was no need for checks in the middle of the night (Sibayan et al. 2010). AWD reduces hours of irrigation use without statistically significant reduction in yields and profits (Rejesus et al. 2011). AWD may ease other labor operations such as harvesting because of better soil conditions (Lampayan et al. 2012a).

The increases in area, production and income, and savings in labor time are an important contribution to household livelihoods and food security – "*before AWD, nothing was left for consumption and paying debts, now we have some surplus*" (field visit discussion in: Upper Sinyawan, 29/6/12; see Appendix 3). However, these are outcomes of a range of improvements in rice cultivation, in addition to AWD. Investments are made in household goods and appliances, farm investment, personal transport, children's education, livestock, and improved housing (field visit discussion in: LA, Bohol 27/6/12; Upper Sinyawan, 29/6/12).

The main cultural impacts were the change in knowledge about irrigation, a change in beliefs about noncontinuous flooding, and a change in irrigation management practices (Palis 2011). Studies on AWD on P38 in Tarlac and in Bohol both indicated that, initially, farmers were worried about the consequences of AWD since there was a strong belief that continuous flooding was necessary for the rice crop. Fear was an important constraint to implementation, but with training, information, and awareness building and actual experience, attitudes changed and concerns lessened (Lampayan et al. 2012a; field visit discussion in: NIA/CRS Davao 29/6/2012). Farmers knew they could produce rice at similar yields, even with less water (Palis et al. 2004b, Palis 2011, Sibayan et al. 2010, Valdivia et al. 2012). In UPRIIS, downstream farmers had peace of mind, knowing that water would be available (Sibayan et al. 2010). Changes in attitude were encouraged through processes of facilitated learning–through training and briefings, by doing and by sharing knowledge (Palis 2011). For example, having used the water tube to assess water levels in their fields at the start of AWD introduction, farmers learned how to make their own judgments on water requirements (field visit discussion in: Region 2, P38 24/6/2012; Upper Sinyawan 29/6/2012).

Gender and equity impacts included more equitable sharing of water between upstream and downstream farmers (Sumalde et al. 2012). AWD has improved water availability for downstream farmers and the recovery of irrigation fees, in some cases, up to 100% (field visit discussion in: Upper Sinyawan 29/6/2012). Downstream farmers on the UPRIIS scheme were able to plant early and to secure loans from informal lenders (Sibayan et al. 2010). Those upstream have learned the benefit for the whole community (field visit discussion in: UPRIIS 25/6/2012). NIA managers agree that AWD has contributed to more equitable distribution of water, increased system efficiency, and lessened complaints on water use (Palis 2011).

In Canarem (Nueva Ecija), an additional benefit from AWD was the increased availability of domestic water, which benefited women and children, the main individuals who collect and use domestic water. Water was available in the storage tank for domestic consumption for most of the day, unlike in the past when water was restricted to certain hours (Palis et al. 2012b). However, no studies systematically investigated the changes in gender and labor allocation, either to rice cultivation and other water-related tasks. The effects of AWD on agricultural laborers are not highlighted in any reports. Field discussions indicated that patterns of work were slightly changed (field visit discussion in: Upper Sinyawan 29/6/2012). Labor schedules were said to be more relaxed with AWD, as there were breaks in the irrigation schedule. It is uncertain whether the overall work situation of landless laborers has improved or deteriorated with AWD. However, AWD combined with other interventions, appears to have improved yields in which case sharecroppers get a larger quantity for the same percentage share.

Palis et al. (2004b) note that adoption of AWD requires successful collective action for management of the common water resource. This relies on a perception of shared interest and mutual benefit and is enhanced by the support of strong local partnerships. If mutual benefit and mutual contribution are weakened, there is a risk of conflict. As indicated previously, in the early stages of AWD adoption in P-38, there was an initial increase in water theft and conflict, which had to be resolved with the help of village security officers. This was reduced as farmers learned about the benefits of AWD and they became more confident of the system (Palis et al. 2005; Palis et al. 2012c). This led to improved social cohesion of the IAs and their members and more harmonious relationships among NIA, IAs, and farmers. Lampayan et al. (2012a) also reported reduced competition for water among households who are into rice farming, satisfaction with the irrigation schedule, and improved relationships among farmers.

A further source of potential conflict the nonpayment of irrigation fees and running costs was addressed in several cases by making water provision conditional on payment and requiring individual farmers to supply their fuel and oil. Thus, farmers have a clear incentive to improve efficiency and reduce fuel costs for irrigation (field visit discussion in: Region 2, P38 24/6/2012). Alternatively, changing the incentives for joint action can also stimulate joint action for mutual benefit. An IA under UPRIIS was collecting less than 50% of the fees before AWD. They agreed with NIA that, if they collect at least 60% of irrigation fee (charged on a per-hectare basis), then they can retain 40% of the total amount and the other 60% goes to NIA. If it is less than 60%, the division is 20% to them and 80% to NIA (field visit discussion in: UPRIIS 25/6/2012).

The main institutional impacts were through the development of active multistakeholder partnerships around AWD and other aspects of rice development, which created an enabling environment for joint learning and capacity strengthening (Palis et al. 2012c). The partnerships among IRRI/IRRC, PhilRice, the Department of Agriculture, the NIA, and the Bureau of Soil and Water Management and, through them, to local partners and champions supported the out-scaling of AWD throughout the Philippines (Palis 2011). AWD and other rice technologies were integrated into partners' institutes, agencies, programs, and projects and training was provided for staff and farmers (Palis et al. 2012c). AWD was used in three PhilRice programs, and water savings became a banner program for NIA.

The approach to promoting AWD with its emphasis on demonstration and learning was also taken up. Training events and the outreach program integrated recommendations on other relevant technologies, such as improved varieties, drum seeder, IPM, SSNM, and postharvest technologies. IRRC made an important contribution to the development of the training modules. As stated by a LA member in Bohol, "*I recall the way we introduced technologies here in Bohol was done in a holistic manner as in our training, from seed to postharvest*" (field visit discussion in: LA, Bohol, 27/6/2012). The outreach program is a partner of PhilRice in the FSSSP, contributing to the subproject "Unified Capability Building Support." FSSSP being a national program, it is expected that IRRC technologies will be disseminated on a national level.

At the policy level, Administrative Order No. 25, or the "Guidelines for Adoption of Water-Saving Technologies in Irrigated Rice Production in the Philippines" was signed in September 2009. This stipulated AWD as the main water-saving technology of the Philippines (Palis 2011, Lampayan 2012). It was implemented in 2010 and 2011, with regional briefings and regional technical working groups created through the NIA. Funds were acquired for wide-scale dissemination.

4.4.1.2 AWD in Vietnam

IRRC conducted training on AWD (in 2005), established demonstration plots, and developed extension materials. By the 2011 dry season, 23% of farmers in An Giang had adopted AWD (Lampayan 2012). However, distinguishing the specific impacts of AWD is quite difficult since it was promoted as part of the 3R3G program in 2007 and later with the 1M5R. Therefore, the higher yields reported by farmers could be a result of a combination of factors. Farmers reported benefits such as reduced pumping and labor cost with AWD and they no longer worry if rice fields do not have water

In terms of social aspects, similar issues relating to collective action apply in Vietnam as in the Philippines. Since schemes involve a number of farmers, there needs to be joint agreement on the pumping schedule, supported by the local administration (field visit discussion in: Chan Phu District 23/10/12). Similar problems arise with the incentive structure, where farmers make flat rate payments for water rather than pay by volume. Pump owners were included in the training, but farmers were not able to negotiate a reduction in pumping costs with AWD. Pump owners said a reduction was difficult unless they did it for all (field visit discussion in: Phutan District 23/10/12; Codo District 24/10/12).

4.4.1.3 AWD in Bangladesh

An impact pathway assessment of AWD in Bangladesh (Kürschner et al 2010) concluded that dissemination and adoption of AWD in Bangladesh was still in the early stages, although according to Lampayan (2012), partners' reports suggest more than 120,000 adopters in 2009. Farmers reported average yield increases of 0.5 t ha^{-1} with AWD, confirmed by more than 75% of adopters (Kürschner et al. 2010, Lampayan 2012). However, as in the other countries, additional interventions such as improved fertilizer use may have influenced this outcome. Consequences of AWD, for labor demand for weeding are similarly complex since herbicide use has been introduced. Although irrigation cost when using AWD is lower by between 18% and 27%, this reduction is not necessarily benefiting farmers, many of whom pay fixed rates for the whole season. There were some changes in attitudes; 90% of AWD adopters agree that there is no need to keep rice under continuous flooding, except at specific growth stages. There were mixed opinions among the nonadopters, with 57% believing that maintaining standing water in the field is essential while others thought that allowing the soil to dry during tillering stage helps increase the yield (Kürschner et al 2010).

Social changes at the farm level were not observed (Palis et al. 2012b). Unlike in the Philippines where AWD implementation seems to have contributed to social equity by improving the situation of disadvantaged downstream farmers, in Bangladesh, targeting of AWD has focused on medium and larger farms with educated and innovative farmers, particularly those who own pumps. Tenant farmers, marginal farmers, and sharecroppers were not targeted (Kürschner et al 2010). Women were not a main focus of AWD dissemination as they were seen to play a limited role in rice cultivation. However, this depends on location. The NGO, RDRS Bangladesh, was working in northern Rangpur with groups of farmer leaders, of whom 70% were women. Some were opinion leaders in villages and were relevant actors to spread knowledge.

Fixed-rate arrangements for paying irrigation costs are the most common system. This discourages adoption of AWD. Pump owners do not pass on economic benefits from water and energy savings. In Rajshahi, 57% farmers did not have control or influence on the timing of irrigation (Palis et al. 2012b). These factors limit the scope for implementing AWD in Bangladesh. Farmers were aware that if they bargained together, they could have the power to reduce their irrigation fees. Like farmers in An Giang, Vietnam, farmers from Rangpur (40% of them) asked for a price reduction in irrigation but had limited success (Kürschner et al 2010). The NGO RDRS made efforts to facilitate farmer organization and influence. A farmers' forum with a legal identity was formed. RDRS held a workshop with pump owners and organized a dialogue (field visit discussion with RDRS 16/10/2012). Farmers think that pump owners should reduce the cost according to number of irrigations (unless more area is covered) (field visit discussion in: Akkelpur 17/10/12). Conflicts between farmers and pump operators arose, especially in dry season or drought years (Kürschner et al., 2010) and mostly with farmers whose plots are far from the irrigation source.

The main partners for AWD research and dissemination in Bangladesh were IRRI, BRRI, DAE, BMDA, RSDS, BADC, Syngenta, and IDE. Trials on AWD were conducted in 2004 (Palis et al. 2012b), then a piloting and implementation phase in 2009 (following a national workshop and training and technical advice from IRRI for NARES staff). The extent to which this shared knowledge has resulted in actual uptake is unclear. Kürschner et al. (2010) identify a lack of ownership of the process of institutionalization, although Lampayan (2012) considers that AWD is widely disseminated by various organizations with different core functions. In July 2009, the secretary of the Ministry of Agriculture endorsed AWD as a national program and directed the Department of Agricultural Extension (DAE) to promote it to farmers nationwide. However, Kürschner et al. (2010) point out that this did not result in nationwide dissemination.

Results in other countries (Myanmar and China) are consistent with those discussed earlier. Yields were maintained with AWD and fuel cost was lowered (Yi et al.2010). AWD was more likely to be adopted in cropping areas with limited water resources as in central and upper Myanmar. There are studies of technical and economic impacts (Moya et al. 2004, Cabangon et al. 2001), but no discussion of social, cultural, or institutional impacts.

4.4.2 Aerobic rice (AR)

Aerobic rice (AR) is a production system wherein specific rice varieties are grown under nonflooded, nonpuddled, and nonsaturated soil conditions. Since AR requires less water than other rice varieties, it is particularly suited for situations of low water availability, such as water-short irrigated areas, uplands, and rainfed lowlands (Lampayan et al. 2012b). Research and on-farm testing of AR was conducted in IRRC Phases 2 to 4 and linked to the Challenge Program for Water and Food. Relevant sources of information are available for Philippines and China, however, information on impacts is limited since adoption of AR is still considered to be in the early stages. The number of adopters is estimated at 3,700 farmers (Banks et al. 2011).

The social, cultural, and institutional impacts of AR relate to its potential contribution to food security and incomes of farming households in more marginal rice-producing environments, or where irrigation water is scarce and where labor is short. In the Philippines, on-farm trials on AR were conducted in Central Luzon from 2001 to 2005 (Lampayan 2004, Lampayan et al. 2010, Lampayan et al. 2012b). Participatory variety trials and demonstrations were done in partnership with the Bulacan State Agricultural College (BASC), Department of Agriculture, and the local government. A socioeconomic study of 80 farmers, both adopters and nonadopters of AR, found that AR yields were around 75% of traditional lowland yield (Lampayan et al. 2012b, Templeton and Bayot 2011). However, as costs were lower, it had comparable profitability. The lower water requirement and consequent reduced irrigation costs (of US$330–395 ha^{-1}) are especially important where fuel costs are high. However, the attractiveness of AR, linked to lower irrigation costs, may reduce with a fall in oil prices (Templeton and Bayot 2011).

Resistance to drought and waterlogging makes AR a suitable alternative for summer cropping on upland soils. In Tarlac and Bulacan (Philippines), farmers were interested in AR as a summer crop and for fields where maize cannot be grown because of unsuitable soils or where other potential summer crops have market-related constraints. This can increase farm income and food supply.

Adoption of AR is driven by different considerations (Templeton and Bayot 2011). A study conducted in three provinces of China in 2007 (Ding et al. 2010) describes how, in the North China Plain, the motivation for AR adoption is scarcity of irrigation water for traditional lowland rice cultivation. AR, though lower yielding, is a profitable alternative because of 20% lower production costs in comparison with lowland rice. AR is also a low-risk alternative in drought- or flood-prone areas in comparison with other summer crops (Ding et al. 2010). The lower labor requirement makes AR an attractive option for situations of labor scarcity and out- migration. In both Philippines and China, AR required less labor input. The 2005 wet-season trials in Philippines found a 50% reduction in time spent on irrigating fields (Lampayan et al. 2012b). In China, AR labor requirement (86.7 days ha^{-1}) was lower than that for lowland rice (102.4 days ha^{-1}) or for maize (127.1 days ha^{-1}). This is useful in areas which have small household sizes and high rates of out-migration and which contributes to food self-sufficiency (Ding et al. 2010).

Studies investigating farmers' perceptions of AR found a range of advantages and disadvantages (Lampayan et al. 2012b, Ding et al. 2010). Common to both studies were the positive factors of lower input requirements, particularly water and labor, ease of crop establishment, and drought tolerance. Problems of weed control and market acceptance were identified by farmers in both studies. Respondents in the Philippines also mentioned AR responsiveness to fertilizer, but also the problem of lodging. Additional factors mentioned by Chinese AR farmers were resistance to waterlogging and low yields. Knowledge of appropriate management techniques and experience were found to be important for getting good yields from AR.

There are no specific references to gender or equity issues associated with AR in the sources reviewed. However, in trials in the Philippines, the inclusion of farmers with fields on the edge of the pump area or on higher elevation sites with relatively large water losses and dry soil conditions does suggest the targeting of the technology to farmers with resource constraints. AR has advantages for poorer farmers in non-irrigated areas (now a new priority of the government [Soriano 2012]). Ding et al. (2010), comparing AR adopters and nonadopters, found a significant difference in the proportion of land owned that was unsuitable for rice. Those with less suitable land were more likely to grow AR. AR was also associated with more migrants and less available male family labor. No mention was made of women's participation in the trials/demonstrations or assessment of postharvest qualities of AR.

Development and promotion of AR through the IRRC and other IRRC-linked projects had a positive influence on collaborating partner organizations. In the Philippines, BASC was successful in winning research grants and funding for AR seed production (Lampayan 2012) and was appointed the Aerobic Rice Center of the Philippines. In China, it has increased researchers' knowledge and confidence and influenced the research approach toward becoming more interdisciplinary, participatory, and field-based (Templeton and Bayot 2011). No specific policies have been developed for AR rice in either country, although there are some provincial initiatives like, for example, in Yunnan province in China. AR falls within both countries' general support for rice production (Templeton and Bayot 2011).

4.5 Synthesis, analysis, and lessons learned from the sociocultural impact evidence

In general, existing impact studies have shown that IRRC technologies produced tangible sociocultural, institutional, and policy impacts. Common sociocultural impacts documented are improved farmer livelihoods and well-being, improved food security, reduced vulnerability to adverse economic and climatic conditions, changed farmers' beliefs on traditional agricultural practices, improved social cohesion in communities (i.e., for EBRM and AWD), and reduced social conflicts.

Among the livelihood impacts relating to human capital were the reduction in labor time (and labor cost) associated with DSR, AWD, CH, laser leveling, etc., whereas in Bangladesh, introduction of DSR and SDVs helped create demand for labor in the hungry period (*monga*). AR was shown to be an attractive option for situations of labor scarcity and out-migration in China. Changes in famers' knowledge and skills were brought about through participatory technology development, especially with AWD and nutrient management. In some cases, such as EBRM, the process built on and extended indigenous knowledge.

The increased yields resulting from the adoption of EBRM and SSNM, farm mechanization, and postharvest technology and the increase in cropping intensity from AWD, DSR and AR contributed to increased food security and incomes, as well as national food self-sufficiency. Incomes were also enhanced by lower irrigation and input costs brought about by AWD, AR, EBRM, laser leveling and, in some cases, SSNM/LCC. However, realization of income benefits depended on paddy prices. The benefits from enhanced income included the ability to invest in children's education and in assets and enterprises, such as improved farm irrigation, livestock, trade, household goods, housing, and transport. For some farmers, increased income helped to reduce indebtedness (Bangladesh), while others were able to secure loans (Philippines).

Some technologies have contributed to reducing vulnerability and risk for small and marginal farmers; these include DSR/SDVs for the *monga* period in Bangladesh and a wider repertoire of options for responding to seasonal climate variability. Mechanical drying reduces risk for smallholders as millers who own dryers can buy wet paddy whereas previously this may have been refused. AR is a lower risk alternative in drought- or flood-prone areas.

The social impacts of reduced conflict and improved social cohesion were reported for AWD where changes in irrigation schedules benefited downstream users without detriment to farmers upstream, and for DSR/SDV, which by providing income and earlier harvest, reduced family conflict and petty theft in the community. EBRM was also reported as strengthening community cohesion and extending community contacts. Nevertheless, it is noted that pre-existing social norms and social relationships make a difference to the speed and scale at which community consensus and joint action can be achieved. Farm and postharvest mechanization has been more commonly adopted by individuals than by farmers' groups.

IRRC has had institutional impacts through influencing the way local agricultural institutions formulate their priorities and conduct their research and extension and tasks (i.e., increased focus on field-based participatory learning with farmers, multidisciplinary approaches and partnerships with a broader range of national and international agencies and the private sector). The importance of multistakeholder partnerships for extending impact through out-scaling was particularly noted for EBRM in Vietnam and for AWD in Philippines.

In several countries, IRRC played an instrumental role, enabling the implementation of agricultural policies and regulations that support the NRM technologies developed. These include the national program for *monga* mitigation in Bangladesh and the endorsement of AWD, government support for EBRM in Vietnam and Indonesia, and Administrative Order 25 in the Philippines with guidelines on water-saving technologies.

However, even with this body of evidence, there are other issues that need to be better addressed in order to more fully understand the sociocultural effects of IRRC technologies. With the notable exception of studies relating to DSR and SDV in Bangladesh, sociocultural impacts are typically not disaggregated by gender for most of the existing impact studies. In some cases, gender has neither been acknowledged in farmer consultation processes nor mainstreamed into an analysis of different perspectives or differential outcomes from the use of technology. The lack of gender analysis in the post-production area is a somewhat surprising omission, given that in the region, women often play a more active role in postharvest activities.

Similarly, further analysis of differences in adoption of technologies by status land owners, large farmers, those with access to machinery, marginal farmers and landless, etc. would help to refine understanding of impacts. Future studies should examine the social impacts of changes in labor requirements, the introduction of mechanization and contract services (combines, laser leveling, drying, etc.) to identify how benefits are distributed and any negative unforeseen social aspects of technology adoption.

In most cases, the uptake of recommendations into policy has been described and the key roles of partners in 'brokering' this influence is indicated. However, further analysis of the mechanisms and relationships which have, or have not, brought about policy change would be a useful contribution.

The use of complementary quantitative and qualitative methods has been a strength of the existing studies on sociocultural impacts of IRRC technologies, however, the methodologies used to explore these dimensions have been rather limited in range, mainly relying on FGDs, key informant interviews, and household questionnaires. More details could have been provided on the methods of qualitative analysis, the coding for thematic analysis, and the degree of consensus or divergence within and across the FGDs. The use of network analysis may be beneficial in the future to track changes in social relationships involving community action and management of common property resources and to assess changes in influence and communication across social groupings. This would supplement the enumeration of individual and collective actions and ex post discussions with farmers.

The development of more detailed 'theories of change' as part of project planning can help to structure the lines of qualitative enquiry in baseline studies and provide a more robust framework for examining and attributing impacts. Stakeholder analysis, including disaggregated analysis of relevant actors in rural communities, should be part of this and would help identify at an early stage the potential winners, losers, disincentives and areas for action; for example, ways in which adoption of water-saving technologies are affected by payment agreements with pump owners and how recommendations advising farmers to reduce pesticide use and target fertilizer application may be undermined by the operation of private dealers.

5. Environmental impacts

Intensification of irrigated rice systems resulted in unintended environmental consequences related to water use, soil degradation, and agrochemical runoff, which have had implications beyond just the areas cultivated (Pingali 2012, Burney et al. 2010). Thus, potential environmental impacts associated with the development, distribution, and adoption of agricultural technologies (which may be positive or negative, intended or unintended) becomes a challenge for designing sustainable agricultural systems that meet food security objectives.
This section aims to review and document the environmental impacts of IRRC technologies based on existing studies.

5.1 Labor Productivity and Community Ecology (LPCE) Work Group

5.1.1 Direct-seeded rice (DSR)

The operation of direct-seeded rice is associated with minimum tillage and weed management systems. It provides both beneficial and adverse environmental impacts. The environmental benefits include reduced energy use for tillage preparation and irrigation water in dry seeded rice (DSR) and lower water demand for wet-seeded rice (WSR). It also prevents soil erosion accompanying the drainage of flooded paddy fields before transplanting (Harada et al. 2004). Tillage for dry-seeded rice is reduced because it is not necessary to repeat plowing for puddling the soil as with traditional transplanting of rice. Pregerminated seed is sown either by broadcasting or by line-planting and then covered by harrowing. However, the WSR would require the same tillage as for transplanting rice.

Rice can be established by DSR with 150 mm of rain or irrigation water as compared with 450 mm needed for transplanting. DSR establishes a deeper root system and is more efficient at using soil moisture; less frequent irrigation is required.

In Bangladesh, to be cost-effective, DSR requires the use of preemergence herbicide called oxidiazon 2 days after sowing and the post-emergence herbicide called ethoxysulfuron 30 days after sowing (Mazid and Johnson 2010). Inappropriate use of herbicides may lead to evolution of herbicide resistance in weed species.

Some widespread species have already developed resistance following 5–7 years of continuous use of herbicides such as cinosulfuron (Set Off©) and butachlor (Machete©) in Bangladesh where *C. difformis*, *Monochoria*, *Lindernia*, and *Scirpus* occur. It is therefore highly likely that resistance to cinosulfuron will develop in a number of species in Bangladesh (Johnson et al. 2003). For instance, *Echinochloa crus-galli*, a widespread annual grass weed in Bangladesh, has evolved resistance to butachlor in both China and Thailand.

DSR offers resource-poor farmers opportunities to increase the capacity to exploit prevailing growing seasons more fully, with early rice planting followed by a second crop on improved residual soil moisture (Johnson et al. 2008). DSR increases land use intensity in both rainfed and irrigated lowland environments.

Technology options for direct seeding and related weed management were developed within the rice-wheat cropping system in India both in on-station and on-farm studies (Singh et al. 2010). The systems are relatively knowledge-intensive and are subject to variability of the monsoon season, especially in relation to crop establishment and weed control. It is also recognized that the great advantage of DSR, particularly for larger farmers, is that the system enables them to establish the crop earlier and have an earlier harvest, thereby allowing the planting of subsequent crops such as maize, legumes, or potato after the rice harvest.

In Sri Lanka, DSR was demonstrated in three different agroecological zones. Weeds, about 28 species identified in farmers' fields, have been a major constraint faced by farmers irrespective of agroecological zone. The farmers' field trials showed the benefits of an integrated practice of rice establishment, including proper herbicide use with mechanical and cultural weed management. However, a common view among farmers was that herbicide use would be a preferred way to eradicate weeds rather than relying on integrated measures. More than 70% of farmers using herbicides supplemented it by hand weeding, and there has been an increase in the incidence of annual grass. A farmer survey estimated that they were losing about 22% of their rice yield to weed competitors. It appeared that farmers lacked adequate sources of information on herbicide use (Abeysekera et al. 2010).

The perceived environmental benefits of DSR have not been covered extensively by various studies. As the success of DSR is closely associated with integrated management for good establishment of rice crop and is highly dependent on successful weed management practice, the research so far focused on integrated approaches to improved crop establishment under direct seeding of rice, but there is an indication of adverse environmental impact embedded within the system, such as a shift of weed species with continued use of a single type of herbicide, which could lead to a wider spread of herbicide-resistant weeds.

5.1.2 Ecologically based rodent management (EBRM)

The EBRM approach is strongly based on scientific knowledge of rodent biology, population dynamics, taxonomy, and a range of rodent control strategies that would be implemented by farmers. Collective community action is necessary for effective control of rodent outbreaks and damage. This would require a combination of various activities, including village campaigns and hunting for rodent control in early season and at rice booting stage, synchronized planting, field sanitation, and keeping rice bunds between paddy fields small.

The ACIAR-supported project "Implementation of rodent management in intensive irrigated rice production systems in Indonesia and Vietnam (2006-2009)" had successfully developed the community actions required for rodent management. At the national level, the EBRM was integrated into the 3R3G program in the Mekong River Delta of Vietnam and the ICM-FFS in Indonesia. The key environmental impact includes the significant reduction in the use of rodenticides, plastic sheeting for fencing to protect crop, and use of insecticides (e.g., endosulfan) mixed with sump oil that is spread over paddy fields (29% reduction) (Singleton et al. 2003). For instance, in West Java, implementation of EBRM led to a 50% reduction in the use of rodenticides. In the treatment village, the use of chemical rodenticides was 46% compared with 85% in the control village after 2 years of farmer participatory adaptive research (Sudarmaji et al. 2010). The effectiveness of the EBRM rodent management approach is associated with ecological knowledge, social organization, and collective action, which has greatly reduced the use of chemical rodenticides.

In Vietnam, evidence in Palis et al. (2004) indicates that the CTBS has reduced the use of plastic sheet for fencing, which is a commonly used method by rice farmers to protect the rice crop. Typically, the discarded plastic sheets are either left in the field or burned. The discarded materials, which are nonbiodegradable, could clog irrigation channels and serve as habitat for rodents. If burned, the emitted dioxins could cause air pollution and harmful effect on human health. The use of CTBS and integrated rodent management at the village level (IRM-V) in Vietnam has also reduced the use of chemical rodenticides, which are toxic, and when it seeps through the groundwater, could have hazardous health impact on humans, livestock, and other nontarget organisms.

5.2 Post Production (PP) Work Group

The PP Work Group collaborates with scientists and NARES staff in the following countries: Myanmar, Lao PDR, Vietnam, and Indonesia. This collaboration allows them to work on development and dissemination of postharvest technologies in the aforementioned countries and at the same provides a research and development platform for an ADB-funded postharvest project that covers Cambodia, Vietnam, and the Philippines. The postharvest technologies developed to reduce postharvest crop loss include HSS, FBD, CH, and mechanization with laser land leveling (to provide improved field conditions for crop growth).

Among these technologies, laser leveling has been reported in India to have a positive impact on the environment, favoring conditions for crop growth (Jat 2012). In a workshop presentation, Jat (2012) discussed the success of laser leveling in India. The benefits observed from laser leveling include increased crop yield, 15–25% reduced water requirement, 24% time savings in tillage, a similar amount of fuel saving, and a 7% gain in crop productivity.

In Vietnam, laser leveling is seen as a practice that saves water and agricultural inputs on lowland fields, prevents soil erosion, and increases production on upland fields. The system is suitable for advanced agricultural practices on larger fields. Benefits of laser leveling in Vietnam are similar to those seen in India, including an average yield increase of 0.5 t ha^{-1}, ease of weed control with 70% less labor requirement for weeding, no need for postemergence herbicides, and increase in effective land use by 5–8% by removing unnecessary levees (Hien 2012). As reported from studies in India and Vietnam, the key direct environmental impacts from laser leveling would be reduction in the use of water and herbicides.

Gummert (2012a) also mentions several potential environmental impacts of other PP technologies developed. The FBDs with rice husk furnaces reduce reliance on kerosene (i.e., fossil fuels) and are environmentally cleaner. The mechanical FBD was first developed in the Philippines in the 1970s as an alternative to sun-drying rice (which typically has poor quality). The technology was successfully modified and adapted by the University of Agriculture and Forestry at Ho Chi Minh City (Nong Lam University, NLU), headed by Dr. Phan Hieu Hien. The rice husk, which is locally available and cheap, is used as fuel to replace the high-cost kerosene-fueled burner. Continued modification of the furnace design has improved thermal efficiency, with automatic control of the combustion rate and drying temperature, creating cleaner fuel gas, and minimum labor requirement (Xuan et al. 1996). The IRRC, in collaboration with NLU, NARES partners, and the private sector, introduced the FBD with the rice husk furnace in Southeast Asia in 2006, covering Myanmar, Indonesia, the Philippines, and Cambodia. The increasing quality consciousness of the export rice market, as well as high production, has driven the demand for mechanical dryers.

Gummert (2012a) also points out that HSS can reduce the use of chemical pesticides because this technology provides better stored grain pest protection than ordinary bags. However, some potential negative environmental impacts can be observed when manual labor in harvesting is replaced by CHs that use fossil fuels, and when typical sun-drying practices are replaced by FBDs that use fossil fuels.

5.3 Productivity and Sustainability (PS) Work Group

The SSNM approach provides scientific principles for optimal supply of essential nutrient to rice plants as and when needed (Buresh 2012). The principles and practices of SSNM, supported by associated decision tools such as the LCC and the *Nutrient Manager* software, enable rice farmers to tailor nutrient management to specific field conditions by determining fertilizer needs before the season and during the season to maintain soil fertility.

The environmental impact of SSNM was evaluated by Pampolino et al. (2007) using a denitrification-decomposition model with field experiments carried out in India, Vietnam, and the Philippines. The assessment showed that the use of SSNM never resulted in increased emissions of N_2O per unit of grain yield, and higher yields could be obtained with less fertilizer N. The use of SSNM could result in reduced N_2O emissions per unit of grain yield.

5.4 Water Savings (WS) Work Group

On-farm studies of water-saving technology in the Philippines (Tabbal et al. 2002) indicated that the adoption of AWD as a water-saving technology at the farm level will have consequences for the hydrology and water use at larger scale levels. Tabbal et al. (2002) argued that water saved at the farm level does not always mean that water is saved in the whole irrigation system, and suggested that a study is needed to examine the relation between field level and whole system hydrology to predict the large-scale and long-term effects of the AWD irrigation technology.

However, the premise of using AWD itself suggests that the major environmental contribution of this technology is the reduction in water use in rice production that, in turn, frees up water for other purposes (i.e., residential and domestic uses) and provides more equity in water distribution. Lampayan (2012) and Wassmann et al. (2009) also showed that AWD has the potential to reduce methane emissions by almost 50% as compared to rice produced under continuous flooding, which merited certification from the Intergovernmental Panel on Climate Change (IPCC).

In Bangladesh where arsenic is an environmental problem, the mixed cultivation of mustard and direct-seeded *boro* rice with the use of AWD irrigation technology in rice after harvest of mustard had reduced the arsenic content in rice grain. The AWD technique reduced grain arsenic content up to 32% compared with that using continuous standing water.

5.5 Integrated technologies and others

The integration of natural resource management (NRM) technologies for intensification of irrigated rice production systems was expressly designed by IRRC for scaling out in different ICOP country partners. The integrated technologies aimed to increase rice productivity, increase water and fertilizer use efficiency, reduce pesticide use, and reduce production cost. The expected outcomes are to improve farmers' health by virtue of pesticide use reduction, advance farmers' knowledge in rice production through social collective learning, and increase farmer adoption. Moreover, improved environmental conditions and strengthening farmers' capacity building and organization were anticipated based on these integrated technologies.

The IRRC CU facilitated cross-country learning and helped develop the research-extension continuum by strengthening NARES partners in adaptive research, farmers' capacity building, and improving communication strategies. These factors altogether provide a strong groundwork for scaling out integrated NRM technologies.

Three partner countries Indonesia, the Philippines, and Vietnam–have successfully implemented integrated NRM technologies at the community, provincial and regional levels during Phase IV of IRRC.

5.5.1 Vietnam: 3R3G, No Early Spray, 1M5R

Vietnam's national policy on 3R3G was initiated in South Vietnam in 2003 to increase rice productivity, farmers' incomes and health, and improve environmental conditions through reduction in seeding rate, fertilizer application, and pesticide use. The dissemination tools for spreading information about integrated NRM technologies have been professionally designed in a format that is easy to understand so as to reach out to millions of rice farmers. For instance, "No Early Spray" has proven to be a well-accepted slogan for the judicious use of pesticides. The 3R3G and "No Early Spray" campaigns were then "extended" to become the 1M5R program where a multistakeholder process was used as the basis for scaling- out this integrated technology (i.e., linking research-extension-civil groups and mass media was utilized to promote the integrated technology) (Heong et al. 2010). The 1M5R package aims for better use of agricultural resources by reducing irrigation schedules and installing a measuring tube, reducing fertilizer application by monitoring crop growth with an LCC or *Nutrient Manager*, reducing pesticide use with "No Early Spray," and reducing postharvest loss with FBD and the IRRI Super Bag. The use of certified seed is a prerequisite for high-quality rice production in this integrated package.

From the reduction practices in 1M5R, there should definitely be a reduction of adverse environmental loadings due to the reduction in the amount of chemical fertilizer use and amount of pesticide application. However, the continuous cultivation of irrigated rice (with balanced fertilization on submerged soils) maintained or slightly increased soil organic matter and maintained soil N-supplying capacity (Pampolino et al. 2006). Continuous double-rice system shows 11–12% more carbon sequestration and 5–12% more N accumulation in soils than those in maize-rice rotation with greater amounts sequestered in N-fertilized treatments (Witt et al. 2002). Long-term dynamic soil carbon and nitrogen cycling in intensive rice systems are indicative of potential impact of crop intensification (Dobermann and Witt 2000). Attempts to monitor methane gas emission have been carried out in An Giang province. A reduction of methane gas emission by 31.6% has been reported in farmers' fields that adopted AWD as compared with conventional farmer practice.

The success of 1M5R in Vietnam has prompted the government to initiate a large pilot site of 50–100 ha to continue implementing this integrated technology approach in conjunction with good agricultural practice (GAP) certification to produce quality rice for processing companies. Environment impact assessment would then be useful in this case – to create additional value to rice production under GAP.

5.5.2 Indonesia: ICM

In Indonesia, the integrated NRM technologies introduced are in line with the government policy to promote integrated crop management through the FFS approach. The ICOP in Indonesia, which is actively engaged and collaborates closely with local champions from government agencies and farmer communities, helped strengthen the adaptive and participatory action research for the integrated technology package. The FFS approach has been modified and redesigned to better facilitate experiential learning,and mobilize the scaling out of locally adapted NRM technologies.

The integrated crop management (ICM) package introduced in Indonesia consists of AWD water management in DSR planted with drum seeder, integrated pest management to control stem borer, EBRM at community level, and SSNM with the use of soil test kit, and/or the *Nutrient Manager* software. The four project sites in South and Southeast Sulawesi have achieved higher productivity than the projected target by 10%. No direct assessment of environmental impact has been carried out in the four pilot sites, but farmers have integrated at least two NRM technologies into their rice production practices, which resulted in higher yield and income (Singleton et al. 2011a).

5.5.3 Philippines: PalayCheck

In the Philippines, PhilRice formed a partnership with ICOP by integrating the latter into the Institute's Technology Promotion Program to localize and promote rice production technologies in different rice-growing areas of the country (Corales et al. 2010). The IRRC technologies were incorporated in the PalayCheck (Rice Check) platform to promote ICM. The key technological components include water-saving technologies (aerobic rice, AWD, SSNM,), drum seeder, and EBRM. PhilRice worked with the NIA to promote AWD and SSNM. The success of AWD in the NIA's irrigation project areas enables the scaling up of the integrated technologies to improve rice productivity in the irrigated rice-growing areas. In addition, improved distribution and equal access to irrigation water in the service area havve been observed, especially in the downstream areas. The improved water management practice is seen as a pathway toward achieving the country's goal of rice self-sufficiency in 2013.

There is no concrete evidence on the environmental impact of the ICM in the irrigated rice area of the Philippines. However, based on the Vietnamese studies, the AWD practice would be able to reduce methane gas emission, and a significant impact could be envisaged when the NIA has implemented the AWD throughout the irrigated rice areas under its administration.

5.6 Synthesis, analysis, and lessons learned from the environmental impact evidence

The participatory adaptive research of the IRRC focuses on identifying resource-efficient management practices that work towards enhancing rice productivity in the irrigated lowlands of Asia. The mature NRM technologies developed by IRRI/IRRC scientists have been extended to farmers through collaboration with NARES, having the IRRC as a learning and sharing platform.

Various participatory learning approaches, communication innovations, as well as coordination mechanisms, have been designed and adopted to facilitate the transfer of IRRC technologies. These include farmer field schools, participatory impact pathway analysis, multi-stakeholder processes (as in the learning alliance), collective community action, demonstration, facilitation and training. All the approaches aim to build-up farmer capacity, and improve the adoption environment of the relevant technologies. The different IRRC technologies are interrelated, and they could probably function and perform better when applied as an integrated manner, as in the case of ICM-FFS in Indonesia, and 3R3G/1M5R campaigns to increase rice production efficiency in Vietnam.

Not all studies that examine the impacts of IRRC technologies have been designed to explicitly determine their impacts on environment. However, through participant observation, farmer interviews and responses from various adoption studies by the IRRC coordination unit, specific environmental impacts of selected IRRC technologies and practices have been observed and discussed. Some of the main environmental impacts noted in the existing literature, and some suggestions to improve the documentation of these impacts in the future, are described in the proceeding paragraphs.

The design of on-farm participatory experiments to determine the effectiveness of EBRM (by having control and treated fields) has provided strong evidence to support the approach and its practices. The key output is the effective control of rodent and reduction of chemical rodenticide use, and an important outcome is the improvement of farmers' knowledge and the change in farmers' behavior about rodent management. The result has implications on environmental improvement and human health. This is also true as in the case of ecological engineering for rice pest management by planting hedgerow of flowering plants to attract natural enemies.

The AWD irrigation management and dry seeded rice (DSR) practice are closely associated with weed management. The performance of (and results from) these technologies are site-specific and require good agricultural practices, especially during the early stages of crop establishment and growth. Increased use of pre-emergence herbicides when using DSR could lead to herbicide-resistant weeds, and a shift in weed species. The observations in Bangladesh with regard to the weed issue could be used as a learning exercise and could be supported by further field experimentation.

Laser leveling is shown to be a promising postharvest practice for reducing weed and water requirements and, together with AWD irrigation management under the dry-seeded rice practice, the system could likely overcome observed weed problems without using preemergence herbicides (and thus have important environmental implications). AWD is claimed by farmers to improve soil structure. There has been no field experiment to support the observation, but the notion that the practice of alternate wetting and drying allows better soil aeration, permits better root growth, and enhances microbial activities needs to be empirically verified. SSNM and AWD have implications for N_2O emission, as shown by Pampolino et al. (2007). Environmental impacts of soil, nutrient, and water management in irrigated rice systems, particularly in relation to GHG emission, have been reported, but ICM approaches with these IRRC technologies, which are shown to be resource-efficient and sustainable rice production practices, still require further studies. Table 5.1 summarizes some of the observed positive environmental impacts from different IRRC technologies. The majority of the impacts are not measured but are observed and noted by farmer adopters.

Resources permitting, perhaps more studies that explicitly aim to explore the environmental impacts (i.e., both advantageous and disadvantageous) of selected individual IRRC technologies and integrated technology packages (e.g., 1M5R) need to be conducted and eventually published in peer-reviewed journals. More formal documentation of environmental impacts in peer-reviewed scientific outlets increases credibility and makes the "non-market" benefits of IRRC technologies more visible to donors (and

Table 5.1. Examples of positive environmental impacts from IRRC technologies.

Type of impact	IRRC technology
Land/soil	
Enhanced soil fertility	AWD improves aeration and root environment (soil oxygen content increased by 120–200%)
Improved nutrient management	SSNM: judicious use of fertilizer based on LCC,- and *Nutrient Manager*
Water	
Efficient use of water	AWD reduces water use by 30%
	Laser leveling enables even distribution of water and provides better weed control. Reduces the crop's water requirement
	Less amount of water demand for wet-seeded rice
Pesticide pollution	
Human health	Laser leveling reduces herbicide use for weed control
	Hermetic seed storage reduces the use of chemical pesticides
	EBRM reduces pesticide use by 66%, which could contribute to reduction of health hazard due to agrochemical contamination
	Community trap barrier system reduces the use of plastic sheets for fencing, leading to less plastic waste in the field and less pollution from burning of plastic waste
Biodiversity conservation/loss	
Balancing pest-predator relationship	Ecological engineering in pest management, "No-Early Spray" enhancing pest-predator interaction, which provides favorable conditions for biological control
Climate change	
Methane gas reduction	AWD mitigates methane emissions by 50%
Energy saving	Flat-bed dryer (use of rice husk burner replaces fossil fuel and produces cleaner fuel gas) reduces fuel cost and improves grain quality
	Reduces energy use for tillage preparation in direct-seeded rice

policymakers). Perhaps the criteria developed by Wani et al. (2005) can be used by future studies as a framework to more rigorously track and make judgments on the environmental impacts from IRRC technologies. The Wani et al. (2005) criteria include indicators for changes in biodiversity, agro-biodiversity, agro-ecosystem efficiency, environmental services, soil quality, and water availability/quality.

Overall, there is evidence on the environmental impact of the NRM technologies developed and disseminated by IRRC. But this evidence is "thin" and the broader scientific community can use some of the observations from existing literature to develop more rigorous experimental designs to more effectively document the environmental effects of these technologies. Policymakers and donors are encouraged to further examine the possibility of emphasizing and funding these types of research.

6. Scientific impact: citation analysis

The scientific impact of the IRRC is assessed by the number of publications and citation counts broken down by publication type and by work group. Publication and citation counts offer a measurable impact of the research effort and an indication of the influence of the research effort on research conducted elsewhere (Renkow and Slade 2012, Spilsbury and Kaimowitz 2000).

This review aims to provide an overall assessment of the scientific impact of IRRC's publications that were produced by the work groups over the period from 1997 to 2012. The publications include peer-reviewed journal articles, books, monographs, book chapters, research reports, proceedings volumes, conference papers, poster presentations and seminars, and unpublished theses. Many publications are multiple outputs resulting from the same research initiative. For instance, conference, seminar, research report, and workshop presentation are typically considered as intermediate outputs that are subsequently developed into a peer-reviewed journal article.

Each work group developed and evolved at different time scales over the 16-year project period. The publications are collected from the IRRC annual reports from Phase I to Phase IV, the IRRC web site, and research reports to funding agencies. In the spirit of conciseness, the complete list of publications considered in the analysis is not presented here, but is available from the authors upon request. Note that this list is admittedly far from complete/ comprehensive (and there are a number of years with missing information), but nevertheless we consider this as close to being representative of the full body of work from IRRC to date.

6.1 Publication outputs

Table 6.1 and Figure 6.1 show the number of publications produced by the IRRC's eight work groups from 1997 to 2012. A total of 461 publications were considered available and accessible for this analysis. It is important to note that the list of publications used in the analysis in this section may still be incomplete at the time of writing (i.e., some of the 2012 publication outputs may not have been included yet). Further note that the Hybrid Rice Work Group was active in Phase I of the project but was subsequently withdrawn from the IRRC in Phase II. The Crop Health Work Group was initiated in Phase IV.

The distribution of publication outputs over the four phases showed noticeable publication spikes. In IRRC's Phase I, there was a surge in publications for the PS Work Group with 17 in 1999 and 24 in 2000. The PS Work Group has 19 peer-reviewed journal articles (50%), a book, a book chapter, a proceedings volume and several conference papers, as well as two Master's theses. Seven publications from the LPCE Work Group dealt with IPM in rice, especially in the Mekong Delta, Vietnam.

In Phase II, publication output was highest in 2003 and was dominated by the LPCE Work Group (i.e., the work on weed and rodent management), constituting about 49% of the output for that phase.

Table 6.1. Number of publications, by work group, 1997–2012.

Work Group	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	**Total**	**%**
LPCE-Weeds	-	-	-	-	-	-	10	-	8	8	9	13	14	19	5	-	**86**	**18.7**
LPCE-Rodents	-	-	7	-	-	-	5	2	4	7	4	6	8	22	2	-	**67**	**14.5**
Postproduction	-	-	-	-	-	-	1	-	-	1	2	1	4	15	5	4	**33**	**7.2**
Productivity/ sustainability	-	-	17	24	4	1	-	-	2	7	6	13	21	25	13	-	**133**	**28.9**
Water saving	-	-	-	-	1	-	1	3	7	5	4	6	14	15	7	5	**68**	**14.8**
Crop health	-	-	-	-	-	-	-	-	-	-	-	-	2	6	7	-	**15**	**3.2**
Hybrid rice	-	1	-	2	5	-	-	-	-	-	-	-	-	-	-	-	**8**	**1.7**
Coordination Unit							2		1	3	3	3	5	18	16	-	**51**	**11.0**
Total	**-**	**1**	**24**	**26**	**10**	**1**	**19**	**5**	**22**	**31**	**28**	**42**	**68**	**120**	**55**	**9**	**461**	
%		**0.2**	**5.2**	**5.6**	**2.2**	**0.2**	**4.1**	**1.1**	**4.8**	**6.7**	**6.1**	**9.1**	**14.8**	**26.0**	**11.9**	**2.0**		**100**

Sources: IRRC Phases I, II, III Final Reports, Phase IV Annual Reports, and IRRC Web site.

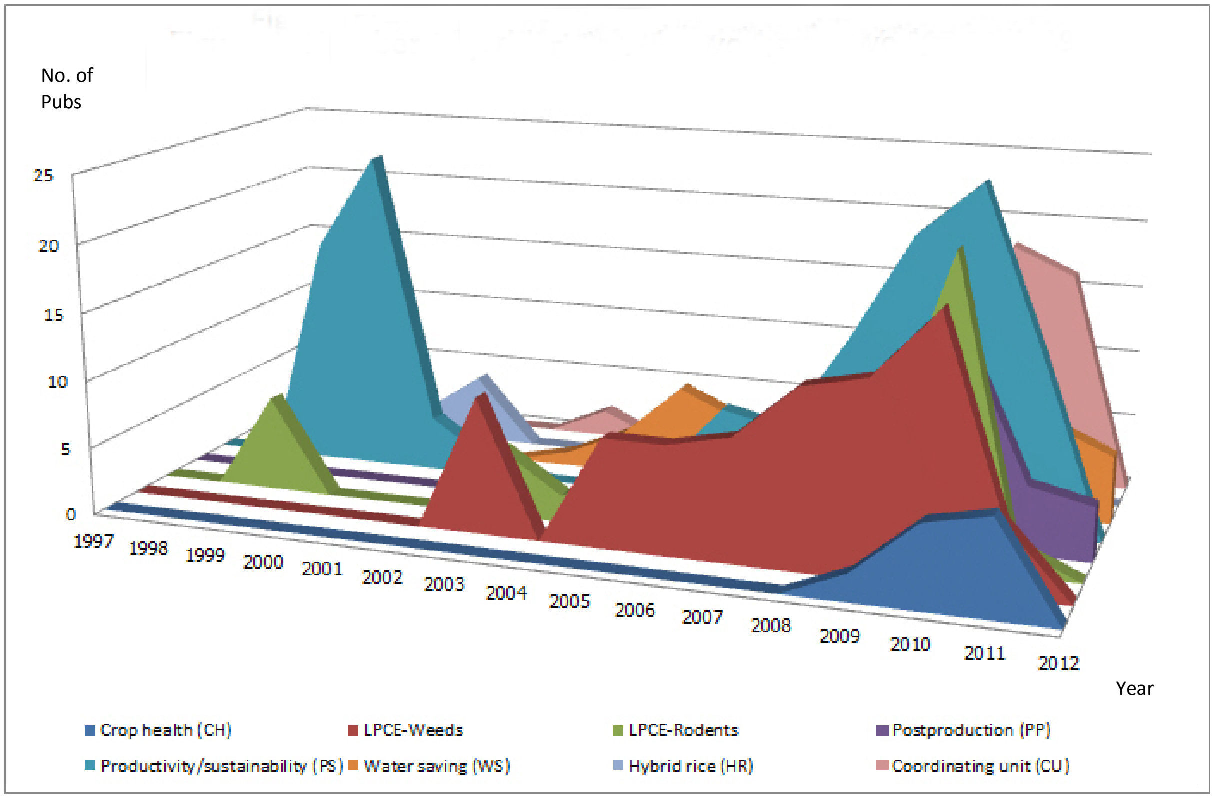


Fig. 6.1. Number of publications, by work group, 1997–2011

But the total publications (35) are less than half of Phase I (75). The weed management work produced publications in the form of proceedings volumes, and research reports, while the rodent management work mainly produced monographs and research notes in this period. The WS Work Group produced two highly cited papers, one was a book chapter and the other was a peer-reviewed journal article (see below). One assessment report of the agro-industrial situation in Cambodia was produced by the PP Work Group in this project phase.

The number of publications in IRRC's Phase III grew almost four times as large as the publication number in Phase II. Publication number steadily increased from 22 in 2005 to 42 in 2008 (with a total of 123 publications for the 2005–08 period). The weed management and rodent management research (from the LPCE Work Group) together contributed 48% of the total publications, followed by the PS and WS workgroups with about 23 and 18%, respectively. The rest were taken up by the CU (8%), which was institutionalized and became an active IRRC unit during Phase III, and the PP Work Group (3%), respectively.

In Phase IV, majority of the publications were produced during the first 3 years from 2009 to 2011. The highest number of publications (120) was produced in 2010. The PP Work Group had four workshop presentations, while the WS Work Group produced four research reports in 2012. The total number of publications in Phase IV (252) was more than double that of Phase III. In the 2009–11 period, all work groups have maintained relatively high publication numbers ranging from 28 to 59. The only exception is the Crop Health Work Group, which was a new initiative in Phase IV, with 15 publications of the following types: journal articles, book, and conference papers.

The PS Work Group produced the highest publication numbers (59) in Phase IV where: 52 were conference papers, posters, and seminars, three were journal articles, and, four were book chapters. The weed management research (38), the rodent management work (32), the WS Work Group (36), and the CU (39) contributed almost the same number of publications in this period. The weed management work (from the LPCE Work Group) produced 28 journal articles (74% of total output), followed by the WS Work Group, which produced 9 journal articles), the rodent management work (7 journal articles) and the CU (5 journal articles). The rodent management research (LPCE Work Group) and the CU produced 9 and 7 book chapters, respectively, in this period.

6.2 Publication types and citation counts

Table 6.2 presents an overview of the IRRC publications broken down by publication type, and Table 6.3 shows citation counts of each work group over IRRC's four phases (1997–2012). About one-third (148) of the total output were peer-reviewed journal articles, and 65 were externally reviewed books, research monographs, and book chapters, which cumulatively accounted for 14% of the total output.

The distribution of publications over the eight work groups was less balanced. Research efforts related to weed management, rodent management, nutrient management, and water management dominated the research agenda and publication spectrum. About 29% of total publication outputs were from nutrient management research, 15% from rodent management, 19% from weed management, and 15% from water management. The CU, with its emphasis on participatory research and scaling out of the technologies, showed increasing publication numbers in Phases III and IV of IRRC (e.g., 11% of the total publications).

The citation analysis over IRRC's four phases indicated that 53.1% of the total citations were associated with the nutrient management work of the PS Work Group, 13.6% with the rodent management research of the LPCE Work Group, 18.9% with the water resource management work of the WS Work Group, and 8.8% from the weed management research activities of the LPCE Work

Table 6.2. Publication types, by work group.

Type	LPCE-Weeds	LPCE-Rodents	Post production	Productivity/ sustainability	Water saving	Crop health	Hybrid rice	Coordination Unit	**Total**	%
Journal article	35	23	3	41	27	4	3	12	**148**	**32.1**
Book	3	1	-	2	-	1	1	1	**9**	**2.0**
Monograph	-	2	-	-	-	-	1	-	**3**	**0.7**
Book chapter	10	15	6	7	3	-	1	11	**53**	**11.5**
Research report	1	4	3	-	5	-	-	6	**19**	**4.1**
Proceedings volume	27	1	1	23	7	-	-	6	**65**	**14.1**
Conference paper/poster/presentation	8	14	19	57	20	9	2	14	**143**	**31.0**
Research note	2	6	1	1	3	1	-	-	**14**	**3.0**
Unpublished thesis	-	1	-	2	3	-	-	1	**7**	**1.5**
Total	**86**	**67**	**33**	**133**	**68**	**15**	**8**	**51**	**461**	**-**
%	**18.7**	**14.5**	**7.2**	**28.9**	**14.8**	**3.2**	**1.7**	**11.0**	**-**	**100**

Sources: IRRC Phases I, II, III Final Reports, Phase IV Annual Reports, and IRRC Web site.

Table 6.3. Number of citations,[a] by work group and year.

Work Group	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	**Total**	**%**
LPCE-Weeds	-	-	-	-	-	-	19	-	52	14	46	132	148	31	10	-	**452**	**8.8**
LPCE-Rodents	-	-	146	-	-	-	190	22	70	33	43	36	80	77	2	-	**699**	**13.6**
Postproduction	-	-	-	-	-	-	0	-	-	0	0	0	20	8	0	-	**28**	**0.5**
Productivity/ sustainability	-	-	601	1052	132	227	-	-	41	235	146	167	16	114	0	-	**2731**	**53.1**
Water saving	-	-	-	-	31	-	171	197	6	178	260	39	75	10	5	-	**972**	**18.9**
Crop health	-	-	-	-	-	-	-	-	-	-	-	-	15	1	31	-	**47**	**0.9**
Hybrid rice	-	7	-	22	43	-	-	-	-	-	-	-	-	-	-	-	**72**	**1.4**
Coordination Unit	-	-	-	-	-	-	11	-	7	46	41	8	20	7	6	-	**146**	**2.8**
Total	**-**	**7**	**747**	**1074**	**206**	**227**	**391**	**219**	**176**	**506**	**536**	**382**	**374**	**248**	**54**	**-**	**5147**	**-**
%		**0.1**	**14.5**	**20.9**	**4.0**	**4.4**	**7.6**	**4.3**	**3.4**	**9.8**	**10.4**	**7.4**	**7.3**	**4.8**	**1.1**	**-**	**-**	**100**

[a]Citation counts based on output from *Google Scholar*.

Group. Approximately 36% of the total citation counts were from outputs in Phase I, particularly from publications on nutrient and pest management in 1999 and 2000. This is not surprising, given that it has been more than a decade since the publication dates of these outputs.

Table 6.4 provides the cumulative number of publications and citation counts, by publication type, for the different work groups. The intermediate products of the peer-reviewed journal articles, such as conference papers, posters, presentations, research notes, and reports, accounted for about 54% of the total outputs. But, in the aggregate, these intermediate outputs only provided 480 citations, which were about 9.3% of the total citation counts. The postharvest work of the PP Work Group had 73% of its total output under the intermediate product category and had the lowest share of citation counts.

A selection of IRRC publications with the highest citation counts for each work group is shown in Table 6.5. The nutrient and IPM research published in the early phases of the IRRC had the greatest citation counts and, consequently, may have had the influence on the literature. Book, book chapters, and peer-reviewed journal articles provided the largest share of the citations. The book on nutrient disorders and nutrient management in rice has been highly cited maybe because of its insights about how to reverse rice yield declines in intensive rice-based cropping systems. The research outputs from the PS Work Group were also published in influential journals such as *Field Crops Research*, *Plant and Soil*, and *Nutrient Cycling in Agroecosystems*. The early work on field methods for rodent studies (an ACIAR monograph), integrated management of rodent pests, and its impact on rice productivity also had fairly high citation counts. Output from the WS group that was published from 2003 to 2006 had the highest citations among the publications from that work group (Table 6.5). The highest number of citations for the weed management and crop establishment work was for output published in 2007–09. In addition, a series of studies on seed ecology of important broadleaf and grass weeds were published in *Weed Science* in 2008 with high citation counts ranging from 5 to 31.

The published output from CU from 2006 to 2009 produced high citation counts (Table 6.5). This work mainly focused on farmer learning and technology adoption, farmers' behavior and belief system with regard to pesticide safety, and knowledge of unintended consequence of culling in rodent species. The social and cultural aspects of rodent pest management published in *Integrative Zoology* and the impact of IPM published in the *Review of Agricultural Economics* also received relatively high citations.

For the Crop Health Work Group, four selected publications on crop health (i.e., one book on planthoppers and three journal articles on plant diseases) had high citation numbers. The highly cited journal article published in 2011 is related to an analytical framework for climate-change effects mediated by plant disease and published in a special issue of *Plant Pathology* on climate change and plant diseases.

There were three publications from the PP Work Group (published in 2009 and 2010) that were highly cited (Table 6.5). The work with high citations included two journal articles and one book chapter. The "Learning Selection" model, published in *Agricultural Systems* in 2010, updates the innovation theory to describe the development and adoption of postharvest technologies, such as the flat-bed dryer, low-cost dryer, and stripper harvester in Vietnam, the Philippines, and Indonesia. The Work Group maintains its adaptive location-specific research with postharvest research networks in Southeast Asian countries and carries out a research-for-development approach. Perhaps this might explain why 73% of its publication outputs were in the form of research notes and conference and workshop presentations (Tables 6.2 and 6.4).

Table 6.4: Cumulative publications and citations,[a] by publication type and work group.

	LPCE-Weeds	LPCE-Rodents	Post Production	Productivity/ sustainability	Water saving	Crop health	Hybrid rice	Coordination Unit	Publications (total no.)	%	Citations (total no.)	%
Journal article	35 (330)	23 (427)	3 (13)	41 (2013)	27 (756)	4 (32)	3 (29)	12 (114)	**148**	**32.1**	**(3,714)**	**(72.2)**
Book	3 (9)	1 (9)	-	2 (414)	-	1 (15)	1 (8)	1 (0)	**9**	**2.0**	**(455)**	**(8.8)**
Monograph	-	2 (123)	-	-	-	-	1 (21)	-	**3**	**0.7**	**(144)**	**(2.8)**
Book chapter	10 (20)	15 (57)	6 (11)	7 (72)	3 (171)	-	1 (4)	11 (19)	**53**	**11.5**	**(354)**	**(6.9)**
Research report	1 (9)	4 (11)	3 (0)	-	5 (2)	-	-	6 (0)	**19**	**4.1**	**(22)**	**(0.4)**
Proceedings volume	27 (69)	1 (0)	1 (0)	23 (111)	7 (31)	-	-	6 (13)	**65**	**14.1**	**(224)**	**(4.4)**
Conference paper/poster/presentation	8 (15)	14 (1)	19 (1)	57 (102)	20 (12)	9 (0)	2 (10)	14 (0)	**143**	**31.0**	**(141)**	**(2.7)**
Research note	2 (0)	6 (67)	1 (3)	1 (19)	3 (0)	1 (0)	-	-	**14**	**3.0**	**(89)**	**(1.7)**
Unpublished thesis	-	1 (4)	-	2 (0)	3 (0)	-	-	1 (0)	**7**	**1.5**	**(4)**	**(0.1)**
Total	**86**	**67**	**33**	**133**	**68**	**15**	**8**	**51**	**461**	**-**	**-**	
%	**18.7**	**14.5**	**7.2**	**28.9**	**14.8**	**3.2**	**1.7**	**11.0**	**-**	**100**	**-**	**(100)**
Total citations (no.)	**(452)**	**(699)**	**(28)**	**(2731)**	**(972)**	**(47)**	**(72)**	**(146)**	**-**	**-**	**(5,147)**	
%	**(8.8)**	**(13.6)**	**(0.5)**	**(53.1)**	**(18.9)**	**(0.9)**	**(1.4)**	**(2.8)**				**(100)**

Sources: IRRC Phases I, II, III Final Reports, Phase IV Annual Reports, and IRRC Web site.

[a]Numbers without brackets are publication counts and numbers in brackets are citation counts. Citation counts based on output from *Google Scholar*.

Table 6.5: Selected IRRC publications with high citation counts, by work group.

Citation	Year	Authors	Title	Source
Nutrients (Productivity and Sustainability) Work Group				
332	2000	Dobermann A, Fairhurst T	Rice: Nutrient disorders and nutrient management	Book, Rice: Nutrient disorders and nutrient management. Potash & Phosphate Institute (PPI), Potash & Phosphate Institute of Canada (PPIC), and International Rice Research Institute (IRRI), Singapore and Los Baños. 191 p.
228	1999	Witt C, Dobermann A, Abdulrachman S, Gines HC, Wang GH, Nagarajan R, Satawathananont S, Son TT, Tan PS, Tiem LV, Simbahan GC, Olk DC	Internal nutrient efficiencies of irrigated lowland rice in tropical and subtropical Asia	Field Crops Res. 63: 113-138
129	2000	Dawe D, Dobermann A, Moya P, Abdulrachman S, Bijay Singh, Lal P, Li SY, Lin B, Panaullah G, Sariam O, Singh Y, Swarup A, Tan PS, Zhen QX	How widespread are yield declines in long-term rice experiments in Asia?	Field Crops Res. 66: 175-193
120	2000b	Witt C, Cassman KG, Olk DC, Biker U, Liboon SP, Samson MI, Ottow JCG	Initial effects of crop rotation and residue management on carbon sequestration, nitrogen cycling and crop productivity of irrigated rice systems	Plant Soil 225: 263-278
115	1999	Dobermann A, White PF	Strategies for nutrient management in irrigated and rainfed lowland rice systems	Nutr. Cycl. Agroecosyst. 53: 1-18
Rodent Management (LPCE Work Group)				
94	2003	Aplin KP, Brown PB, Jacob J, Krebs CJ, Singleton GR	Field methods for rodent studies in Asia and the Indo-Pacific	Aplin eds. Field methods for rodent studies in Asia and the Indo-Pacific. ACIAR publication
61	1999	Huan NH, Mai V, Escalada MM, Heong KL	Changes in farmers' pest management between 1992 and 1997 in Mekong Delta, Vietnam	Crop Prot. 18: 557-563
58	2009	Meerburg BG, Singleton GR, Kijlstra A	Rodent-borne diseases and their risks for public health	Crit. Rev. Microbiol. 35: 221-270
52	2003	Singleton GR	Impacts of rodents on rice production in Asia	IRRI Discussion Paper No.45
49	2005	Singleton GR, Sudarmaji, Jacob J, Krebs CJ	Integrated management to reduce rodent management in lowland rice crops in Indonesia	Agric. Ecosyst. Environ. 107: 75-82
Water Saving Work Group				
171	2003	Tuong TP, Bouman BAM	Rice production in water-scarce environments	Chapter in: Water productivity in agriculture: limits and opportunities for improvement. UK:

				CABI Publishing
165	2004	Belder P, Bouman BAM, Cabangon R, Lu Guoan, Quilang EJP, Li Yuanhua, Spiertz JHJ, Tuong TP	Effect of water-saving irrigation on rice yield and water use in typical lowland conditions in Asia	Agric. Water Manage. 65: 193-210
115	2007	Bouman BAM, Humphreys E, Tuong TP, Barker R	Rice and water	Adv. Agron. 92: 187-237
90	2006	Peng S, Bouman BAM, Visperas, RM, Castañeda A, Nie Lixiao, Park Hong-Kyu	Comparison between aerobic and flooded rice in the tropics: agronomic performance in an eight-season experiment	Field Crops Res. 96: 252-259
74	2006	Bouman BAM, Yang Xiaoguang, Wang Huaqi, Wang Zhimin, Zhao Junfang, Chen Bin.	Performance of aerobic rice varieties under irrigated conditions in North China	Field Crops Res. 97: 53-65
Weed Management and Crop Establishment (LPCE Work Group)				
46	2007	Choudhury BU, Bouman BAM, Singh AK	Yield and water productivity of rice-wheat on raised beds at New Delhi, India	Field Crops Res. 100: 229-239.
31	2008	Chauhan BS, Johnson DE	Influence of environmental factors on seed germination and seedling emergence of eclipta (*Eclipta prostrata*) in a tropical environment	Weed Sci. 56(3): 383-388
22	2009	Rodenburg J, Johnson DE	Weed management in rice-based cropping systems in Africa	Adv. Agron. 103: 149-218
22	2009	Mahajan G, Chauhan BS, Johnson DE	Weed management in aerobic rice in northwestern Indo-Gangetic Plains	J. Crop Improv. 23: 366-382
21	2008	Chauhan BS, Johnson DE	Seed germination and seedling emergence of giant sensitive plant (*Mimosa invisa*)	Weed Sci. 56: 244-248
Coordination Unit				
22	2006	Palis FG	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. Hum. Values 23: 491-500
22	2006	Palis FG, Flor R, Warburton H, Hossain M	Our farmers at risk: behavior and belief system in pesticide safety	J. Public Health 28: 43-48
22	2007	Singleton GR,Brown PR, Jacob J, Aplin KP, Sudarmaji	Unwanted and unintended effects of culling: a case for ecologically based rodent management	Integr. Zool. 2: 247-259
15	2007	Palis FG, Singleton G, Sumalde Z, Hossain M	The social and cultural dimensions of rodent pest management	Integr. Zool. 2: 174-183
11	2009	Rejesus RM, Palis FG, Lapitan AV, Chi TTN,	The impact of integrated pest management	Rev. Agric. Econ. 31(4): 814-833

		Hossain M	information dissemination methods on insecticide use and efficiency: evidence from rice producers in South Vietnam.	http://aepp.oxfordjournals.org/content/31/4/814.abstract
Crop Health Work Group				
21	2011	Garrett KA, Forbes GA, Savary S, Skelsey P, Sparks AH, Valdivia C, Bruggen AH C van, Willocquet L, Djurle A, Duveiller E, Eckersten H, Pande S, Vera Cruz C, Yuen J	Complexity in climate-change impacts: an analytical framework for effects mediated by plant disease	Plant Pathol. 60: 15-30
15	2009	Heong KL, Hardy B, eds.	Planthoppers: new threats to the sustainability of intensive rice production systems in Asia	Book, Planthoppers: new threats to the sustainability of intensive rice production systems in Asia. Los Baños (Philippines): International Rice Research Institute. 460 p.
5	2011	Huang SW, Wang L, Liu LM, Tang SQ, Zhu DF, Savary S	Rice spikelet rot disease in China. 1. Characterization of fungi associated with the disease	Crop Prot. 30: 10-19
5	2011	Huang SW, Wang L, Liu LM, Tang SQ, Zhu DF, Savary S	Rice spikelet rot disease in China. 2. Pathogenicity tests, assessment of the importance of the disease, and preliminary evaluation of control options	Crop Prot. 30: 1-9
Postproduction Work Group				
8	2009	Gummert M, Balingbing C et al.	Management options, technologies and strategies for minimized mycotoxin contamination of rice	World Mycotoxin J. 2(2): 151-159
8	2009	Haefele, SM, Knoblauch C, Gummet M, Konboon Y, Koyama S	Black carbon (bio-char) in rice-based systems: characteristics and opportunities	Chapter *in* Amazonian dark earths: Wim Sombroek's Vvsion. p 445-463
5	2010	Douthwaite B, Gummert M	Learning selection revisited: how can agricultural researchers make a difference?	Agric. Syst. 103: 245-255

6.3 Influence of publications

In the scientific community, it is recognized that publication of research findings in peer-reviewed journals will have greater scientific impact, especially in journals indexed in the Journal Citation Report (database) that has impact factors calculated annually.

The IRRC work groups produced 148 peer-reviewed journal articles (about 32% of the total publications). These have been published in 63 academic journals, in which 44 (70%) are indexed in the Journal Citation Report (Table 6.6). The 44 academic journals show a wide range of impact factors. With the exception of the journal *Science*, which has the highest impact factor of 31.201, the other 43 journals have impact factors ranging from 0.05 to 6.27. Note that one IRRC article was published in a special issue of *Science* that focused on EBRM. Based on the value of the impact factor, indexed academic journals could be arbitrarily arranged into five broad groups: those having impact factors higher than 3, impact factors between 2.001 and 2.999, impact factors between 2.000 and 1.001, and impact factors below 1.000. There are 14 journals where IRRC has published that are not yet indexed (or are in the process of being indexed).

Forty-six (31%) of the peer-reviewed journal articles by IRRC were published in journals having impact factors ranging from 2.001 to 3.000 and 58 (~39%) were in journals with impact factors between 1.001 and 2.000. *Field Crops Research,* with impact factor of 2.474, published 26 articles from three IRRC work groups LPCE-weeds (7), PS (10), and WS (9). *Agricultural Systems*, the journal with the highest impact factor (2.899) within the 2.001 to 3.000 group, had four articles coming out of IRRC research – one from the PP Work Group and three from the PS Work Group.

In journals with impact factors ranging 1.001 to 2.000, the IRRC has published in *Weed Science* (16), *Crop Protection* (7), *Wildlife Research* (7), Journal of the Soil Science Society of America (5), and *Integrative Zoology* (4). *Crop Protection* had published articles from IRRC's LPCE and Crop Health work groups, as well as two articles from the CU. The other journal that had published articles from more than one IRRC work group – LPCE and the CU – is *Agriculture and Human Values* (with an impact factor of 1.54). The IRRC had 11 articles in the last grouping of academic journals with impact factors lower than 1.000 (0.05–0.986). Five IRRC work groups had published in this group of journals, namely LPCE (5), PP (1), PS (1), WS (5), and CU (1).

Among the 15 peer-reviewed journals that IRRC has published in but are not yet indexed (or are in the process of being indexed), about half are "country" or "regional" journals, such as *Omonrice* (Vietnam), *Philippine Journal of Crop Science*, *Bangladesh Journal of Agriculture and Environment*, *Kasetsart Journal of Natural Science* (from Kasetsart University, Thailand), *Lao Journal of Agriculture and Forestry*, *Acta Agronomica Sinica*, and *Chinese Journal of Eco-Agriculture*. These journals publish results of scientific investigation more relevant to their own countries or in similar agroecosystems. The publisher is within the country. Most of the journal articles published in these journals report on IRRC activities in-country, and majority of papers are coauthored by NARES staff and IRR/IRRC.

Among the 148 peer-reviewed journal articles published by IRRC, 77 articles (52%) were coauthored with NARES staff members. It is encouraging to see that IRRC publications with high citation counts are those where NARES partners have been coauthors (Table 6.5). The participation and engagement of NARES staff in these peer-reviewed outputs are indicative of the scientific impact of IRRC with respect to building the capacity of NARES staff in partner countries. Moreover, given that these IRRC articles have been published in fairly influential journals, these peer-reviewed articles can serve as important references in learning modules and courses about NRM technologies in partner countries.

Table 6.6. Impact factors of journals with IRRC articles and number of IRRC articles published, by work group.

Journal	Impact factor in 2011	Number of articles	LPCE-Weeds	LPCE-rodents	Post production	Productivity/sustainability	Water saving	Crop health	Hybrid rice	Coordination Unit
Science	31.201	1		1						
Critical Review of Microbiology	6.27	1		1						
Advances in Agronomy	5.204	4	2			1	1			
Ecological Applications	5.102	1		1						
Annals of Botany	4.03	1	1	1						
Agronomy for Sustainable Development	3.33	1				1				
Agriculture, Ecosystems and Environment	3.004	2		2						
Agricultural Systems	2.899	4			1	3				
Plant and Soil	2.733	2				2				
Journal of Integrative Plant Biology	2.534	1					1			
Field Crops Research	2.474	26	7			10	9			
Soil Tillage Research	2.425	2	1			1				
European Journal of Soil Science	2.34	2				2				
Biology and Fertility of Soils	2.319	2				2				
Geoderma	2.318	1				1				
Population Ecology	2.287	1		1						
Pest Management Science	2.251	1		1						
Annals of Applied Biology	2.179	1	1							
Plant Pathology	2.125	1						1		
Journal of Microbiological Methods	2.086	1				1				
Food Policy	2.054	1					1			
Agricultural Water Management	1.998	3					3			

Soil Science Society of America Journal	1.979	5				5				
Bulletin of Entomological Research	1.882	1		1						
Agronomy Journal	1.797	3				3				
Nutrient Cycling in Agroecosystems	1.792	2				2				
Weed Science	1.733	16	16							
Irrigation Science	1.635	1					1			
Euphytica	1.554	1							1	
Agriculture and Human Values	1.54	2		1						1
World Mycotoxin Journal	1.452	1			1					
Crop Protection	1.402	7	1	1				3		2
Journal of Public Health	1.35	1								1
Wildlife Research	1.323	7		4						3
Integrative Zoology	1.208	4		2						2
Soil Science	1.144	1				1				
Journal of Physics and Chemistry of the Earth	1.11	1					1			
Soil Science and Plant Nutrition	1.017	2				1	1			
Paddy Water Environment	0.986	1					1			
Netherlands Journal of Agricultural Science	0.96	1		1						
Transactions of the Chinese Society of Agricultural Engineering	0.89	2					2			
Weed Biology and Management	0.707	1	1							
Review of Agricultural Economics	0.643	1								1
International Journal of Pest Management	0.488	2		2						

Agricultural Science in China	0.45	1					1			
Journal of Agricultural Science and Technology	0.436	1	1							
Communications in Soil Science and Plant Analysis	0.432	1				1				
Science Asia	0.344	1					1			
AMA (Agricultural Mechanization in Asia, Africa, and Latin America	0.05	1			1					
Omonrice	n/i	3		1		2				
Philippine Journal of Crop Science	n/i	3				1	1		1	
Bangladesh Journal of Agriculture and Environment	n/i	1				1				
Better Crops with Plant Food	n/i	1				1				
Kasetsart Journal of Natural Sciences	n/i	1	1							
Journal of Crop Improvement	n/i	2	2							
AoB Plant	n/i	1	1							
Journal of Applied Communications	n/i	1		1						
Lao Journal of Agriculture and Forestry	n/i	1		1						
Acta Agronomica Sinica	n/i	1					1			
Chinese Journal of Eco-Agriculture	n/i	1					1			
Journal of Agricultural Education and Extension	n/i	1								1
Applied Anthropology	n/i	1								1

Journal of Crop Science	n/i	1							1	
Total		148	35	23	3	41	27	4	3	12

n/i = not indexed

6.4 Synthesis, analysis, and lessons learned from the scientific impact assessment

Overall, the IRRC has produced an impressive output of publications. IRRC publications have appeared in peer-reviewed journals with high impact factors. A number of publications outputs have been cited numerous times. This suggests that findings from IRRC output have had influence on research conducted elsewhere, most especially in IRRC's partner countries and other rice-producing countries in Asia.

In the early phases of IRRC, the authorship of scientific publications is made up of IRRI scientists but, as the Consortium develops into Phase IV, scientists from the NARES partners are increasingly included in the scientific publication, especially when more adaptive research for development has been initiated to improve context-relevant production practices. The NARES staff has been encouraged to produce intermediate products in the form of conference papers, proceedings volume, workshop presentations, and research notes, which would become knowledge assets for further development into peer-reviewed journal articles. The learning process is essentially an important feature for capacity building.

7. Human resource development impacts: educational and curricular outcomes

Human resource development within the IRRC framework is seen as an important strategy for developing and extending transformative NRM technologies to NARES partners, rice farmers, private sector organizations, and NGOs. Its capacity-building efforts aim to expand human capital within the NARES, farmer groups and organizations, as well as the private sector and NGOs, to achieve improved rice productivity from pre-production to post-production (with focus on more efficient use of resources). The IRRC employs several approaches to extend NRM technologies to different target groups, integrating training, organization, and business development efforts to improve individual, group, and organizational performance. The human resource development approaches also include postgraduate training and university curriculum development.

7.1 The IRRC work groups and contribution to capacity building

Training on specific subject matters was carried out by the different IRRC work groups either in-country or at IRRI headquarters in Los Baños, Philippines. Each work group develops its own key competencies to enable trainees to develop their scientific knowledge with practical applications.

It is noteworthy that a number of human resource development approaches adopted and implemented by each work group go beyond training for disseminating technologies. It encompasses strengthening capacities of NARES in adaptive research, empowering farmer organizations through shared learning (by modifying the FFS approach), and building LA among multiple stakeholders in the rice value chain using a business model approach. Brief descriptions of the various learning approaches implemented by the IRRC work groups are given in Table 7.1.

Labor Productivity and Community Ecology (LPCE). The Work Group has engaged in training of extension staff about adaptive research on direct seeding and related weed management, and weed ecology. The out-scaling activities included training of farmers and on-farm demonstrations and trials. For effective rodent control, the Work Group supports the study of rodent ecology in Vietnam and Indonesia, and information and knowledge are used to provide a better understanding of ecologically based rodent management for farmers in entire villages. The management system requires a basic understanding of rodent ecology and needs collective action at the village level for effective control.

Post-Production (PP). The Work Group introduced well-established laser land leveling for improved plant establishment, weed, fertilizer, and water management. It also covers mechanical

Table 7.1. Learning approaches adopted by the IRRC work groups to scale out NRM technologies and to develop human resources of various partners.

Work group	Objectives	Key principles and tools	Learning approaches
LPCE	To reduce labor cost for crop establishment; to develop ecologically based rodent management at the community level	Direct wet seeding with drum seeders and weed management; rodent ecology, trap and barrier system	Training, workshops, facilitating farmer organization
PP	To improve rice value chain from rice maturity to end use and to decrease loss; to improve irrigation efficiency and even crop establishment as well as to facilitate mechanical harvesting with advanced land leveling technology	Small harvesters, seed storage, flat bed dryer, laser leveling	Training, workshops, participatory impact pathway analysis, business model approach through learning alliances to outscaling post-harvest technologies
PS	To increase profitability by developing and disseminating sustainable nutrient and crop management practices	*Nutrient Manager*, leaf color chart	Training, workshops
WS	To reach a million farmers with IRRC technologies; to provide e-learning materials to NARES	Aerobic rice, alternate weting and drying	Training, workshops
CH	To strengthen NARES partners' capacity for diagnosis and advisory services in rice crop protection; to develop decision support tools for crop health through diagnostic activities	Diagnosis of diseases, with emphasis on epidemiology of sheath blight and rice brown spot, statistical methods and modeling	Training, workshops
CC	To develop methods and assist farmers in mitigating GHG emission	*Newly formed in the latter part of Phase IV*	*Identification and*

	and adaptation to climate change		*prioritization of researchable issues*
Integrated technologies	To increase rice productivity and profitability with NRM technologies by collaborating with NARES to work with farmers	Adaptive and participatory action research and extension, farmer field school approach	Training, workshops, facilitating farmer organization, farmer field school

harvesting, seed storage, and FBDs to improve grain quality in the rice value chain. In addition to training and on-farm demonstrations, the Work Group adopted the LA method to maintain multistakeholder learning processes between research and development agencies, as well as farmers, so that they can benefit from each other through sharing of knowledge and experiences. For instance, in the Philippines, the Work Group collaborates with the NARES, the private sector, NGOs (e.g., Catholic Relief Services [CRS]), rice millers, and farmer groups/organizations to develop business models associated with improving the rice value chain. The Work Group also conducts training workshops on participatory impact pathway analysis (PIPA) for postharvest projects in Cambodia, Vietnam, and the Philippines, in which PIPA participants can become members of an LA.

Productivity and Sustainability (PS). The Work Group, based on accumulated knowledge on nutrient management for intensive and sustainable rice production, has developed decision support tools for SSNM. This includes tools such as the LCC and the Internet-based *Nutrient Manager* software. In the Philippines, mobile applications of the *Nutrient Manager* was developed and evaluated already. In Indonesia, the Work Group strengthened the NARES partners by providing training to help promote the adoption of Web-based and mobile phone-based decision tools. Given that the LCC and *Nutrient Manager* are relatively new to farmers, direct training and on-farm demonstration may prove effective in the technology transfer. But note that in South and Southeast Sulawesi, farmers have become familiar with the LCC and are now able to make fertilizer application decisions based only on observations.

Water Saving (WS). The Work Group has helped strengthen NARES partners in many countries. In the Philippines, the Work Group has facilitated joint learning activities between various institutions that led to a viable research, extension, and education network that includes PhilRice, NIA, universities, and NGOs. This network facilitated the out-scaling of AR and AWD technologies. In Vietnam, the AWD approach has been incorporated as the water use practice in the 1M5R program in An Giang province, with extensive farmer training carried out by the provincial office of agriculture and rural development, as well as by regional rice research institutes.

Crop Health (CH). The Work Group was initiated in Phase IV and emphasized epidemiological studies of sheath blight and rice brown spot.

Climate Change (CC). The Work Group was initiated in 2011 in Phase IV of IRRC. Its studies will help provide evidence on the environmental impact of NRM technologies in irrigated rice ecosystems, especially the impact of the following: AR, AWD, and SSNM.

Integrated technologies. The CU, in cooperation with NARES partners, helps promote the out-scaling of integrated NRM technologies through training that covers development-oriented adaptive research, multistakeholder learning processes, and farmer empowerment through an FFS approach. In Indonesia, the CU, supported by a resident IRRI scientist based at South Sulawesi, worked together with (1) provincial BPTPs (Balai Pengkajian Teknologi Pertanian, also known as Assessment Institute for Agricultural Technologies (AIAT)) to develop pathways for the promotion of NRM technologies in selected villages, and (2) farmer groups to demonstrate NRM technologies within the national ICM-FFS framework. The curriculum for ICM-FFS was developed into a season-long intensive learning process at demonstration farms, which functioned as “lighthouses” for training of extension staff and other farmers. The impressive out-scaling of NRM technologies and farmer capacity building in South and Southeast Sulawesi are driven by a combination of factors, such as the placement of a resident scientist, the support of champions within the BPTP agency (i.e. they help develop good communication and trust-building with local farmers), and the identification of key farmer leaders. The skillfully designed modifications made to the national ICM-FFS curriculum (for dissemination of NRM technologies) allowed for a smoother learning process and provides greater impact in terms of human resource development. The CU, BPTP, district and subdistrict extension staff, and key farmer leaders of the lighthouse sites continually review and update their NRM curriculums so that it would be appropriate to their local conditions.

The work groups have established close working relations with NARES personnel, NGOs, the private sector, and farmer groups, especially the within-country "local champions" who are important supporters for scaling-out NRM principles and technologies. Capacity building organized and conducted by the IRRC work groups covers various forms of training, including lectures, workshops, and seminars.

The training conducted by IRRC have participants from NARES partners whose staff will become extension/farmer trainers, key farmer leaders, and even farmer groups. The CU also conducts training on the methods and tools for impact assessment studies (e.g., household survey development, stakeholder analysis) and how to work with farmers in a participatory, adaptive, and action-oriented research approach. The communications subunit affiliated with the CU facilitates the training in agricultural communications, such as production of in-country training materials and video production about IRRC technologies.

In terms of the number of trainings conducted, more than 400 training activities were conducted by IRRC (see Table 7.2). There was a twofold increase in the number of training activities conducted in Phase IV of the project as compared with the number in Phase III. This came about primarily because of the emphasis on out-scaling and farmer adoption in this phase. In Phase IV (2009–11), there were a total of 291 training activities with 20,782 participants. Most of the training covered nutrient management (PS Work Group) and water saving technologies (WS Work Group). But there were also training courses conducted for postharvest technology (PP Work Group), direct seeding, weed management, and community-based rodent management (LPCE Work Group).

7.2 Incorporation of NRM technologies into curriculum development

The Philippines is more proactive in terms of including IRRC technologies into their university curriculums. For instance, Dr. Junel Soriano, professor of agricultural engineering at the Bulacan Agricultural State College (BASC), has integrated topics on AR and AWD technologies in selected undergraduate and graduate course curriculums. In La Union province, Don Mariano Marcos Memorial State University (DMMMSU) students conduct field and laboratory activities using AR production systems to complete their course requirements. Dr. Soriano is also currently working with Dr. Marina Sabado, a professor of agriculture at DMMMSU, on a proposal (to be submitted to the university's academic council) that would officially integrate water-saving technologies into the school curriculum. BASC now has projects ineight other provinces to continue its research on water-saving technologies and has demonstrated the benefits to students and farmers as well. Isabela State University (ISU) has also developed its own program on AR technology, formulated a road map for the Cagayan Valley region, and has now implemented projects in Isabela and other parts of the region.

In Vietnam, there are at least three universities in the south that have a long association with IRRI and IRRC in terms of working toward sustainable intensification of rice production in the Mekong Delta. These are Cantho University and An Giang University, both of which are located in the Mekong Delta, and Nong Lam University, which is in Ho Chi Minh City. Dr. Vo Tung Xuan, who is a former vice-rector of Cantho University and the founder and a former rector of An Giang University, was the key person who introduced science-based rice research from IRRI and the rice-based farming systems approach into the agricultural curriculum of the two

Table 7.2. Training activities from 1997 to 2012, by work group.

Work Group	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	Total
LPCE									1	2	2	1	2	5	7	**20**
PP									7	6	5	7	16	15	15	**71**
PS									9	9	9	17	46	57	54	**201**
WS									9	8	14	19	12	17	20	**99**
CH													3	2	3	**8**
CU										6	6	5	7	5	5	**34**
Total									**26**	**31**	**36**	**49**	**86**	**101**	**104**	**433**

Sources: The IRRC Phases III and IV Annual Reports.

universities in the Mekong Delta. Dr. Xuan is also a former IRRI Board member and he has previously led the Food Security Program for the Mekong Delta. At present, An Giang University is an active research partner of the provincial DARD in terms of out-scaling IRRC technologies included in the 1M5R program. In the universities mentioned above, to fulfill requirements for the completion of the degree of Bachelor in Agriculture, students are required to conduct their project research with farmers. Students are also engaged in farmers' field days that have been organized by the local ARD office to demonstrate research results.

Professor Dr. Phan Hieu Hien, who conducted research at IRRI for his PhD degree in energy engineering from the University of the Philippines-Diliman, is an active collaborator with the PP Work Group. Dr. Phan and the team from the Faculty of Engineering and Technology at Nong Lam University, Ho Chi Minh City, helped develop and disseminate the FBDs in Vietnam, and they are currently promoting the laser land-leveling technology. It is anticipated that the knowledge and practical experiences they gathered from research in postharvest technologies will be included in the agricultural engineering academic curriculum, but there is no published course document yet. Dr. Phan and the teaching staff of the Faculty of Engineering and Technology are the key drivers in the development and dissemination of pre- and postharvest technologies that aim to improve rice productivity and quality in the Mekong Delta region.

IRRC scientific papers, books, and publications are made available to the public and are extensively used in universities in South and Southeast Asian countries. The IRRC have produced books that have covered the essential features needed for developing and disseminating technologies for sustainable intensification of rice production systems. Some examples include *Water management in irrigated rice, Increasing productivity of intensive rice systems through site-specific nutrient management, Pest management of rice farmers in Asia, Rodent outbreaks: ecology and impacts,* and *Improved postharvest technologies for reducing postharvest losses*. One research-to-impact workshop also generated a book that includes country case studies with discussions about strategies and approaches for out-scaling of the IRRC technologies in Asian countries. These outputs can be viewed as a "knowledge bank" that can be used as a basis for formulating courses on sustainable rice production systems for undergraduate and graduate programs in partner countries.

7.3 Graduate students and visiting scholars

The IRRI-IRRC further facilitates human resource development by offering students the opportunity to pursue graduate studies (MS or PhD) with research focusing on NRM principles and practices in Asia. Each work group often announces a selection of researchable issues for students to choose from. The research findings provide basic understanding of scientific principles with practical implications. The outcome is an accumulation of science-based knowledge about the management of sustainable rice production.

Table 7.3 highlights the number of students who completed their graduate studies in collaboration with IRRC scientists and staff. In Phase I, two graduate students worked under the PS Work Group and completed their Master's degrees in agronomy and soil science, respectively. There was no record of graduate students during Phase II. In Phase III, there were 23 students whose research focused on water-saving technologies – AWD and AR. The students were enrolled in different universities, such as the Chinese Agricultural University (14), Central Luzon State University (3), UPLB (3), Wageningen Agricultural University and Research Centers (2), and Universita Degli Studi di Firenze (1) (Italy). During Phase IV, students were better distributed over three IRRC work groups (LSCE, PP, WS) and the CU, where the latter was able to accommodate several graduate students focusing on the socioeconomic dimensions of diffusion and interns focusing on agricultural communications.

Table 7.3. Summary of graduate students, interns, and visiting scientists affiliated with the IRRC work groups during 1997–2011 (IRRC Annual reports, Phases I–IV).

Work Group	Phase I	Phase II	Phase III	Phase IV
Labor Productivity and Community Ecology (LPCE)				9
Postproduction (PP)				3
Productivity and Sustainability (PS)	2			-
Water Saving (WS)			23	4
Crop Health (CH)				
Coordination Unit (CU)				9

Information on the postgraduate activities of these former IRRC students after completion of their studies is not easily available. Typically, students affiliated with government agencies of IRRC partner countries (i.e., often under fellowship support) are required to return to their respective home institutions. For instance, Ms Nyo Me Htwe, a former PhD student affiliated with the IRRC CU who was working on rodent management strategies, has gone back to her native Myanmar to work in the Plant Protection Division of the Ministry of Agriculture and Irrigation after completion of her PhD at the Northern Arizona University.

7.4 Synthesis and lessons learned from the human development impacts

The IRRC provides a platform for adaptive research and out-scaling of transformative NRM technologies to Asian countries. One of its key success elements is providing opportunities for human resource development to citizens of partner countries in order to improve rice productivity and quality. These include training, workshops, seminars, internships, and advanced studies leading to graduate degrees (MS or PhD). It helps build the capacity of NARES partners to conduct adaptive research and facilitate multistakeholder learning processes. The subject matters cover a broad spectrum of topics, ranging from specific rice production technologies to facilitating learning approaches, socioeconomic aspects of adoption and impact assessment, and business models. The outcomes of and experiences from IRRC research initiatives have already been included in the university agricultural curriculum. Key publications of the work groups have formed the basis for developing curricular topics about the management of sustainable and intensive rice production systems. The beneficiaries of IRRC's human development efforts have included NARES personnel, farmers, NGOs, the private sector, and students.

8. Impact pathway analysis

8.1 Introduction

Impact pathway analysis is a tool that can help identify the ways in which IRRC technologies have been disseminated and adopted in specific countries and across the program as a whole.

Impact pathway analysis in the context of research has been widely discussed (Walker et al. 2008, Douthwaite et al. 2008). It links to broader discussions on 'theory of change' approaches (White and Phillips 2012). The approach followed here is to identify the actual outputs, outcomes, and impacts of the program, both anticipated and unanticipated, and then construct a diagram showing the significant relationships, mechanisms, and channels through which the technologies have been disseminated and adopted and with what results. It also allows, in so far as information is available from the documentation and interviews with researchers, country partners, and farmers, the examination of the factors that have influenced these outcomes at different levels for example, the specific partnerships and networks created within and across countries and their role in initiating new directions, encouraging joint learning, and disseminating research findings. While the analysis is initially done at the country level, an effort has been made to assess the effectiveness of cross-country learning for technology development and dissemination.

Impact pathways are not linear but follow multiple channels over different time scales. The technologies validated and promoted by IRRC partly derive from investments in previous research work, and their implementation in some cases has been supported by funds from different sources. Attribution becomes more challenging in the further stages of the impact pathway, with the increase in the number and complexity of dissemination channels, organizations, and stakeholder groups. Consideration is given to alternative explanations or pathways to the identified outcomes.

8.2 Data sources

The main documents used to compile the impact pathway analysis are the reports and papers from the respective work groups as well as the IRRC annual reports and end of phase reviews.

In addition to this material, interviews were held with IRRC stakeholders in Bangladesh, Vietnam, Indonesia and the Philippines (see Appendix 3b for list of questions). These meetings were an important opportunity to explore the outcomes and impacts of the program from the perspective of the participants and target groups. As far as possible, there was an effort to go beyond description to assess the causal relationships underlying the perceived changes. While interviews in the field were limited in number, they allowed comparison of actual examples of implementation and outcomes with the theoretical impact pathway. These data provide an important complement to that available in reports and publications.

Discussions of outcomes and impacts were conducted at different levels (see Appendix 3 for the list of field visits conducted, as well as the standard list of questions asked to various respondents). These included IRRC partners at the *policy level*, examining changes in policy and implementation strategy relating to the main technology/work group areas over the course of the program and the factors or influences that brought about these changes. It included a discussion of how collaboration with IRRI/IRRC may have influenced policy or whether such policy change would have happened anyway.

Institutional influences were also explored with national researchers and managers – whether IRRC collaborative research processes had influenced the structure and interrelationships of local agricultural institutions, the research and extension agenda and resource allocation, and the extent to which stakeholder linkages, information exchange, and learning and capacity building has occurred across the public and private sectors.

At the *field level*, interviews with national researchers, extensionists, and participating NGO staff and private sector stakeholders were important in building a picture of the outcomes from the work of IRRC. These attempted to understand the broader context of technology change in rice management practices over the last 15 years and then explored the part played by IRRC within this, particularly the extent to which it facilitated local organizations to engage in technology testing and dissemination.

Meetings were held at the *farmer level* and, where possible, interviewing men and women. There were some opportunities for observations in the field, although these were limited by time. Discussions traced the main elements of rice technology change, the channels through which they were developed, the stakeholders involved, and how technologies were shared and promoted. There was discussion of adoption, local adaptation or rejection, and the factors that had encouraged or limited the impact of the technologies. The outcomes and impacts arising from applying the new technologies and practices were explored—e.g., changes to livelihoods, income, food security, resources, health and well-being, and access to information. There was discussion of which social groups benefited, for example, landless versus smallholders; men and women, as well as any negative impacts. Community-level impacts in terms of social cohesion, social conflict, joint action, etc. were also discussed.

8.3 Impact pathways of major IRRC technologies

The impact pathways of the main IRCC technology areas are presented below (by work group), compiled from the available documentation and field visit discussions. In some cases, there were already existing impact pathways identified. These were reviewed, adapted, and incorporated.

8.3.1 Labor Productivity and Community Ecology (LPCE) Work Group

8.3.1.1 Direct-seeded rice (DSR)

The impact pathways for DSR and short-duration varieties, combined with effective weed management, are shown in Figures 8.1.a and 8.1.b, for Bangladesh and India, respectively. The outputs largely led to the anticipated outcomes and impacts and, in the case of Bangladesh, a range of unanticipated social impacts were experienced as a result of addressing the food security challenges faced in the *monga* period.

In both cases, the time frame of technology development is shown, moving from early phase on-station research through on-farm trials to wider scale dissemination. However, it appears that institutional innovation is needed for these technologies to be actively promoted at scale. For Bangladesh, the IRRI project, Poverty Elimination Through Rice Research Assistance (PETRRA) and the creation of the Northwest Area Focal Forum were important for establishing a clear focus on technology delivery and interaction with farmers, which was then continued in subsequent phases of work, particularly from 2007 onwards. The Northwest Focal Forum was an extension-policy network for facilitation and coordination of rice development.

The processes of technology dissemination have been greatly assisted by the cooperation of different stakeholders, taking the technology from research station and on-farm trials, through to FFS and capacity building for local service providers and community-based organizations, and developing sustainable systems supported by the market. The implementation of actions at different levels, from local to district to national, has been particularly effective.

Important roles were played by international and local NGOs in community mobilization, seed distribution, and training (Harun-Or-Rashid-Lal et al. 2010), by the research organizations in providing technical support and training, the private sector in seed supply, the farmers organizations in developing capacity of farmers' groups, and the media in sharing information more widely. The broader facilitating role of the Northwest Area Focal Forum also had an influence on the emergence of national-level programs, such as the Government of Bangladesh's National Program for *Monga* Mitigation – which aims to promote *monga* mitigation using SDVs, DSR, and investment in post-rice crops. The role of IRRC and in particular the IRRC resource person was important in adding new impetus to the multistakeholder grouping.

While the channels of dissemination are clear and the types of outcomes and impacts identified, it is more difficult to assess the actual *scale* of impacts in terms of total numbers of farmers adopting the technologies (see Section 3.1.6 and Section 3.2.2.2 for more discussion on the availability of adoption numbers). Some conditions for sustainable uptake emerge – the need for supply systems for seed and herbicide, access to drum seeders and lithao, and agreements between tenant sharecroppers and landowners. The gender impacts are likely to relate to the specific roles of women in farming in different regions, in particular, the effects of reduced demand for weeding labor on the poorest women.

In India, the main proponents of technology development and uptake were the agricultural universities and NGOs. Similar processes of on-farm trials, demonstrations, farmer field days, and training and capacity-building were used to disseminate the technologies. An exchange learning visit to Bangladesh was used to good effect. The approach to working with farmers in a more participatory way was a positive influence on scientists in research institutes who had not previously worked this way.

For farmers, the impact pathway from use of DSR and SDV leads more simply to higher net incomes through reduced labor costs and the opportunity to grow an additional crop following the earlier harvest (Singh et al. 2008). Participatory evaluation of on-farm trials identified labor savings as the most important advantage. However, the choice of variety and planting method is influenced by the conditions in a specific season. The different methods available may help farmers respond to variability in the onset of the monsoon with different strategies and options.

Again, there is little information available on the actual scale of uptake. There are some indications that larger and less risk-averse farmers

Fig. 8.1.a. Impact pathway: direct-seeded rice and short-duration varieties – Bangladesh.

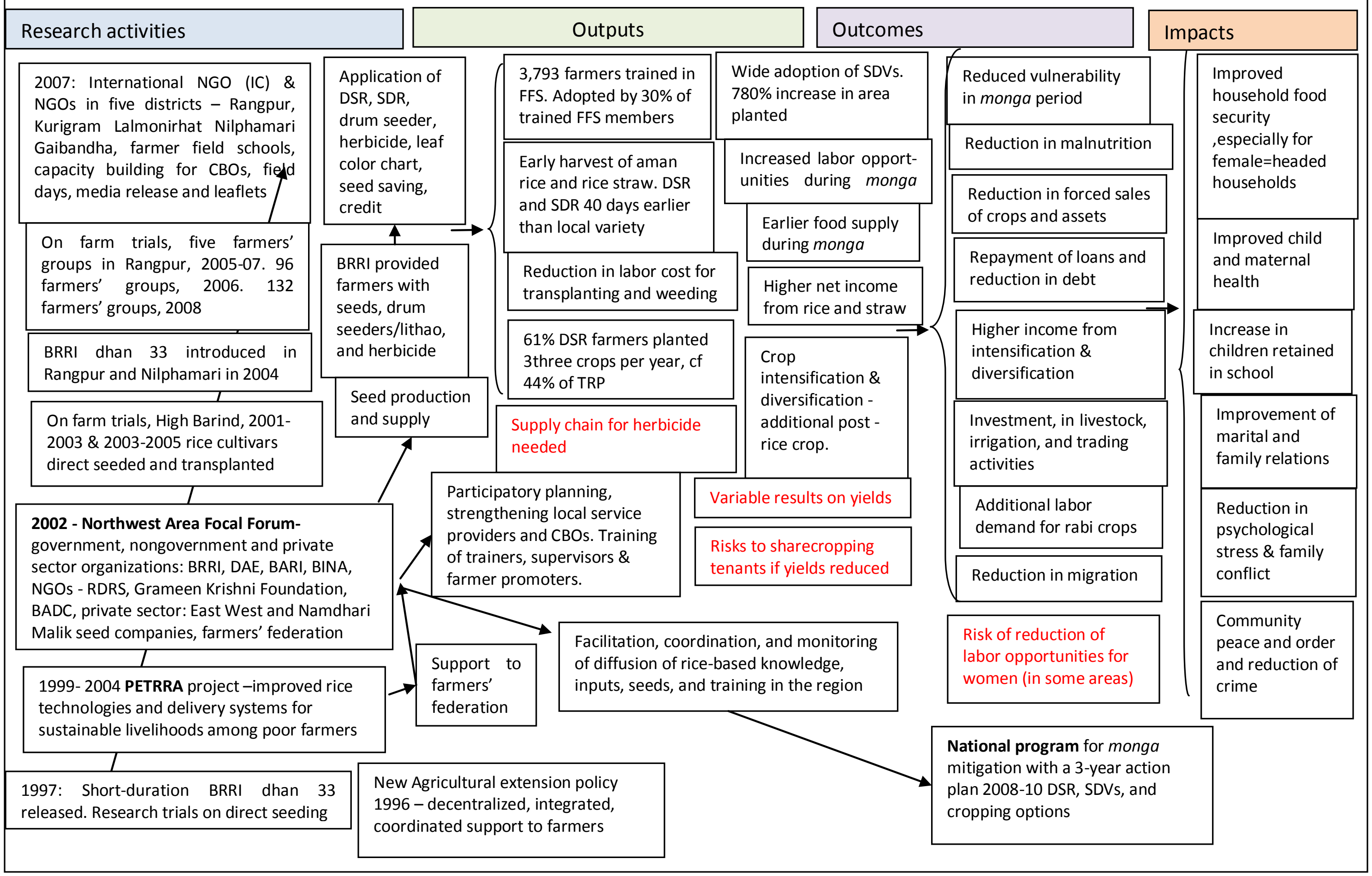
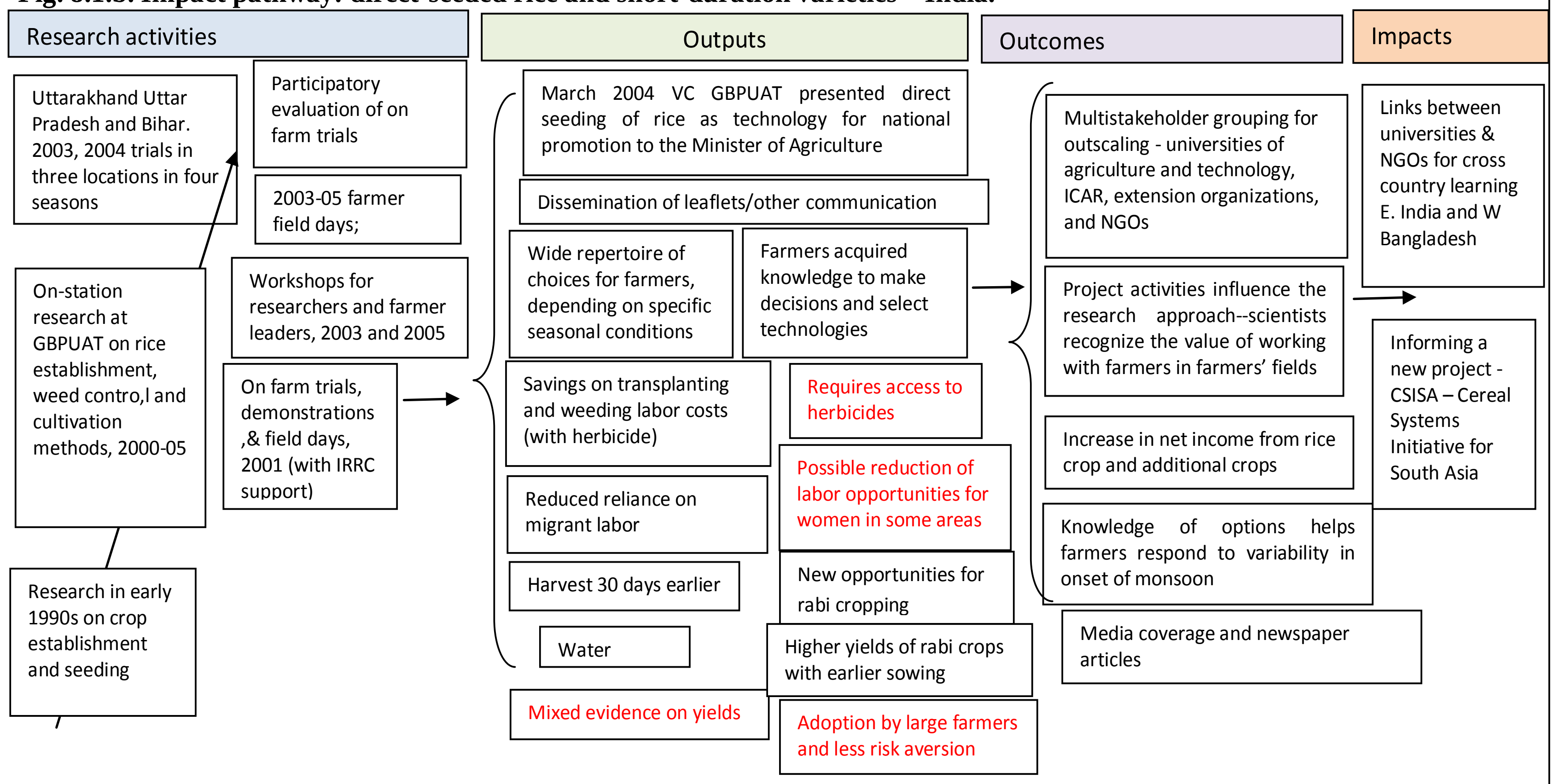


Fig. 8.1.b. Impact pathway: direct-seeded rice and short-duration varieties – India.



are more likely to adopt the technology. The media were important for up-scaling in India leaflets and information materials were produced and press coverage was substantial (40 newspaper articles between 2003 and 2005).

As in Bangladesh, there were efforts to influence the more strategic policy levels and out-scaling. DSR was presented as a technology for promotion to the Minister of Agriculture and a multistakeholder grouping was formed, involving research, extension organizations, and NGOs in addition to the universities, to encourage out-scaling. The grouping was important in exploring opportunities for cross-country learning and exchange with eastern India and western Bangladesh.

A similar program was introduced in Sri Lanka, 2005–07 in collaboration with the Rice Research and Development Institute (Abeysekera et al. 2010), including on-farm testing of DSR, demonstration plots, and training of trainers and farmers on DSR and integrated weed management. Training manuals, videos, and leaflets were developed to expand outreach and training was conducted for senior extension managers.

The experiences gained from the different phases of this work informed the new project, Cereal Systems Initiative for South Asia (CSISA).

8.3.1.2 Ecologically based rodent management (EBRM)

The approach to development and promotion of EBRM evolved from an emphasis on the trap-based system to the active facilitation of community action for rodent control, with use of the CTBS only when losses for a particular cropping season are expected to be greater than 10%. Impact pathway diagrams are shown for EBRM in Vietnam, the Philippines, Indonesia, Lao PDR, and Cambodia (see Figures 8.2a to 8.2d).[11]

The lessons learned on the approaches leading to the most effective dissemination are:

- A combination of capacity building, training for extension, and local leaders and farmers with *mobilization of community action* was effective in changing practices. Demonstrations alone were not necessarily effective. The early work on the TBS demonstrated technical effectiveness, but there was limited uptake. Capacity-building has to be broad-based. In Cambodia, capacity-building of extension was affected by high staff turnover.
- The use of different types of *mass media* provided a useful vehicle for awareness creation and technology promotion as exemplified in Indonesia, Vietnam, and the Philippines. Studies in Indonesia found that personal interaction in learning about rodent control is more effective than receiving messages alone. Successful campaigns were supported by training and capacity-building of extension officers, village leaders, and local 'champions.'
- Differences in social and institutional history and strength of *social capital and community cohesion* influenced the extent to which communities engaged in joint actions for rodent control, as well as the sustainability of such actions. The social and political environment in Vietnam, particularly in the north, was conducive to community-coordinated action. Indonesia and Philippines had some success with the approach, while in Lao PDR and Cambodia, there was less community engagement and more of an individual response.
- *Levels of government support and channels for policy influence* varied across countries and influenced the uptake pathways. Vietnam made an early policy change in support of integrated and group-based rodent control

[11] As noted in footnote 9, the EBRM work in Cambodia was not directly led by IRRC, but it is a "spillover" effect of the IRRC research and dissemination efforts conducted in other countries. The evidence and studies in Lao PDR had input from IRRI/IRRC but this was very limited and the EBRM studies in this country only pertain to the upland production situation. Moreover, it is important to note that the CTBS is only one component of EBRM, and this is only recommended if expected rodent losses are greater than 10%.

Fig. 8.2.a. Impact pathway: EBRM – Vietnam.

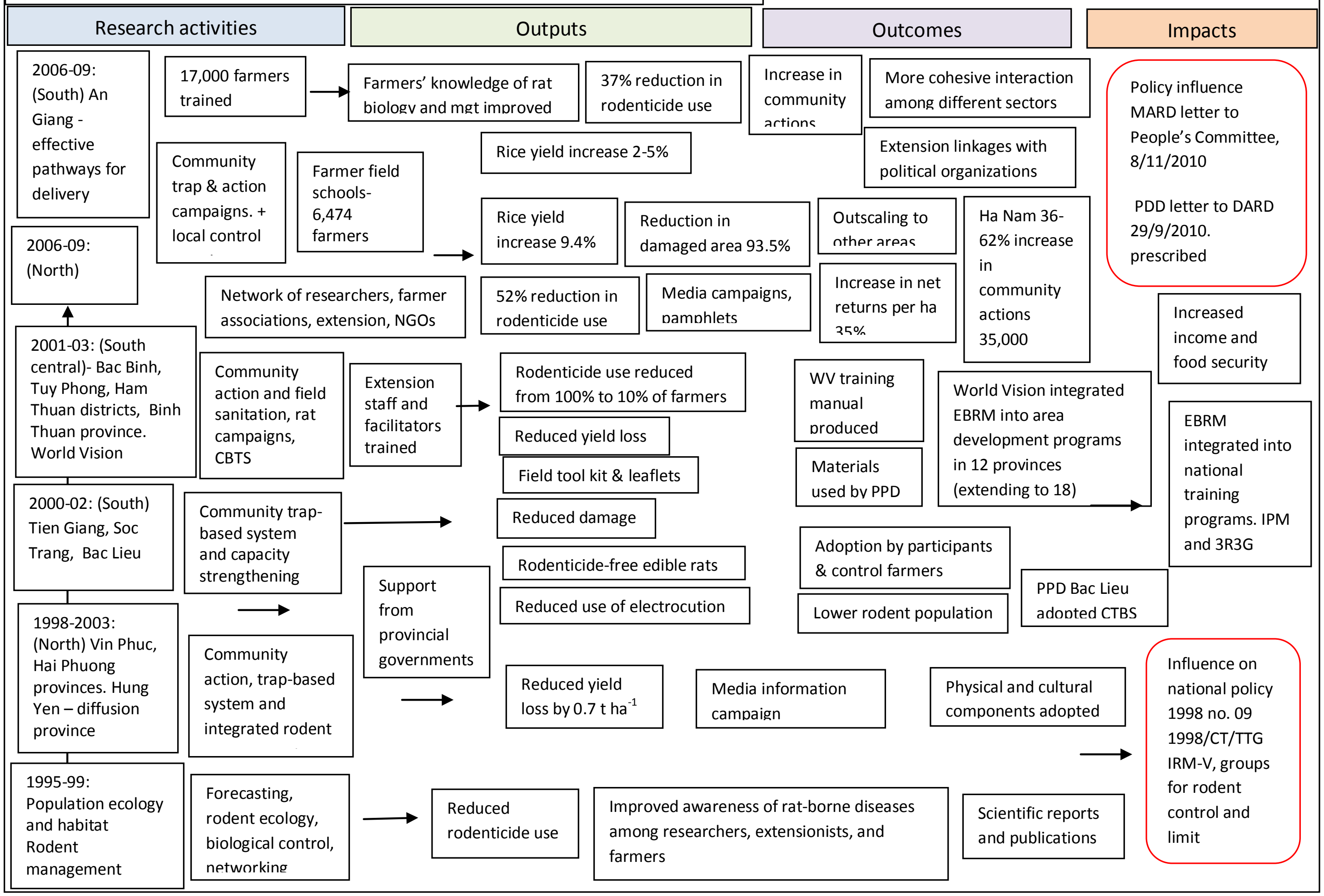


Fig. 8.2.b. Impact pathway: EBRM – Philippines.

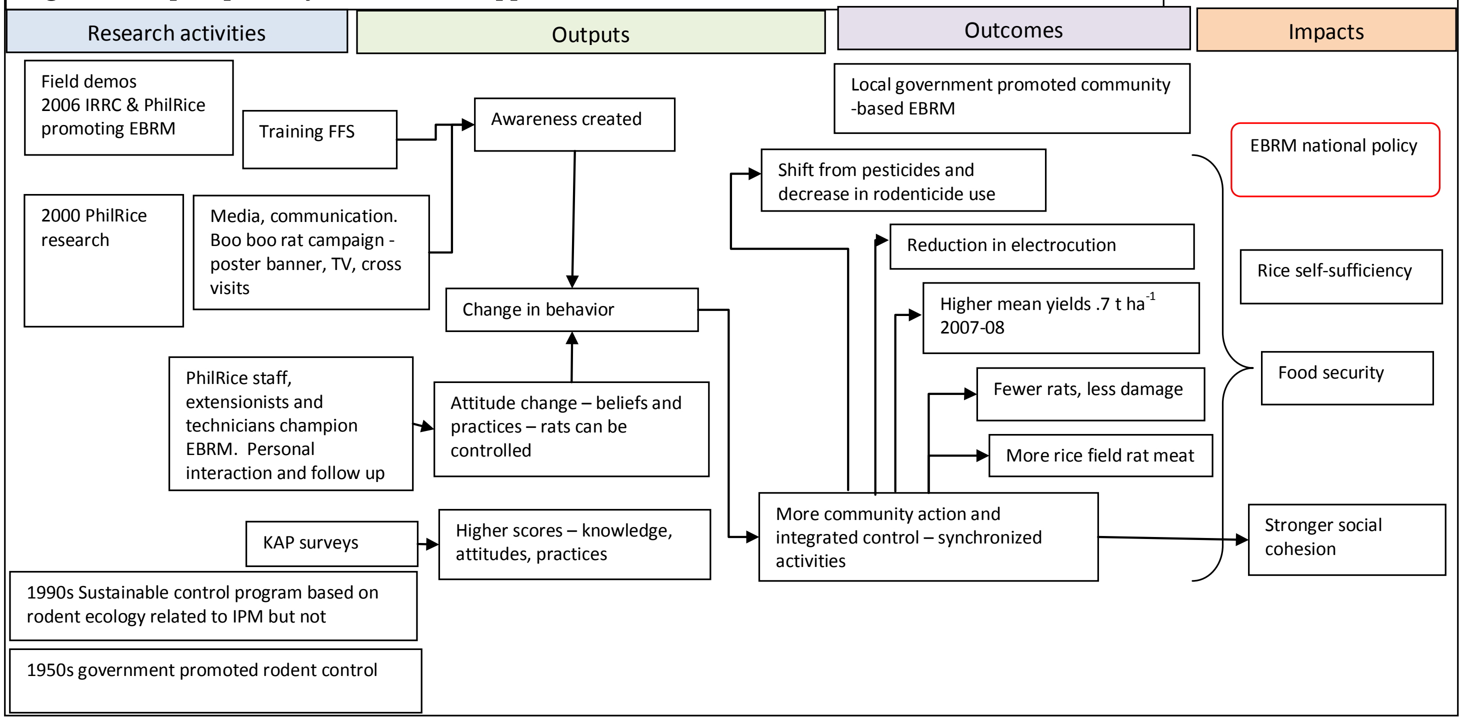


Fig. 8.2.c. Impact pathway: EBRM – Indonesia.

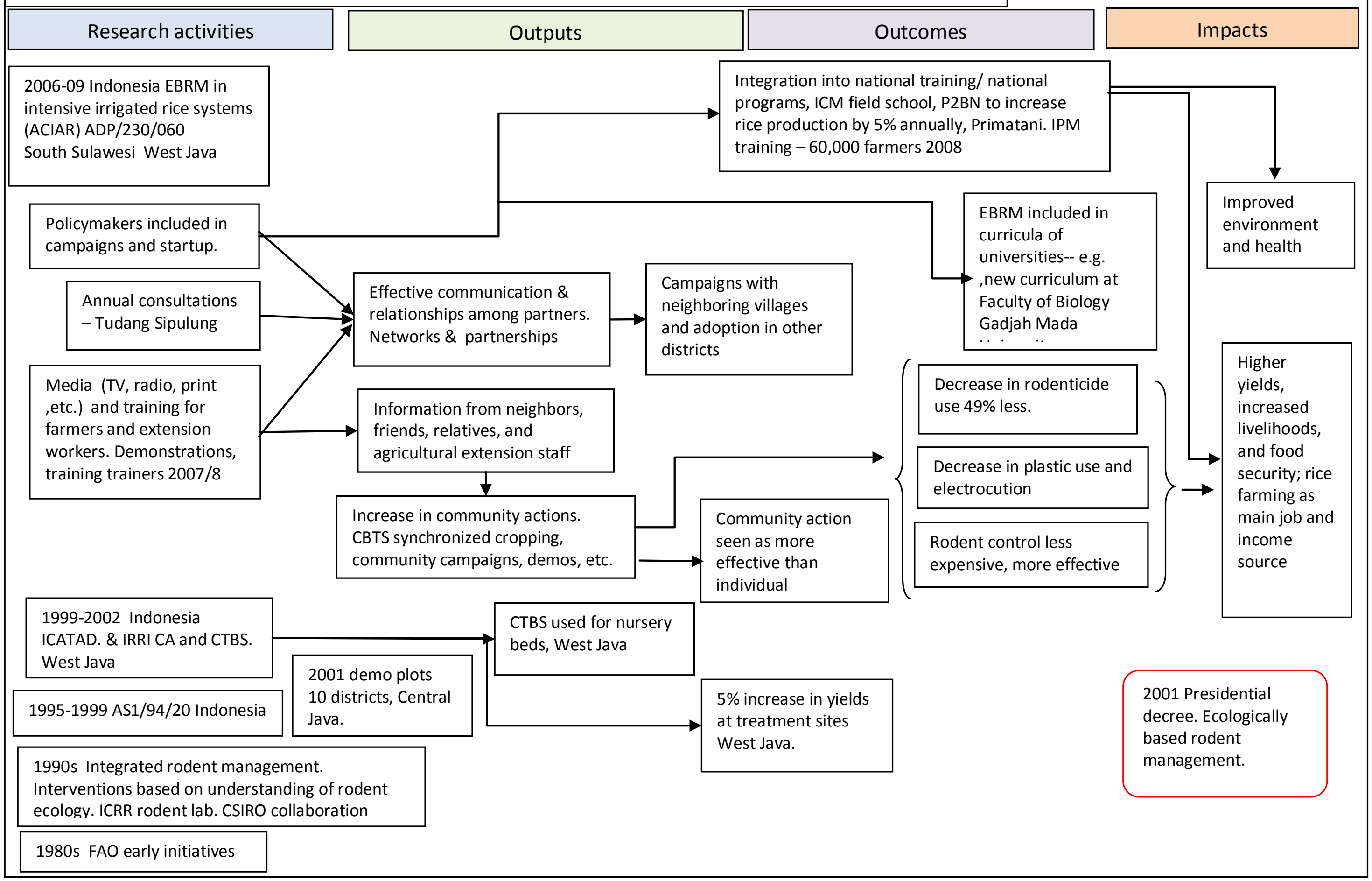


Fig. 8.2.d. Impact pathway: EBRM - Lao PDR.

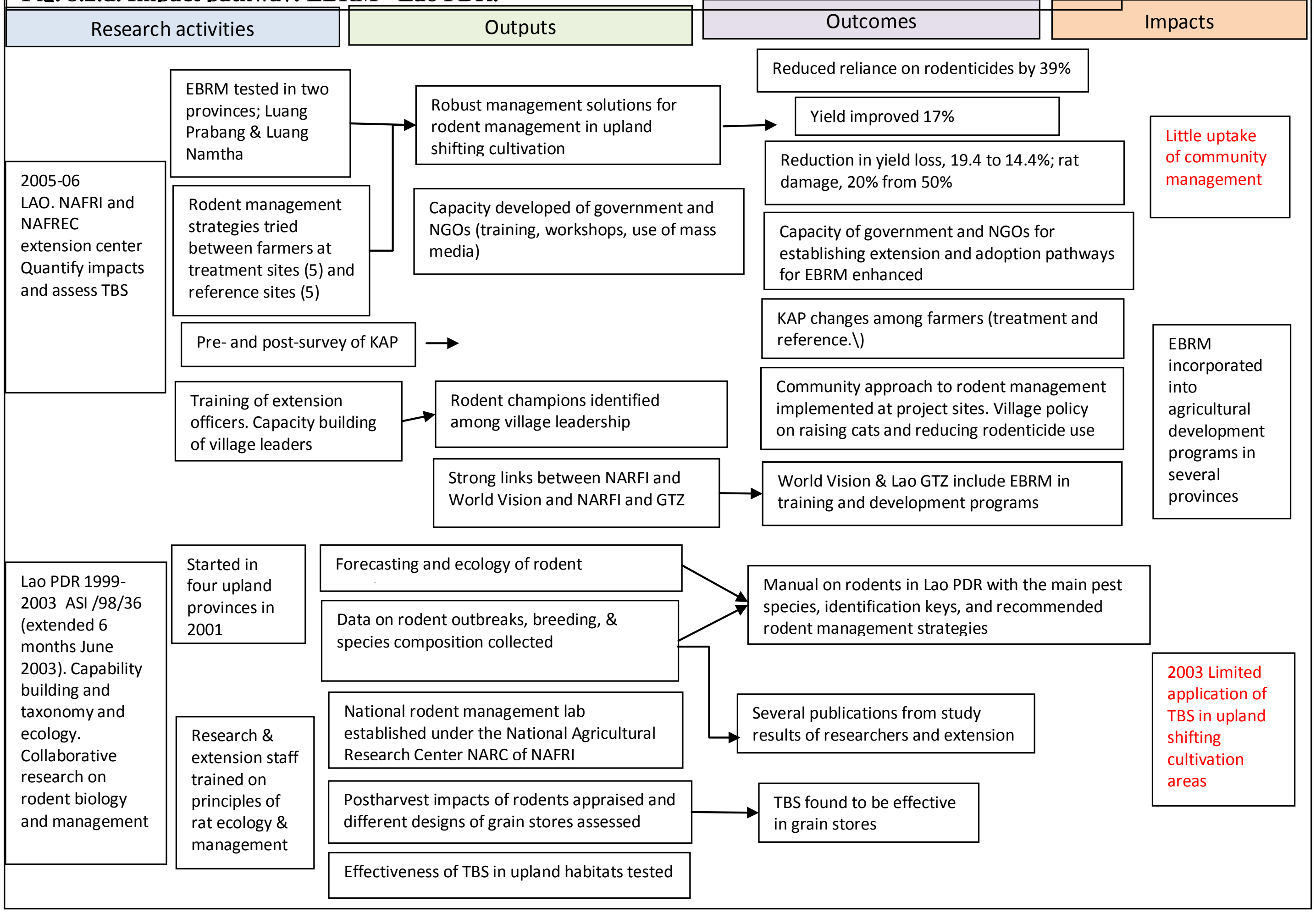
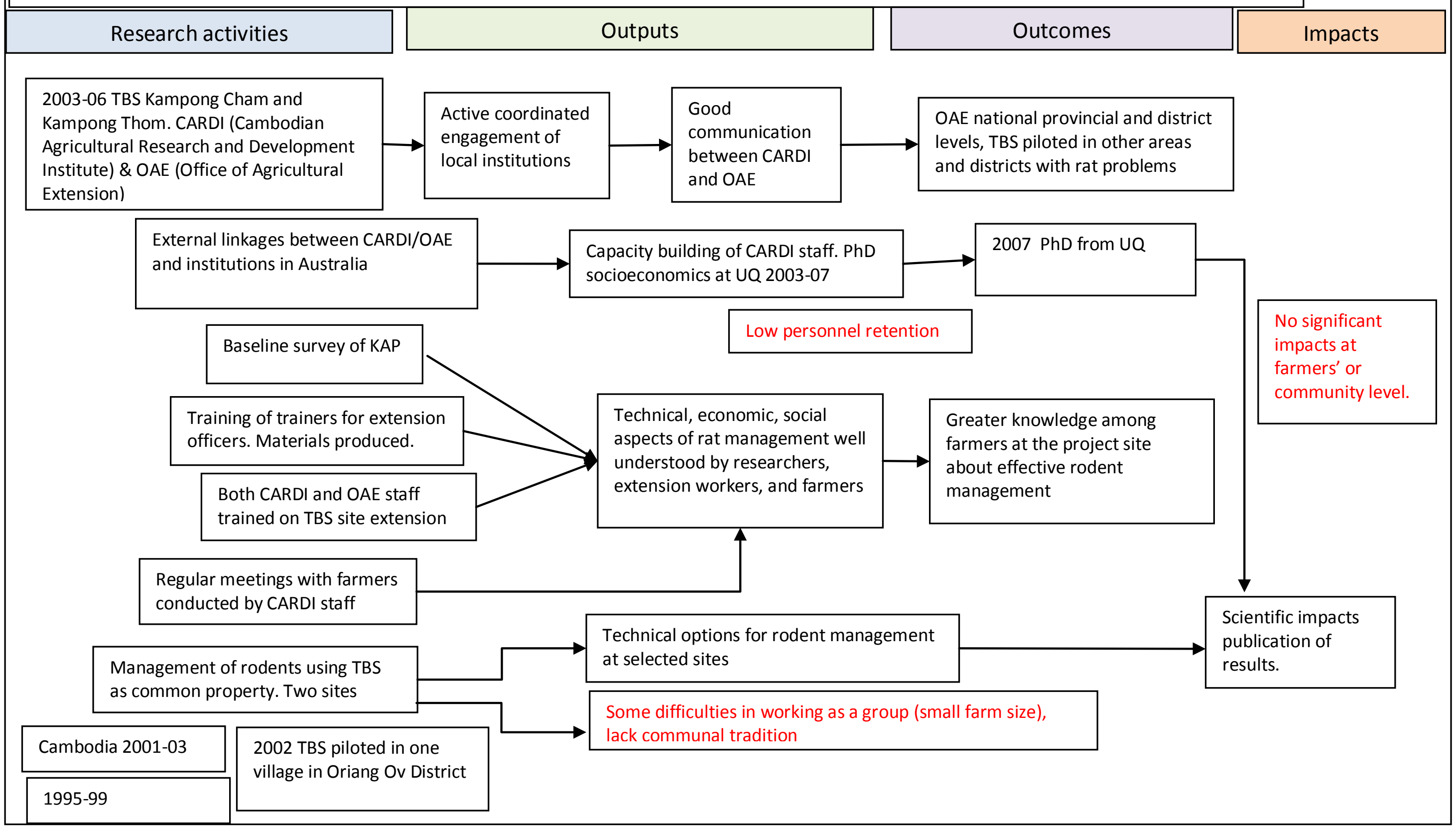


Fig. 8.2.e. Impact pathway: EBRM – Cambodia.



and was later followed-up. The Philippines and Indonesia benefited from the involvement of policymakers in start-up activities and in publicity campaigns. Support at this level encouraged the integration of EBRM into national training programs and FFS. At the local government level, support from local authorities, both administrative and political, can speed up dissemination.

- In the more successful cases, a *strong network of actors* has emerged including research institutes, farmers' associations, extensionists, NGOs' and local and provincial government. In Indonesia and Vietnam, such networks were important in the dissemination of knowledge to other districts and in engaging with local opinion leaders (Tuan et al. 2010). In Vietnam and Lao PDR, a major channel of dissemination and support to uptake was through the NGO World Vision and their area development programs.
- A consistent finding was that *sustainability* of the CTBS was likely to require some form of financial support. Farmers considered it expensive, despite it enabling control over a wide radius from the actual plot. Where there were relatively low levels of damage, the principles of EBRM were adopted with reduction in rodenticide use, electrocution, plastic fences, etc. but not necessarily the community trap. However, traps were used for nursery beds in Indonesia and grain stores in Lao PDR.
- Adoption was facilitated where strategies were based on understanding of *local control* practices and, where possible, their incorporation. The control strategies are knowledge-intensive, and indigenous knowledge, practices, and belief systems relating to rodents are important to recognize.
- EBRM was developed from a *sound scientific basis* in rodent ecology. In some countries, such as the Philippines and Laos, this started in the early 1990s, but the impetus provided by IRRC led to more active field-based promotion of the approaches in collaboration with research, extension, NGOs, and other stakeholders. The approach has also been integrated in the curriculums of some universities and has been included in scientific publications.

EBRM has been incorporated into ICM advice and formulation of best practices for NRM for rice production, e.g., the 3R3G in Vietnam.

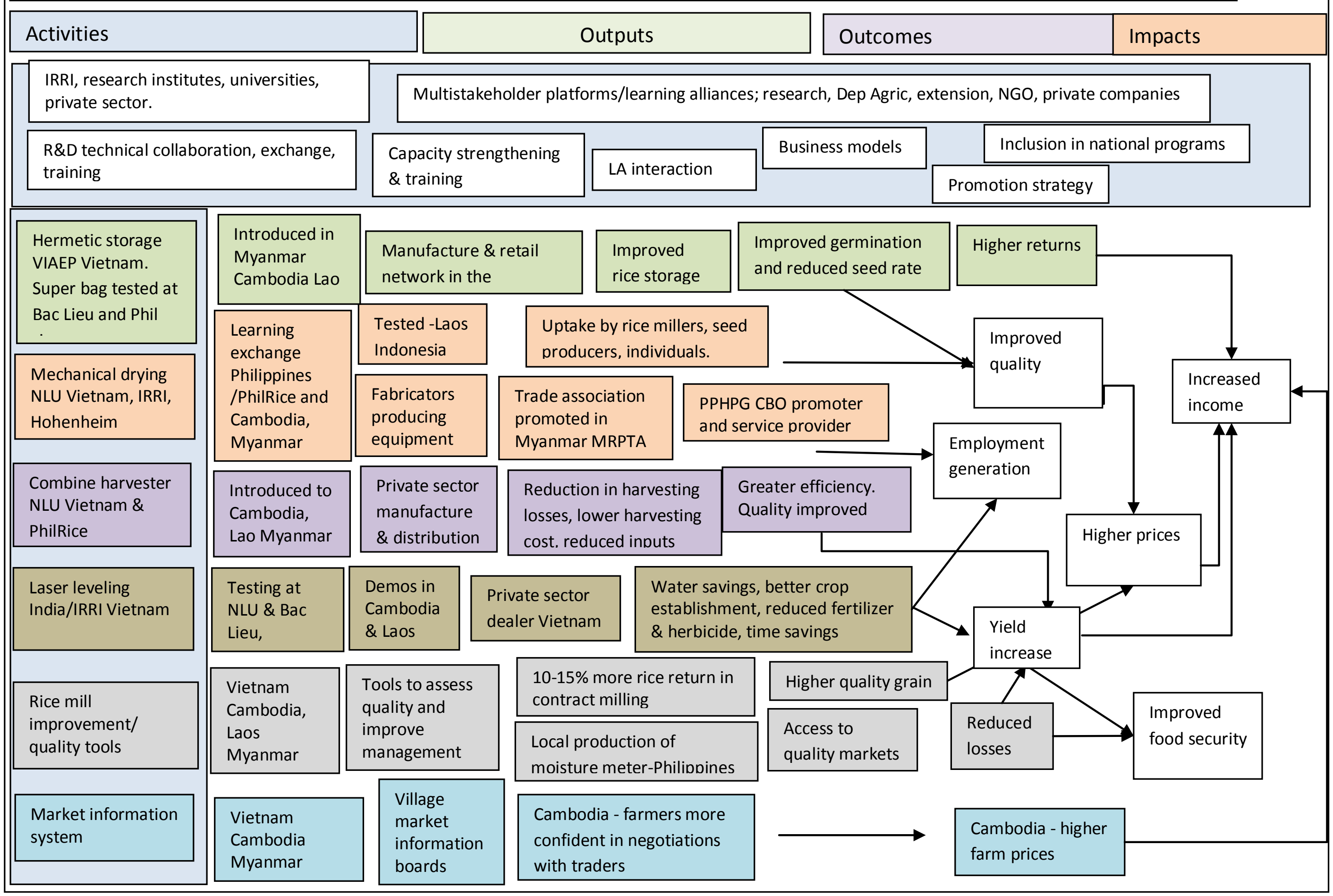
8.3.2 Post Production (PP) Work Group

IRRC supported the development and promotion of PP technologies through partnerships in Vietnam, Cambodia, and the Philippines and it stimulated sharing and dissemination with Myanmar, Lao PDR, and Indonesia. These involved government research and extension agencies, NGOs, and the private sector.

Some interesting features of the promotion of PP technologies have been a) the participatory impact pathway analysis at the outset, which guided strategies for promotion and uptake; b) the technical collaboration and exchange, including cross-country approaches; c) the formation of LAs or multistakeholder groupings to share, adapt, and promote good postharvest practices and technologies, build capacity, and inform public and private-sector policy decisions; d) business model development to ensure appropriate investment and sustainable operation; and e) multiple channels of extension, using both public and private pathways.

Impact pathways for the PP technologies are analyzed by country, taking into account cross-country linkages and exchanges. For each country and technology area, partnerships, platforms and LAs, distribution, and extension services are considered (see Figure 8.3). A limitation on this analysis is the need for further understanding of how the pathways relate to the scale and extent of impact on smallholder farmers or consumers because there is little quantification of the numbers of end users or analysis of their socioeconomic profiles.

Fig. 8.3. Impact pathway: Post-production technologies – multicountry.



8.3.2.1 Vietnam

Vietnam has seen major advances in the development of PP rice technologies, largely due to the active participation of research institutes and universities, manufacturers and distributors of equipment, together with an effective national extension system and assistance from government policy which encouraged development of postharvest services.

The early phases of technology development for *mechanical drying* were conducted by NLU in collaboration with IRRI in the 1980s and the University of Hohenheim in the 1990s. Further technical improvements in the FBD and furnace were made in the following decade. From 2006, IRRC, in partnership with NLU and as part of an ADB project, made efforts to scale out the technology to other countries, working with national partners and private-sector stakeholders. Exchange of expertise with PhilRice in the Philippines led to the development and piloting of further technical innovations, with the support of investors in the industry. Business models were also developed. Following training, dryers were installed in Cambodia, Lao PDR, Myanmar and Indonesia, in addition to Vietnam. The main buyers of this technology were rice millers and seed producers and some village-based individuals providing contract drying services.

The development of the *combine harvester* (CH) in Vietnam and the region was similarly through a partnership approach. From 2004, NLU collaborated with private-sector manufacturers and PhilRice on the development of a mini CH. The combine was promoted in Vietnam from 2006, assisted by publicity from an annual combine contest. It was also piloted in Laos and Cambodia and some units were exported to Malaysia, Myanmar, and the African continent. Local manufacturing took off, and business models were developed for contract services. Combine harvesting is included among the recommendations in the 1M5R program in Vietnam.

The Vietnamese Institute of Agriculture Engineering and Postharvest Technology (VIAEP) was a partner in the piloting of improved *storage options* in the form of hermetically sealed 50-kg super bags and 5-t cubes. The Bac Lieu Seed Center was involved in testing; however, there was a challenge in moving from R&D to wider production and dissemination through the private sector.

Laser leveling is a technology that has been widely adopted in India and there has been some success in efforts to transfer this technology to Vietnam. In 2003, two laser leveling kits were provided by IRRI to Bac Lieu Seed Center and to NLU for local testing. Staff were trained in the operation and adaptive research was conducted. In 2009, NLU acted as an intermediary between a manufacturer in the USA and a local private-sector dealer (i.e., IdealFarm, a private company, became the local distributor for the Greater Mekong Subregion). MARD encouraged the promotion of laser leveling and, in 2012, training was conducted for staff from research institutes and universities and extension personnel from 40 provinces. Short courses were held for 1,000 farmers and service providers throughout the country. The first private purchase of a laser leveler was in 2012. This example shows the transition from public-sector research, development, and demonstration to private-sector distribution and promotion, supported by extension service providers. Further dissemination of information was through the media, particularly local televisions.

There was limited information on the impact pathways for *rice milling improvement or market information* initiatives in Vietnam. The market board appeared to be less relevant than the use of radio at appropriate times or Internet-based market information services to disseminate market price data.

The postharvest LA in Vietnam was an active network involving the NLU, research institutes, extension services, manufacturers, and distributors engaged through adaptive research, demonstration, and training events and the operation of effective business models. Postharvest technologies were consolidated in a textbook and manual for 1M5R.

8.3.2.2 Philippines

The multistakeholder LA in the Philippines has been particularly dynamic, holding a number of national and regional meetings and workshops in 2011 and 2012. Partners in the LA included PhilRice, regional units of the Department of Agriculture, regional and local governments, NGOs such as Catholic Relief Services (which was working with 12,000 farmers), the NGO partners, and private sector companies such as Grain Pro.

The promotion pathways for the *reversible dryer* and *hermetic storage* were initially through the nine PhilRice stations and through them to the LA and to end-users. Adaptive research trials on hermetic storage were conducted at three pilot sites. Super bags were made available to small-scale farmers through a retail network. IRRC and the LA worked with Grain Pro to develop and market the super bag. Arrangements were made for local production of the low-cost moisture tester, and a local electronics firm began initial production in 2012.

Development of the dryer technology in Philippines benefited from collaboration and exchanges with Vietnam from 2006. Following a Memorandum of Understanding with NLU in December 2008, expertise was provided for the construction of reversible dryers at PhilRice central and regional stations. Funds for further installations at PhilRice stations were provided by the Department of Agriculture between 2009 and 2011. A reversible dryer was installed and tested in May 2012. These locations and the LA meetings provided the platform to evaluate dryers in a business context with end users, supported by PhilRice, IRRI, and CRS.

A strong emphasis was put on capacity-building in postharvest technologies briefings were given to regional NGO partners, and training was provided on rice seed storage management. The reversible dryer was provided to seed growers and extension workers and farmers, co-funded by the regional branches of the Department of Agriculture. Training was also provided to regional DA engineers, PhilRice staff, IRRI ADB project staff (i.e., on the operation and maintenance of the 6-t dryer), which was co-funded by PhilRice, Kubota Corporation, and Department of Agriculture, in collaboration with the WS Work Group. CRS provided support for business model development. A sound communication strategy supported these efforts. Partners were trained in message design and materials in 2010, and video and information materials were produced. Information on the technologies was linked to national agriculture sector programs such as the FSSSP.

The Philippine experience is an example of effective co-funding within a dynamic LA. The roles of PhilRice and CRS in championing the technology were very important.

8.3.2.3 Cambodia

The Cambodia Post Harvest Learning Alliance (PHLA) was a multistakeholder platform supported by a range of actors including the Ministry of Agriculture, universities, key farmers, private sector players, and IRRI/IRRC.

Starting in 2006, *flatbed dryers* were introduced from Vietnam and training was provided in Vietnam. IRRC and the Cambodian PHLA supported development, local manufacture, and promotion of FBDs. A 4-t demonstration unit was established at the village-level in Battambang in 2007. In-country training for stakeholders and users was arranged in 2009, and wider uptake by manufacturers was encouraged. IRRI/IRRC provided support for the testing of a recirculating dryer in 2011 and a rice husk furnace in 2012. Information materials handbooks, manuals, posters, business plans and models were produced and distributed. Business models were developed in 2010 and links were made to financing institutions to encourage private investment in the technology.

The uptake of drying technology was on the basis of a private contract service model providing drying services for farmers, seed producers, millers, traders, wholesalers, exporters, etc. The PHLA provided technical backstopping and training support and was the platform for sharing experience and learning. Although the original IRRC business model was to introduce FBDs at the village or farmer cooperative level, most of the uptake has been by larger scale private enterprises. A similar process was followed for *combine harvesters,* which were developed in Vietnam and transferred to Cambodia in 2007. IRRI/IRRC, together with the PHLA, supported training and field demonstrations, as well helped finance and import the first demo unit from Vietnam. There was rapid expansion, with about 2000 combines in use by 2012, operated by as contract service providers.

Hermetic storage (using 50-kg super bags and 5-t cubes) was introduced and assessed with positive results. However, is it unclear whether the farmers' expressed 'willingness to pay' translated into effective market demand, or whether there is a local distributor of the super bags with a functioning supply system. Training for *milling improvement* and the use of moisture meters and weighing scales were promoted and *market information boards* were introduced. Surveys found that, where these were introduced, farmers were able to get a higher price, but information on their actual use and sustainability was sparse. Training materials and a postharvest textbook were produced.

The CPHLA was important in awareness creation, advocacy, capacity building, demonstrations, and stimulating private sector investment. Postharvest interventions were highly compatible with (and likely helped shape) the Cambodian government's rice export policy. The challenge appears to be the dissemination and extension of postharvest technologies at the smallholder level.

8.3.2.4 Myanmar

The multistakeholder approach in Myanmar operated in the context of the IRRC-supported outreach program, which started in 2005 following earlier collaboration with IRRI. Four work groups were formed, which aligned with those of the IRRC. The Myanmar Agricultural Service (MAS) was the lead agency. Baseline surveys were conducted in 2006. Emphasis was also put on building the capacity of extension personnel, building partnerships with research agencies and the private sector, and the briefing of high government officials. An important innovation was the use of two sites by *all* the work groups as a platform for integration of NRM technologies and farmer, and multistakeholder participation.

Introduction of *mechanical drying* in Myanmar was also linked to the earlier developments at NLU in Vietnam. Myanmar participants attended drying system and dryer fabrication training in Vietnam in October 2005 and NLU assisted with the transfer of fabrication technology to Myanmar. Promotional and training activities were conducted through the Myanmar Rice and Paddy Traders Association (MRPTA) in collaboration with other partners in the PP Work Group. Training and capacity building were provided for MAS extension staff. By September 2008, 47 dryers were installed and, by 2012, more than 300 dryers were installed with support from the Pioneer Post Harvest Development Group (PPHDG), a civil society organization and multistakeholder platform. The PPHDG took on promotion from 2008 and became an established service provider for mechanized dryers, encouraging sustainable development of dryers through self-financing and self-reliance.

Networking and exchange were crucial for providing service to users at different levels and locations. International partnership was essential for research knowledge to be successfully adopted by end users, such as the Myanmar rice miller association and the Myanmar rice producer association. Linkages with business entrepreneurs and public organizations were important to engage their support for promoting and disseminating dryers through private and public extension channels. PPHDG developed a promotional strategy for the dryers, including use of the media, e.g., interviews with dryer owners, advertisements, newspaper articles, posters, fact sheets, etc.

In addition to mechanical drying, storage technology in the form of *super bags* were introduced and tested in 2007, but evidence of uptake and sustainable supply is lacking. Other interventions were training for rice millers in collaboration with MRPTA and introduction of moisture testing equipment.

The Myanmar case highlights the important role played by the private and nongovernment sector in multistakeholder platforms. Both MRPTA and PPHDG were NGOs effectively linking with key public and private stakeholders.

8.3.2.5 Lao PDR

There was limited information available on the institutional arrangements in Lao PDR for technology development and dissemination. However, IRRC facilitated the introduction of the storage *super bag*. They also linked Lao researchers to *combine harvester* suppliers in Vietnam and supported the demonstration and training on CH. Similarly, Vietnamese *flatbed dryers* were also transferred to Lao PDR and training was conducted by the PP Work Group. These were sold through government programs rather than being taken up by a private business as in other countries. Other areas of support were piloting of laser leveling and training on rice mill improvement. In addition, four rice mills were assessed for technical and management upgrading for milling and export of organic rice and business plans developed. These were certified in 2012.

8.3.2.6 Indonesia

By way of a contrast to the multistakeholder partnership business-based model evident in the IRRC approach outlined above, Gummert (2012b) provides an example from Indonesia where the approach was very different. The promotion of the hydro-tiller in West Sumatra and Sulawesi was heavily subsidized rather than market-led (although identification of this technology for dissemination was based on a need assessment of farmers). There was a power struggle in the manufacturers' association and no support was given for business development or for training or study visits (after the project ended). No functioning successor mechanism was put in place after project funding ended. Although hydro-tiller manufacture was going well, the institutional relationships and public support structure necessary for its promotion and uptake were not in place.

Drying technology in Indonesia in the 1990s was based on kerosene-fired FBDs based on an original IRRI dryer introduced a decade earlier. From 2003, rice husk fired box dryers were developed and FBD trainings were conducted by the IRRC PP Work Group. By 2010, there were 200 dryers in South Sumatra (mainly in rice milling units) and four local shops making dryers. IRRC also helped facilitate the introduction of the hermetically sealed storage super bags.

8.3.2.7 Lessons learned from the impact pathways of post-production technologies

The various in-country experiences with regard to the impact pathways of the different post-production technologies point to the following important lessons:

- Cross-country technical collaboration and exchange facilitated by IRRC has played an important role in speeding up technology development.
- Multistakeholder groupings and LAs have made a substantial contribution by linking technology development to testing, promotion, capacity building, and sustainable commercialization.
- Effective leading roles can be played by the private and nongovernment sector. Technology champions have successfully used their networks for promotion and provided co-funding.
- Awareness created by the participatory impact pathway analysis has encouraged the development of strategies for promotion and the creative use of different channels and

- media for information sharing with different audiences, including policymakers.
- Business model development has been important in ensuring appropriate investment and sustainable operation. Postharvest technology distribution through government programs, especially where subsidy is involved, has been less sustainable than through the private sector.

8.3.3 Productivity and Sustainability (PS) Work Group

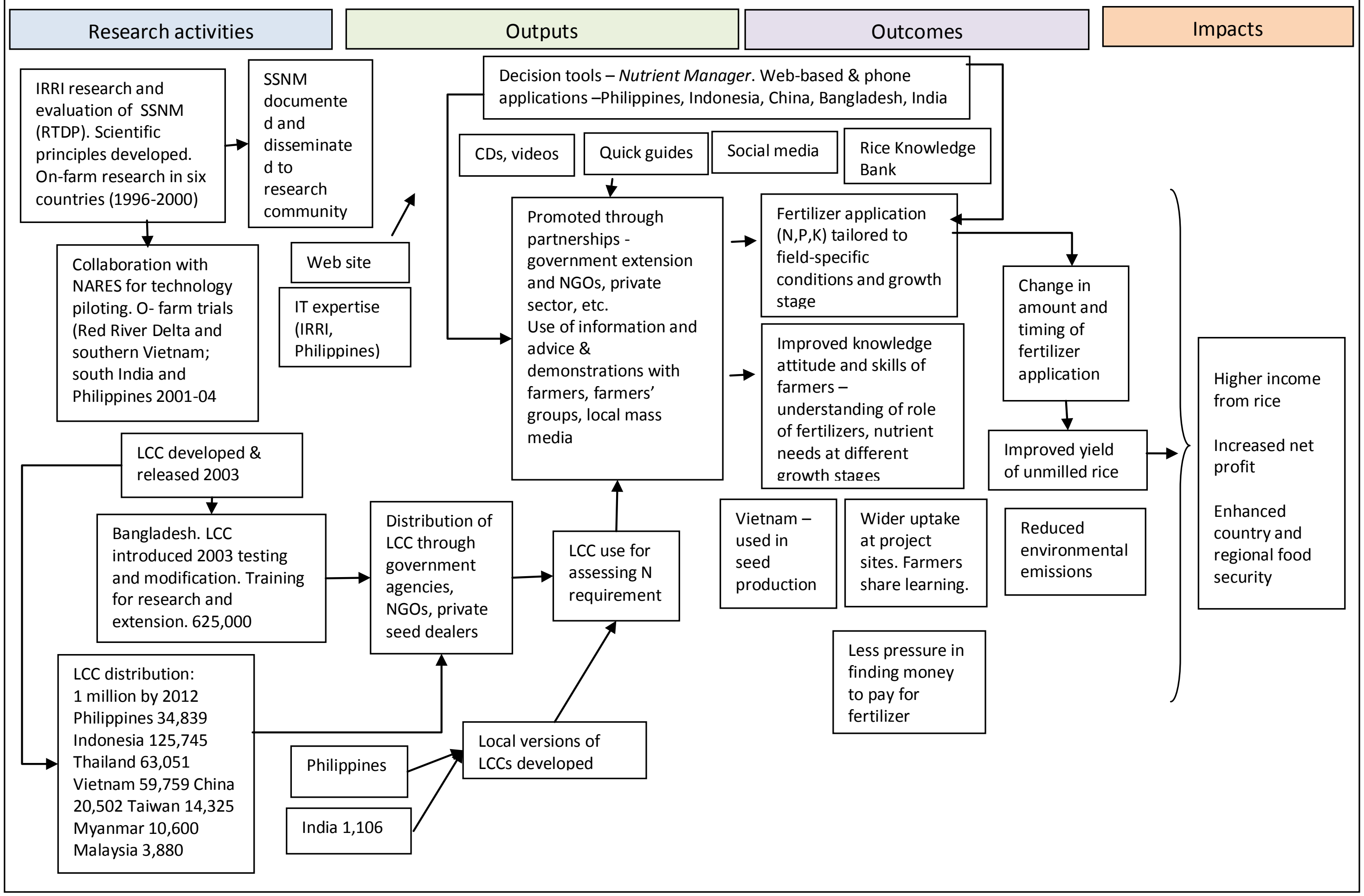
The impact pathways for SSNM vary according to country (see Figure 8.4). SSNM is knowledge-intensive in character. Having developed the scientific principles, refined the field application, and made information tools available, the pathway to applying the principles and information depends crucially on the institutional structure, personnel, and capacities relating to technology outreach and extension. The relevance of the technology is clear with high and increasing proportions of rice production costs allocated to fertilizer (20% in the Philippines, 22% in the Mekong Delta, and 14% in Tamil Nadu, India [Pampolino et al. 2007]), a technology that tailors fertilizer use to specific crop requirements in particular seasons will increase efficiency and overall production.

The principles and methods for field- and season-specific nutrient management were tested on-farm in the Philippines, Vietnam, Thailand, Indonesia, China, and India under the Reversing Trends in Declining Productivity Project (1996–2000). The results indicated potential for improving nutrient efficiency, yield, and profitability, although the latter depends on prices and on existing crop management practices. Furthermore, the principles introduced with SSNM can be applied across other crops (Buresh 2012). Further trials in 2002 and 2003 in south India, the Philippines, and southern Vietnam looked at both environmental and economic impacts.

In Vietnam, research was conducted with the Soil and Fertilizer Research Institute (the first phase from 1997 to 2000 and the second phase from 2001 to 2004), which was broadened to ICM practices. This was followed by wider dissemination and promotion with extension departments and plant protection departments in 11 provinces. A training manual for farmers was developed and training of trainers with extension and leaders of farmers' organizations and FFS was held. Lessons from the Vietnam experience were that information materials should be appropriate for the level of farmers' skills and knowledge, that dissemination of SSNM with other technology such as IPM was beneficial, and that a network of partners, including the private sector was important for spreading the technology. The dissemination and uptake process was inhibited where there was limited or no involvement of input suppliers and limited capability of extension workers and trainers. This gave rise to farmers receiving conflicting messages from public-sector organizations promoting SSNM and private dealers following blanket input recommendations. A further factor limiting uptake in Vietnam was the lack of formal approval of the technology by the Scientific Committee, which is required for national promotion through the extension system. Development and promotion of SSNM were therefore prioritized for countries where there was a more positive response, e.g., the Philippines and Indonesia.

The LCC was widely disseminated, particularly in Bangladesh and Indonesia. Its production and distribution was established on a cost-recovery basis, which no longer required financial support from IRRC. In Bangladesh, the LCC was released in 2003, tested in pilot sites, adapted, and promoted. Under the PETRRA project, efforts were made to develop an active network with a clear focus on technology delivery to farmers. The main partners in LCC promotion (as part of promotion of a number of other rice technologies) were IRRI, BRRI, and the Department of Extension (DAE). From 2006 onward, information meetings were held with agricultural policymakers and officials, DAE staff were trained, and extension materials and user guides in local

Fig. 8.4. Impact pathway: SSNM and LCC – multicountry.



languages produced. The key to dissemination was for partners and collaborators (e.g., DAW, BRAC, BMDA, Pali Karma Sahayak Foundation [PKSF]) to use their networks and partners to reach farmers' groups and to integrate the technology into their own programs; for example, BRAC included LCC in their seed enterprise project, giving training to seed dealers and their agents and PKSF introduced it to farmers' groups in their micro finance project for marginal and small farmers. At the farmer level, informal information sharing and training contributed to further uptake. In this way, technology dissemination was self-sustaining. The process was assisted by a national project from 2008 to 2011, which funded dissemination. The partnerships established in Bangladesh were used for field evaluation of the *Nutrient Manager for Rice*, intended for wide-scale promotion through the Ministry of Agriculture.

In IRRC Phase IV, the positive results from SSNM research and experience encouraged a strong emphasis by the PS Work Group on documentation and dissemination. In the Philippines, *Quick guides* for fertilizing rice were produced for 75 provinces and distributed, demonstrated, and promoted through the Department of Agriculture. *Nutrient Manager* was developed as a rice decision tool based on SSNM principles designed to allow extension workers to calculate specific field fertilizer requirements. A four-part set of videos entitled *Tales of Ryza, the rice plant* was developed and released for farmers in the Philippines. *Nutrient Manager* and the videos were initially distributed on CDs, but with the rapid development of ICTs, Web-based and mobile phone applications became more important.

Web applications of *Nutrient Manager* have been produced in English and local languages for the Philippines, Indonesia, and China and are under development for Bangladesh, southern Vietnam, West Africa, and Tamil Nadu, India. Mobile phone applications have been developed for the Philippines and Cauvery Delta India (web-linked or SMS). These developments drew on expertise from IRRI and the Philippines. Information on nutrient management is updated and maintained within the *Rice Knowledge Bank*. *Nutrient Manager* is also present on *Facebook*. Further innovations are planned, including voice/picture-based interface to reach illiterate farmers in local languages.

However, making the information available is only part of the challenge in reaching rice farmers. Actual implementation requires use of the tools for advising farmers, which depends on training of extension workers and other main actors in the input supply systems. This is facilitated by the existence of multistakeholder partnerships for effective training and support to frontline service providers who advise farmers. It also helps to ensure coherence of practice across the sector. In the Philippines, principles of SSNM and the *Nutrient Manager* were incorporated in training, evaluation, and promotional activities of organizations within the Department of Agriculture and with local government units and into the promotion and marketing strategy of a private sector fertilizer company in the Philippines. An initial partnership was established with an NGO and a bank in the Philippines for exploring the interfacing of *Nutrient Manager* with financial services through mobile phones. In Indonesia, *Nutrient Manager* was included in training, evaluation, and promotional activities of the Ministry of Agriculture.

In other countries, the process has been slower, partly because of lack of institutional commitment and partnerships for implementation. Time is needed for the demonstration and changing of attitudes among agricultural decisionmakers on the benefits of investing in training and promotion of SSNM and the decision making tools.

8.3.4 Water Savings (WS) Work Group

The impact pathways of the WS Work Group are examined for each of the two main technologies, AWD and AR, noting country-specific strategies.

8.3.4.1 Alternate wetting and drying (AWD)

The introduction and development of AWD were mainly focused in the Philippines, Bangladesh, and

Vietnam, with some trials and demonstrations in Myanmar, Indonesia, China, Lao PDR, and Thailand (see Figure 8.5).

8.3.4.1.1 Philippines

The initial work on AWD involving the IRRC was in the Philippines, starting in 2001 with collaborative research with Phil Rice, IRRI, and NIA. This has been described as a participatory research and learning phase, which introduced and validated AWD on farmers' fields as well as developed the partnerships necessary for further development. Accounts of the AWD work do not specify the extent of networks *already existing* between IRRI staff and NARES partners in the Philippines, however, these are likely to have been important in facilitating the start-up of the collaboration.

Research on AWD and AR trials were initially conducted in deep well- and shallow well- irrigated areas in Canarem, Tarlac and Nueva Ecija, involving farmers from irrigators' service cooperatives. By 2003, promising results had led to the refinement of the "safe" AWD approach, and initiated its further out-scaling to 72 other deep well systems covering 3,354.7 ha and 2,256 farmer members. The approach influenced partner organizations; NIA incorporated AWD principles into its projects and promotional material and strengthened training and support for its own staff in its national and regional offices, for leaders of IAs and farmers. In addition, the Bureau of Soil and Water Management (BSWM) of the Department of Agriculture, with the mandate for coordinating small-scale irrigation projects, became involved and conducted training for extension staff and farmers.

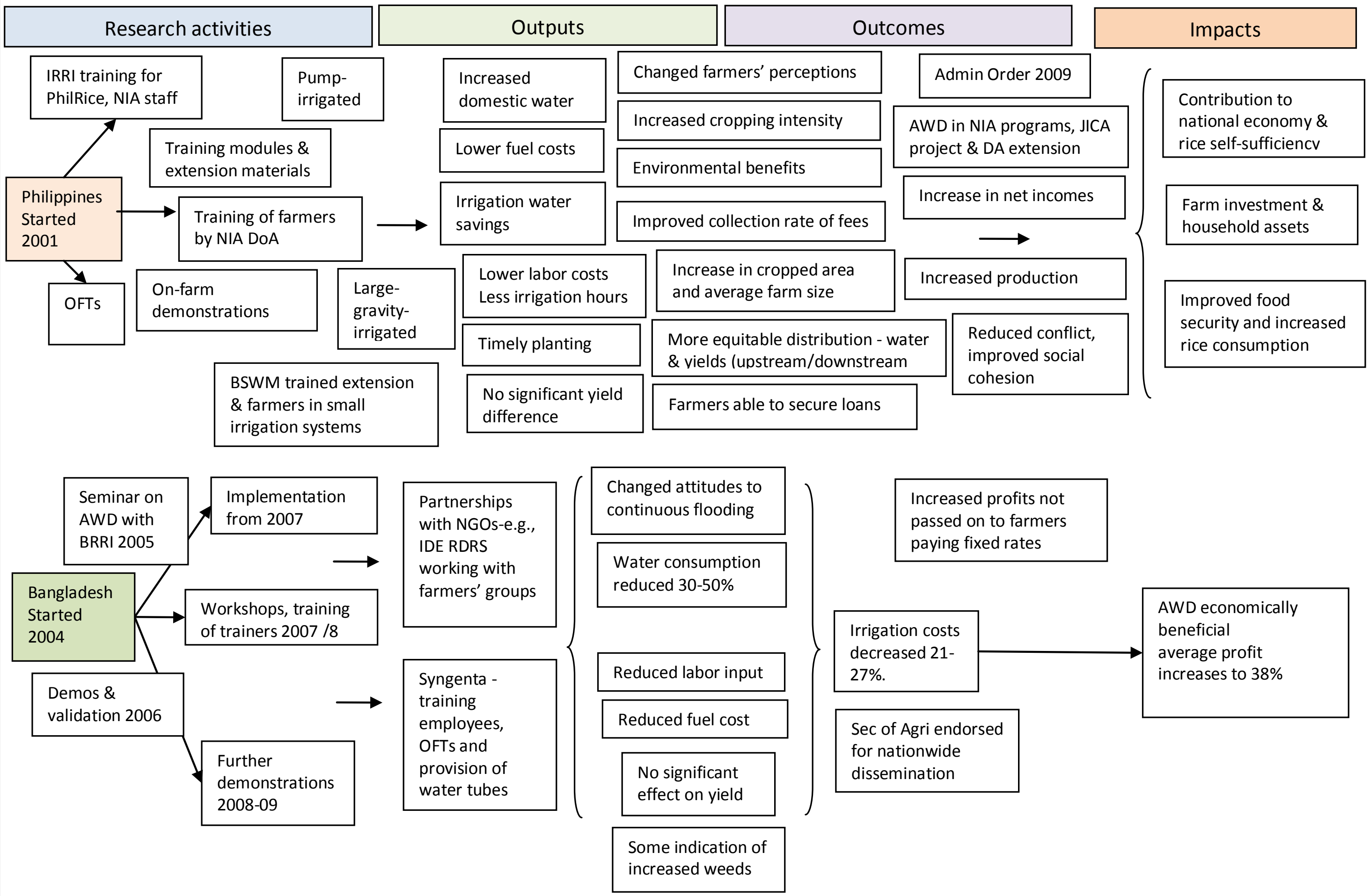
The partnership with NIA and PhilRice facilitated the introduction of AWD into large-scale national irrigation systems. AWD in Bohol started as a pilot in 2005 and was extended to the whole scheme in 2006 as part of a JICA-funded project. Training for NIA staff, IA leaders and more than 3,000 farmers was conducted. Similarly, AWD was piloted on the UPRIIS scheme in 2007, and then extended to the whole system.

Reasons for the successful engagement of partners relate to their shared interest in AWD technology, but they brought specific contributions and perspectives relating to their mandates. For example, PhilRice's mandate is for rice research, training, and delivery of information on rice production, so their role was strongly focused on research and training. AWD was integrated into three of their existing programs. NIA's mandate is irrigation system management and operational development of irrigated and potentially irrigated areas nationwide. It organizes irrigators' service cooperatives, conducts training and demonstrations with farmers, and promotes wider knowledge sharing. AWD has been integrated into NIA projects and awareness of AWD developed in NIA agencies. IRRI made an important contribution in providing a strong scientific basis for the introduction of the technology and contributing to the training for research and extension staff of partner agencies and development of training modules. Other partners were the Department of Agriculture, local government units, and state colleges and universities.

Collaboration within the IRRC helped to strengthen partnerships and to facilitate shared learning and the incorporation of technologies into respective programs, training, curriculum and activities. AWD has been promoted in the Philippines as part of the ICOP. The program has taken an integrated approach to AWD, consistent with policy directions, including those set up by FSSSP. It has emphasized capacity strengthening at all levels and promoted on-farm participatory research. The strong emphasis placed on training and interaction with farmers has contributed significantly to uptake of AWD.

The learning and experience from implementation of AWD fed into the development of a national policy on AWD. The Secretary of the Department of Agriculture issued AO 25 on the "Guidelines for the Adoption of Water-Saving Technologies in Irrigated Rice Production Systems

Fig. 8.5. Impact pathway: AWD – multicountry.



in the Philippines" in September 2009, stipulating AWD as the main water-saving technology of the Philippines. Funds were acquired for wide-scale dissemination.

Technical information, publicity, and other materials were developed during the course of the work. Information materials on AWD were included in the IRRI Rice Knowledge Bank.

8.3.4.1.2 Bangladesh

The first trials on AWD in Bangladesh were conducted in 2004 by BRRI and the Bangladesh Rural Development Academy (BRAC) with technical support from IRRI. Information about the technology was spread through workshops and seminars for NARES staff and training of trainers was conducted with key stakeholder organizations in 2007 and 2008. There was further testing and piloting of AWD from 2008 to 2010 and a national workshop was held in 2009.

As in the Philippines, the out-scaling of AWD was facilitated by multistakeholder collaboration, which included BRRI, IRRI, DAE, and the Barind Multi-purpose Development Authority (BMDA), which manages deep well irrigation schemes. It also included private actors, such as Syngenta and the NGOs IDE and RDRS. BRRI's role was in research and training on AWD, while DAE was responsible for actual dissemination through extension activities linked with their major programs. For knowledge-intensive technologies such as AWD, farmer training and group approaches were particularly useful, especially FFS, which created experiential learning over time rather than in one-off training session. Support from local champions such as village chairmen and representatives of local government were important. In Bangladesh, the media, such as radio and TV, had a strong engagement from the beginning.

It is difficult to get an accurate estimate of the scale of adoption. Partners' reports suggested 120,000 adopters in 2009 (Lampayan 2012), whereas Kürschner et al (2010) reports that adoption was still in its early stages. In July 2009, the secretary of the Ministry of Agriculture endorsed AWD as a national program and directed the DAE to promote it to farmers nationwide. However, according to Kürschner et al (2010). this did not result in nationwide dissemination of the project.

The constraints to uptake of AWD in Bangladesh were mainly institutional in nature. First, the most common arrangement for payment for water, a fixed seasonal rate, does not provide farmers with an incentive for reducing water consumption. Pump owners do not pass on economic benefits from the savings in water and energy. Negotiating a changed arrangement would require a collective agreement of all farmers in a scheme to implement AWD. The NGO RDRS made efforts to facilitate farmer organization and influence, facilitating a farmers' forum and organizing a workshop for dialogue with pump owners. However, pump owners, especially those using subsidized electricity, were not very willing to change. The second constraint relates to a lack of organizational capability for promoting AWD nationally in the way that NIA was able to do in the Philippines. AWD has been successfully promoted at a local level by NGOs working with the DAE, but it was not fully implemented as a national campaign.

8.3.4.1.3 Vietnam

In Vietnam, there has been an integrated approach to promoting AWD, which has built on the long-established relationships between IRRI and the Plant Protection Department, Vietnam, and the success in introducing the 3R3G program since 2002/3. Demonstrations and training on AWD were conducted in 2005 and extension materials were developed. AWD was initially promoted in 2007 with media campaigns and training as part of the 3R3G recommendation and then incorporated into the 1M5R program in An Giang province.

A factor promoting uptake in Vietnam is that farmers are relatively well-organized in cooperatives, an arrangement that facilitates training and support. The idea of not irrigating continuously was not completely new (Chan Phu district 23/10/13). Policy changes are encouraging large fields and synchronized activities in rice production to take advantage of improved technology. Where irrigation is centrally managed, adjustments in irrigation rates and schedules are possible, supported by local administration. AWD has strong government support in An Giang province. However, there remain issues similar to those found in other countries, where farmers pay for water from private pump owners. As in Bangladesh, the payments are agreed at the start of the season, usually at a flat rate per area (An Giang DARD 22/10/12), although it is possible to negotiate a change if all farmers agree. In some locations, pump owners were included in the training, but farmers were not able to negotiate a reduction in cost. A further obstacle identified by agriculture personnel and farmers was the unevenness of fields, which generally have not been leveled (Chan Phu district 23/10/13; Phuton district 23/10/12).

8.3.4.1.4 Other countries

There is limited information on the uptake of AWD in other countries. The strategy has been to disseminate AWD through training, spread of information materials, and curriculum development. AWD technology was promoted in South Sulawesi, Indonesia, and southern Lao PDR through ACIAR-funded projects. Trials were conducted in Myanmar in 2006–07 (Yi et al. 2010). Field trials of AWD were conducted from 1999 in China (Cabangon et al. 2001) with results similar to those from other countries. Adoption of AWD did not affect yield and profitability of rice production was considered to have potential for water-scarce areas. Validation and adaptation trials are ongoing.

In summary, experience indicates that promoting AWD through a multistakeholder grouping was effective in the Philippines and, to some extent, in Bangladesh. Strong central and local government support for the technology as part of national policy was important in Vietnam. In all cases, partners assessed and adapted the technology and incorporated it into their own programs. In all three countries, constraints relate to farmer incentives for adopting AWD, suggesting the need for further emphasis on this area of policy.

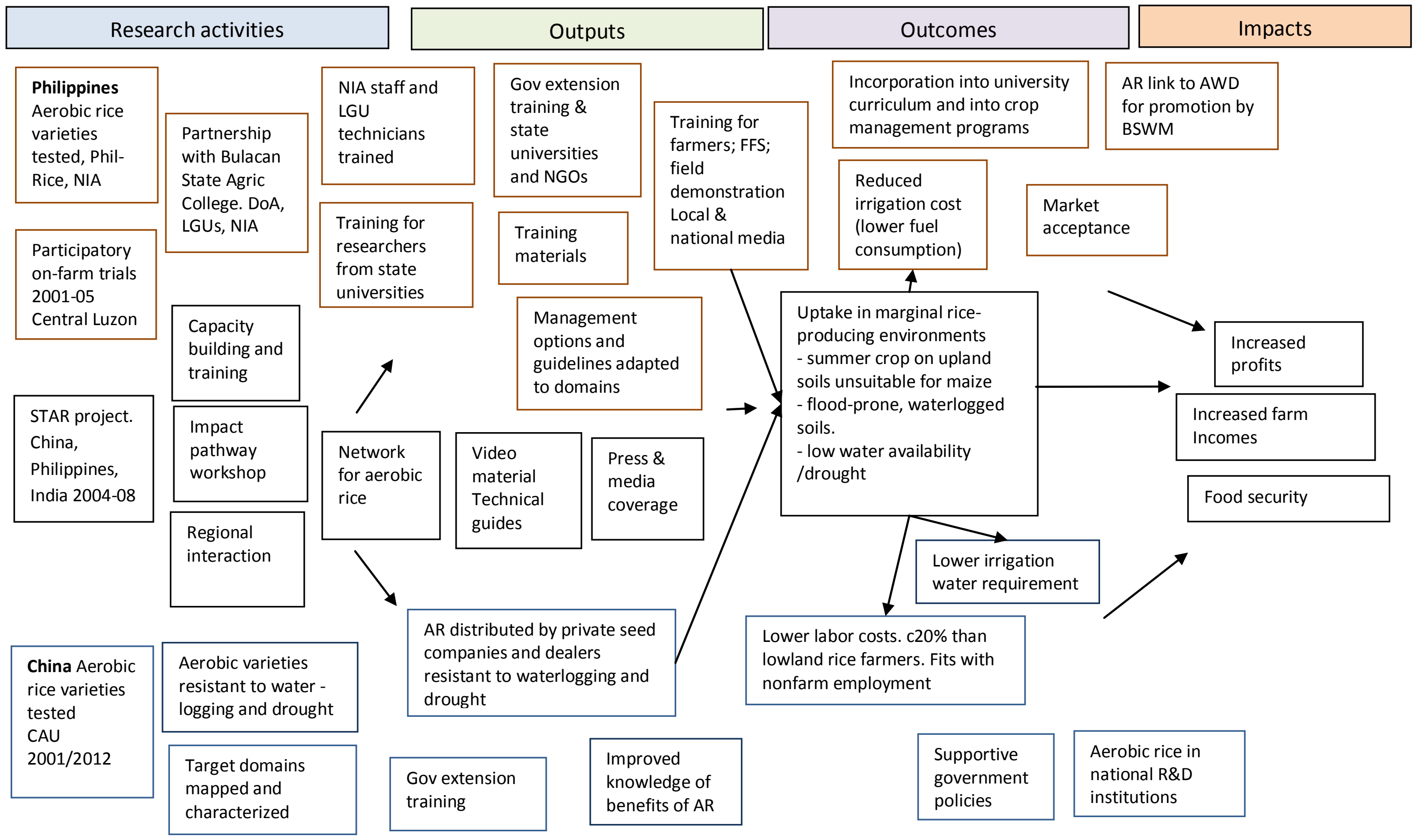
8.3.4.2 Aerobic Rice (AR)

Collaborative research and development of AR has taken place in a number of countries (see Figure 8.6). IRRC collaborated on AR with the China Agricultural University and with PhilRice and NIA in the Philippines. The technology was tested at pilot sites in 2001 and 2002. There was also collaboration with the Indian Agricultural Research Institute in 2003, although the budget was small. AR technology was further tested through participatory on-farm trials, conducted in Central Luzon from 2001 to 2005 in partnership with BASC, the Department of Agriculture, and the local government.

Research and on-farm testing of AR continued, linked to the project ‘Development of a System for Temperate and Tropical Aerobic Rice (STAR) in Asia’ in 2004–08, under the Challenge Program for Water and Food. The main locations were the North China Plain, Philippines, and India, with promotion of AR systems and germplasm in Lao PDR and Thailand as well. The collaborators met in 2007 to analyze and plan the impact pathway for the technology. A further link was with the CURE project. The AR technology was promoted and disseminated through the production and distribution of a technology guide for farmers and technicians and the use of local and national media.

In the Philippines, a number of different routes of promotion of the technology were followed, including training of NIA staff and technicians, farmer training and FFS, field demonstrations, publicity through a national conference, and establishing relationships with LGUs, NGOs, and state universities. By 2011, 2,232 farmers in water-scarce irrigated and rainfed areas had been trained, 85 researchers from state universities, and 100 agricultural technicians from the Department of Agriculture and LGUs. AR technologies were incorporated into the university

Fig. 8.6. Impact pathway: Aerobic rice – multicountry.



curriculum and added to research programs on crop management and varietal selection. AR was linked to AWD for promotion by BSWM, for use in shallow water impounding, small-gravity irrigations systems, and shallow tube wells. Interest in the technology is indicated by the success of partners in attracting additional funding from a range of sources; for example, BASC, together with BSWM, successfully applied for a grant from the National Economic Development Agency of the Philippines ($25,000 from Japan) as support for their AR seed production business and BASC became the Aerobic Rice Center of the Philippines. Video material and technical guides were produced.

The uptake pathway in China developed from the on-farm research on AR led by the China Agricultural University (CAU), which mainly focused on crop varieties, to research on AR systems and more interaction with farmers on farmers' fields under the STAR project. CAU also attracted more research funding from national and international sources. The mechanisms for scaling-out were field days and demonstrations, to which seed companies and input distributors were invited. The private sector was the main channel for promotion and spread of new technologies, but it was supported by public extension in terms of training and demonstrations. The government gave support through the National Program of Aerobic Rice regional trials.

Interaction with IRRC and regional partners has increased researchers' knowledge and, in China, has influenced the research approach toward becoming more interdisciplinary, participatory, and field-based (Templeton and Bayot, 2011). AR was included as a component of training in water management at IRRI for scientists from across the region and a network for AR was formed.

Factors promoting uptake were the tailoring of AR implementation to specific production contexts, meeting farmer needs and priorities. It is possibly this aspect of AR, as an option for reducing risk, labor and water demand and fitting niches, which are not well suited to lowland irrigated rice, that makes it attractive for particular target groups and areas but more challenging to promote on a wide scale. The combination of private and public sector roles in seed supply and training and extension worked well in China, while government organizations and state universities were effective in the Philippines.

8.3.5 Synthesis, analysis, and lessons learned from the impact pathway analysis

The analysis of impact pathways for IRRC work groups shows a wealth of country-specific strategies for increasing knowledge and access to technologies and promoting farmer uptake. There are also some cross-cutting lessons that can guide future activities.

A finding is that, in cases where strong multistakeholder groupings were established, involving a range of research and extension partners, actors from government (national and local), NGOs, and private sector organizations, and farmers' associations, there was more dynamic promotion of the technology and greater impact. This is particularly striking in the case of water-saving technologies in the Philippines; DSR, SDVs, and SSNM in Bangladesh; EBRM in Vietnam; and PP technologies in the Philippines and Myanmar. Multistakeholder groupings have facilitated the integration of technologies from different work groups such as 1M5R in An Giang province and ICM in Indonesia.

Multistakeholder groupings and LAs have made a substantial contribution in linking technology development to adaptation, promotion, capacity-building, and sustainable commercialization. This arises partly from the sharing of knowledge and opportunities for capacity-building, which is stimulated by such an arrangement and also from the combination of different specializations and spheres of influence which span levels from national policy decision makers, through research and extension practice, to farmers. Such platforms encourage contribution of both skills and resources, as in the multistakeholder LA in the Philippines.

Successful technology dissemination requires the building of capacity and skills, through training, experiential learning and sharing through workshops and meetings, and on farm training, technology testing, and demonstration. Most work groups emphasized training at different levels for researchers, extension service providers, local leaders, and farmers. The involvement of organizations that provide training and interactive support to farmers is particularly important in encouraging the spread of knowledge-intensive technologies. Adoption was facilitated where strategies were based on an understanding of local control practices.

Group approaches such as NIA's work with IAs in the Philippines or the FFS in Bangladesh provide a more continuous learning process founded on experience. Good facilitation skills at the community level were important in mobilizing adoption of technologies requiring community action (EBRM, AWD). In countries where there is a cultural tradition of community joint action and cooperative organization (e.g., Vietnam), community-based approaches were easier to introduce. Farmers' agreement to changes in use of common property resources, such as shared irrigation water in Philippines, required regular interaction by local field staff. Where there was no organization actively accepting responsibility for doing this, technology uptake was slower, as in the case of AWD in Bangladesh.

Furthermore, training for private intermediaries fertilizer suppliers, seed growers, and trade associations such as the MRPTA was important. Inclusion of private-sector input suppliers helped avoid conflicting messages on input use being given to farmers. Business model development encouraged private investment in postharvest technology, especially where linkages were established with financing institutions.

The experience of IRRC illustrates the importance of using multiple channels of dissemination extension, public, civil society-based, and private. The dissemination and uptake process was inhibited where there was limited or no involvement of input suppliers and limited capability of extension workers and trainers. In Myanma,r the PPHDG, a civil society organization and multistakeholder platform, promoted mechanized dryers and became an established service provider. In China, a combination of private and public sector roles in seed supply, training, and extension worked well for the promotion of AR, while government organizations and state universities were effective in the Philippines. This contrasts with the experience of postharvest technology promotion in Indonesia and Lao PDR where sales were through government institutions supported by subsidies. Support for private sector business development and training was lacking and uptake was less successful.

All work groups made use of different types of media in promoting their technologies. The development of a clear communication strategy specifying audiences, messages, and the different media required (as in the Philippines and Cambodia for PP) was useful in guiding this effort. Where training was provided for country teams in message design and production, this had good results (e.g., Philippines and Vietnam). A range of written materials and visual media videos, TV programs, radio interviews, and Web and phone applications was produced. There is a lack of systematic information on which of these channels was most effective in reaching which kinds of audiences. However, a study in Indonesia and feedback from other countries indicate that communication materials are most effective when reinforced by local personal contact.

There are examples of effective cross-country learning for technology development, dissemination, and impact. In addition to workshops bringing work group partners together, cross-country collaboration and exchange visits facilitated by IRRC have played an important role in speeding up technology dissemination. Mechanical drying technology from NLU, Vietnam, was shared with the Philippines, Myanmar, and Cambodia and training provided. Combine harvesters developed in Vietnam were transferred to Cambodia. There was cross-country learning and exchange between NGOs in eastern India and western Bangladesh on DSR.

Levels of government support and channels for policy influence varied across the countries and influenced the uptake pathways. Early involvement of policymakers in start-up activities and in publicity campaigns was beneficial and support from local authorities, both administrative and political, can speed up dissemination. When a technology aligns with national policy, then government support can be very positive, e.g., FSSSP in the Philippines, *monga* mitigation in Bangladesh, and rice export ambitions in Cambodia and Vietnam.

Institutional innovation as well as technology innovation are needed for some technologies to be actively promoted at scale. Change in organizational structures and mandate, personnel, and capacities may be needed to enable a focus on technology delivery and interaction with farmers. Local social norms and vested interests may create disincentives for technology change. For example, in countries where farmers pay a fixed seasonal water rate, they have little incentive for reducing water consumption through AWD. Negotiating a collective arrangement to change this is complex.

In work groups that engaged in participatory impact pathway analysis, this has encouraged the development of strategies for promotion and the creative use of different communication channels. However, the analysis could be enhanced by clearer specification of how technology adoption is to be measured and by whom. This would help in estimating the total numbers of farmers adopting the technologies. There is also further scope for disaggregating adoption and impact into different categories of farmers, laborers, or small entrepreneurs: by resource endowment, gender, scale of operation, etc. As the development of rice systems in the region becomes more technology-intensive, mechanized, and consolidated, understanding the economic, social, and distributional impacts of technology adoption needs continued attention.

9. Process evaluation

This section examines the processes of IRRC development and adaptation across its four phases. It considers the learning and decisionmaking processes, the management of change, and the coordination of the Consortium partnerships and communications. Evidence is drawn from presentations and interviews with IRRC CU staff, work group leaders, and country partners, as well as IRRC end-of-phase reports and other program documentation.

9.1 How flexible was the IRRC in moving towards new tasks/skills required for large-scale dissemination of its outputs?

Tracing the evolution of the IRRC over its four phases suggests a high degree of flexibility and responsiveness to lessons learned and the sharpening of IRRC objectives towards achieving impact on food security and livelihoods of smallholder farmers. Starting with a Phase I (1997–2000) objective, which specified IRRC's role in developing partnerships to facilitate research in NARES (IRRI 2001), subsequent phases put increasing emphasis on technology uptake.

Partnerships in Phase II (2001–04) were to facilitate and strengthen NARES' research and *technology delivery* in irrigated rice systems. There was explicit commitment to identify regional research needs in irrigated rice and strengthen interdisciplinary and multi-institutional research collaboration. There was development of the philosophy of joint ownership and joint contribution of resources from Consortium members (IRRI 2005).

In Phase III, the vision referred to impacts on farmers in terms of increased profitability, food security, and environmental sustainability, while the goal was "to provide an international platform and effective mechanism supporting the research-extension partnership to promote the use of sustainable, benefit-enhancing technologies in irrigated rice-based systems." In phase III, there was specific reference to capacity strengthening of NARES partners and knowledge and approaches in addition to technologies. Furthermore, the objectives included strengthening of support to national and local policymaking processes and providing a platform for dissemination (IRRI 2009).

The main goals of Phase IV (2009–12) further emphasize access to technology options and their scaling up and scaling out by NARES and other stakeholders to improve income and livelihoods and meet the increases in rice production required to maintain food security in Asia. Phase IV would also foster innovative research on NRM of irrigated rice-based cropping systems (IRRI 2012).

IRRC showed the capacity for adaptation to changing emphasis over the four phases, recruiting staff with new skills (impact assessment, social anthropology, communications, etc.) However, at the country level, IRRC was of necessity working within the context of the structures and priorities of the NARES. From a starting point where there was limited "interdisciplinarity" within NARES (IRRI 2000) and even less emphasis on multistakeholder approaches, the influence of IRRC over its four phases helped bring about a transition toward such approaches.

For large-scale dissemination and impact, IRRC identified the need to work more closely with national organizations and encourage cross-cutting interaction. In all countries, IRRC was involved in building closer relationships with a wider range of partners, a challenging task since IRRI's traditional partnerships were with research institutions with a strong focus on breeding and crop improvement rather than on soil, fertilizer, and water management. New partners included the Soils Research Institute in Indonesia, state universities and extension departments under the Department of Agriculture in the Philippines (Buresh, 26/6/2012) and NGOs in Bangladesh, Vietnam, and the Philippines.

The development of the ICOP was a further important step in linking with national organizations. The approach would be adapted for different country situations and owned by national programs. The concept took some time to be accepted because it was a departure for IRRI scientists and was 'emergent' in character, depending on country priorities and stakeholder interest, rather than on predefined specific objectives (SDC 6/2012). It shows the confidence of the IRRC in taking quite a risky step since it was up to national programs to take ownership and provide the leadership, with IRRC support. In addition, the LA approach was applied to good use by the PP Work Group in the Philippines.

In terms of the use of media, in Phase III, IRRC developed a multipronged communication strategy. Among the products were a quarterly international newsletter (*RIPPLE*), media coverage, SDC Asia Brief, a new Web presence, e-learning modules, decision analysis tools, and videos. Further communication capacity was added in Phase IV. The communication effort dramatically widened the types and reach of IRRC outputs.

The nutrient management decision tools demonstrate the adaptability of the work group to the rapid development of modern media. Starting with CD-ROM and LCC now the integrated *Nutrient Manager* is available as a web application and a mobile phone application.

Moreover, the strengthening of support to national and local policymaking was highlighted from Phase III onward, for example, interaction with authorities in Vietnam over pesticide policy and with PhilRice on the FSSSP program.

9.2. To what extent have synergy and enhanced impact been created through the coordination of work groups during implementation?

The foundation for work groups was laid in Phase I, building on experience of the research networks. These were the Integrated Pest Management Network (IPMNet) with its project Reaching Toward Optimal Productivity (RTOP), the Integrated

Nutrient Management Network (INMNet), and the Hybrid Rice Network, in addition to work groups on weeds and rodent management. However, IRRC was keen to extend collaborative research beyond national boundaries and to create synergy by fostering multicountry collaboration and a stronger international perspective. IRRC managed the planning process for Phase II and the definition of the work groups, which involved participation of NARES collaborators as well as donors, scientists, and network coordinators. A work group on water savings was added (recommended by the Phase I external review team), working in China, India, and the Philippines. Additional countries, Bangladesh and Myanmar, were added to RTOP (which combined integrated nutrient and pest management, weed ecology, and rodent ecology). A new postharvest work group was formed in 2003, following suggestions from the NARES working in Cambodia, Indonesia, Lao PDR, and Vietnam, and a cross-cutting 'impact' work group was also introduced, which helped to build work group participation and interaction in identifying impact pathways and channels of communication.

The beginning of more integrated approaches to on-farm research and development was signaled with the creation of 'lighthouse sites' where related technologies were tested and promoted. Also, in Phase II, the development of 3R3G in Vietnam successfully integrated nutrient management and seed and insecticide control (Heong, 29/6/2012).

The role of work groups developed from essentially a research collaboration to being a cross-country forum linking research and extension systems in an interdisciplinary and multi-institutional collaboration. Evidence of the extent to which IRRC's coordination role has created synergy and enhanced impact is not explicitly presented in technical reports. However, feedback from country work group participants and the utilization of experience in one country for the benefit of others support the view that the coordination role did speed up the introduction and uptake of technologies and did enhance impact through tailoring them for specific country circumstances. SSNM and weed management are good examples of this in Phases II and III. IRRC facilitated development of work in Myanmar by drawing on lessons learned in other countries.

In addition to formal meetings and agreements, the mechanisms for coordination of the work groups and facilitation of country participation are closely associated with the personal interaction of the work group leaders and the IRRC coordinator with the relevant country organizations, their directors, and key influences/local champions.

IRRC organized a series of consultation workshops at the end of Phase II for planning of Phase III. This involved a wide range of stakeholders. The formulation of the four Phase III work groups shows a trend toward more problem-focused themes signaling the integration of research and extension: Productivity and Sustainability, Water Savings, Labor Productivity, and Post Production. The ICOPs were also introduced in Phase III. The structure of the management team was strengthened to include the four work group leaders. The recruitment of additional skills into the IRRC CU provided support to the work groups in important areas–in social sciences to enhance understanding of economic, social, and cultural impacts and in communications to transform research outputs into information and training materials for wider dissemination.

Also, in Phase III, the notion of an innovation platform gained currency, reflecting the multistakeholder groupings involved in the work groups and ICOP, including extension organizations, NGOs, and the private sector. More concretely, with the ICOP, the practice of the different work groups working on common sites in a more integrated approach was strengthened in Indonesia, Philippines, Myanmar, and Vietnam. In Myanmar, two sites were used by all the work groups as a platform for integration of NRM technologies and farmer and multistakeholder participation. Training of trainers also took place across the four work groups. This was considered to have led to greater farmer and multistakeholder participation and strengthened partnerships (Yi et al. 2010). In Indonesia, adaptive research on integrated technologies was developed in South and Southeast Sulawesi under the ICOP, which created more demand-led and participatory integrated approaches.

The role of IRRC and work group leaders in facilitating wider participation was important, particularly in developing relationship with major NGOs, such as World Vision in Vietnam, CRS in the Philippines, and Intercooperation, BRAC, and IDE in Bangladesh.

In Phase IV, there were initially five work groups: Productivity and Sustainability, Water Savings, and Post Production continued, while Community Ecology was added to Labor Productivity and a new work group, Crop Health, was introduced. The governance model and structure of IRRC remained the same. A new work group, Climate Change, was included in 2011 working with CURE and IRRC. New linkages were formed with ACIAR in Cambodia and Laos and with Syngenta Science Knowledge Exchange Program.

Synergy created through IRRC's coordination of work groups is particularly noted for Indonesia, where IRRC played an important role in facilitation and dissemination activities, interacting at provincial level (specifically with the Assessment Institute for Agricultural Technology) to encourage a locally adapted bottom-up approach through farmer experimentation, FFS, and ICM reaching at least 45,000 farmers.

9.3. To what extent have IRRC and its partners identified new research directions and skill requirements, new partnerships, and communication opportunities and embedded critical learning within the management cycle?

The transitions in IRRC's research and development focus and the skills acquired have been outlined in Section 6.1. New partnerships have been formed with about 18% of partners in universities, 18% in NGOs, 14% in the private sector, as well as 50% in NARES.

New communication opportunities have been taken up, including, TV plays, farmer videos in Sulawesi and the Philippines, and videos on a range of other issues (*Monga*, '*Tales of Ryza, the rice plant*', control of rice field rats, etc.). Web sites exist for IRRC, for SSNM, for rodents, weeds, postharvest LAs (among others), and e-learning and decision tools for postharvest, water management, submerged soils, and the *Nutrient Manager*. A particular innovation was the participatory approach in message design and material development.

The main process for identifying lessons and using them to determine future directions appears to have been through workshops involving country partners, for example, the regional workshop in September 2008 to document progress and lessons learned during IRRC Phase III, 2005–08. The book *Research to impact* (Palis et al. 2010a) was the major output. External review processes have also encouraged reflection and brought about change, not because IRRC has relied on outside reviewers to do the analysis for them, but because the occasion of a review stimulates internal reflection and review of progress.

An example of a new direction relating to IRRC's ongoing work is its facilitation of exchange on information on Rice GAP at a regional workshop in 2011. This links with the increased production and improved quality of rice and responds to the export aspirations of several countries in the region.

9.4. How has IRRC responded to influences external to the program (e.g., IRRI, donor, governments, etc.)?

IRRC has successfully developed its program as a core part of IRRI, negotiating the rather different roles required of IRRC work group researchers, in particular, operating at the interface of research and extension. The argument was made that results of research on NRM technologies in rice production, especially knowledge-intensive technologies rather than those which are material- or equipment-based, are unlikely to spontaneously be disseminated without further action. Hence, IRRC is working with parties in-country to validate technologies and look at pathways for adoption.

The major donor, SDC, has consistently encouraged IRRC to link research more closely with dissemination and extension in order to achieve tangible results. This has been taken up by IRRC as earlier explained.They have also encouraged a focus on poorer Southeast Asian countries, which has led to the strong emphasis on Myanmar in IRRC Phase IV.

Each phase had an external review and the recommendations were discussed and responded to. However, one recommendation of Phase II review, 'that more attention be paid to the specific roles of men and women in rice operations and decisionmaking', has been interpreted rather more generally in terms of pro-women technologies and women-based values for rice products and technological development and the use of a gender-sensitive approach in all its activities. Gender *analysis* in rice operations and decisionmaking is not evident.

IRRC has been responsive to government requests for support, for example, the FSSSP in Philippines and the request from An Giang province in Vietnam.

9.5. What are the main lessons arising from the implementation of IRRC over the four phases that could inform future investments?

- *Shared learning combined with site-specific and country-specific approaches* – IRRC's work has managed to combine shared learning (through the work groups with encouragement of country partners) and site-specific adaptation and ownership of technologies and approaches. This is important, given the variation in country research and extension organizations, their capacities, respective roles and mandates, and national policy priorities. Participatory on-farm trials have contributed to local adaptation of technologies and stimulated interest and uptake. Scientists in national programs have changed their attitudes to technology adaptation, accepting it as a user-driven multistakeholder process.
- *Partnerships with stakeholders* can be accelerated through early involvement in need identification and planning processes that identify their shared interests and different areas of potential contribution. Building the capacity of partners to fulfill these roles in terms of knowledge, skills, and resources is very important as it creates more dynamic participation and a greater likelihood of out-scaling to reach more farmers and up-scaling to influence policy. Partnership and communication are important at all levels, from local extension providers, researchers, private sector and government polic makers.
- *Integration of technologies in country outreach programs* has had good results in the Philippines, Indonesia, Vietnam, and Myanmar. The ICOP is particularly suitable where there is country capacity for management and ownership of the program.
- *Trust and creativity fostered by continuity of IRRC and the work groups.* The continuity of IRRC over its 15-year period has fostered trust and confidence among country partners in the relationship. It has also provided stability and encouraged participating researchers in IRRI and country partners to be creative, share ideas, develop concepts, and test new approaches in an interdisciplinary fashion. The IRRC management team has supported this throughout the evolution of the different phases.
- *IRRC as a mechanism for linking IRRI research to farmers and policymakers*–IRRC was important in enabling IRRI researchers to link with country programs and initial and end users of technologies. IRRC's position as a consortium established a wide stakeholder interest group and created a direct connection to country policy and research and extension

practice, which, in its absence, would have been difficult for IRRI researchers to achieve for multiple countries.

10. Influence assessment

This section explores the extent to which the IRRC has influenced policy and practice among the NARES for lowland rice of the countries where it has been active. The dimensions of influence examined include influence on the research and extension agenda and on approaches to research and extension activities. In addition to national-level influences, regional and international influences are assessed—how far have IRRC and its work groups successfully functioned as a regional platform and catalyst for learning and dissemination of best practices for NRM in irrigated rice-based systems. Finally, also evaluated was the extent to which IRRC has generated leverage from participating countries' own resources and secured enhanced impact through maximizing synergy among different project funding sources.

10.1 National influences

Evidence on national influence is mainly compiled not only from project documentation and reports but also from interviews with people in the NARES of countries visited during the review—Philippines, Bangladesh, Vietnam, and Indonesia. There are some challenges in assessing the contribution of IRRC, since few of the sources clearly document the status of national research and extension *prior* to involvement with IRRC or preexisting networks. Secondly, it was difficult for informants to distinguish between specific activities of IRRC and those of IRRI staff in general. In several cases, there was a long history of relationships with IRRI through training and collaborative research. The main policy impacts in terms of legislation or administrative orders relating to IRRC technologies have been discussed in Sections 3 and 4 and are briefly outlined here. Many of the events contributing to policy influence are not necessarily highlighted as such. They include workshops and meetings and personal interactions.

10.1.1 National-level policy influences

Some policy influences of IRRC at the national level were:

- A 2-day policy workshop was held on the rice economy of Myanmar in February 2007. It was hosted by the Myanmar Academy of Agricultural Sciences and the Ministry of Agriculture and Irrigation and co-sponsored by IRRI, IRRC and MOAI.
- IRRC participated in national rice sector meetings in Lao PDR (November 2011) and in Cambodia (May 2012). The meetings established national priorities for rice development.
- In Bangladesh, the influence of IRRC partners brought about a national-level program to promote *monga* mitigation using DSR, SDV, and investment in post-rice crops. In July 2009, the secretary of the Ministry of Agriculture endorsed AWD as a national program to be promoted by the DAE.
- In the Philippines, in 2009, the learning and experience from implementation of AWD fed into the development of the national policy on Water-Saving Technologies in Irrigated Rice Production Systems.
- '3 Reductions and 3 Gains'(3R3G) was adopted as a national policy in Vietnam in 2002. '1 Must Do and 5 Reductions' (1M5R) was adopted in An Giang province and accredited by the government and is being incorporated in a new World Bank-funded project in the Mekong Delta. IRRC was originally approached by the An Giang government with request for linkage and training support.
- '3 Controls' in Guangdong China, a technology similar to 3R3G, was introduced following a workshop in 2010, which raised its profile at a political level. It is now approved.
- Global GAP policy influence. IRRC facilitated the exchange of information on rice GAP at a regional workshop in April 2011 with Vietnam and Thailand who are engaging with IRRC to

build Rice GAP in Vietnam and are planning to have ASEAN ratification.

An important mechanism of policy influence identified is through the alumni of IRRI/IRRC-supported training. Individuals who did training or research at IRRI have moved into positions of policy influence in ministries of agriculture and departments of planning. This creates strong in-country champions who help facilitate the work of IRRC. While personal influences are important, policy change generally requires a more consultative process among stakeholders, for example, to deal with the issue of pesticide misuse in Vietnam, despite the training to reduce it. Circular 18 on pesticide marketing and distribution was influenced by interaction between an IRRI staff member and the vice minister, emphasizing the need for control of pesticides to avoid misuse. The minister convened a task force, which reported back and then was given the job to develop the circular. If implemented, pesticides will be treated like a pharmaceutical drug and marketing and unnecessary advertising will be controlled. An important lesson learned is the need to invest in building a policy structure to protect innovations and changes in practice. *'We cannot have IPM in an environment where pesticides are sold as consumer goods'* (K.L. Heong 29/062012). There is a need for policy-level efforts to create a sustainable framework for new technologies and approaches.

10.1.2. National-level influence on the research and extension agenda

The influence on the research agenda has been the strengthening of the demand orientation to meet both the priorities of farmers and the interests of major stakeholders in the NARES. The agenda setting for collaborative research has been led by NARES with facilitation from IRRC. This is clearly demonstrated in the operation of the ICOPs in Philippines, Indonesia, Myanmar, and Vietnam. The IRRC strategy included the facilitation of farmer adoption and impact, with an emphasis on participatory research and learning through involvement of end users, on-farm research, demonstrations and FFS and training for research and extension service providers. The second main way of influencing national programs has been through professional and technical support and capacity strengthening, both technical and participatory approaches, encouraging networking and policy dialogue. These factors are illustrated by the experience of the WS Work Group in the Philippines (as seen in the following sub-section).

10.1.2.1 AWD in the Philippines: example of IRRC influence on research and extension agenda

The work of the WS Work Group in the Philippines is an important case study. The impact pathway of this work is outlined in Section 8.3.4.1.1, including adoption of AWD principles by partner organizations involved in research and extension (NIA, BSWM, Department of Agriculture).

IRRC helped to facilitate farmer adoption and impact through encouraging a participatory research and learning phase, which introduced water-saving technologies to farmers and formed part of the training process for extension staff and leaders of IAs. This involvement of end users through on-farm research, demonstrations, FFS, and community-based meetings became embedded in the national approach, including organization of farmers' groups, community interaction, and awareness of issues such as incentives in managing common property resources.

The principles, protocols, and approaches were taken up in PhilRice programs and by NIA in large-scale irrigation schemes and projects such as the NIA-JICA IA Strengthening Support Project TCP II. The IRRC helped to create the platform for capacity-building of national research and extension. Knowledge and experience were shared through social learning among partners and colleagues rather than through 'top-down' approaches (Palis et al. 2012c).

IRRC also supported the development of a national policy on water-saving technology. Drawing on the learning and experience from implementation of AWD and the work of a multistakeholder technical committee, a national policy, AO 25 on the "Guidelines for the Adoption of Water-Saving Technologies in Irrigated Rice Production Systems in the Philippines" was issued in September 2009. A further indication of the acceptance of the technology and the approach was that the government allocated funds for wide scale dissemination. Also, BASC, together with BSWM, were successful in their application to the National Economic Development Agency of the Philippines for financial support to AR seed production.

10.1.2.2 Other examples of influence on research and extension agenda

The involvement of IRRC and ICOP with the Philippines' FSSSP is another evidence of the influence of IRRC on the research and extension agenda of partner countries. IRRC technologies are included in the technology package for promotion in the Philippines (PalayCheck).Among the IRRC technologies included are SSNM, AWD, storage technology, dryers, rodent management, crop health, and DSR (which draws on the ICT knowledge products and e-modules developed by IRRC). A partnership platform for dissemination and development of IRRC technologies has been established and is monitored at the provincial level, providing feedback to IRRC scientists.

IRRC's work in partnership with NARES in Indonesia (South and Southeast Sulawesi) developed an agenda based on need assessments of villages where farmers identified priority constraints, discussed potential solutions, and selected technologies for testing. The approach was through ICM with adaptive research conducted over several seasons covering a range of technologies—AWD, weed management, EBRM, SSNM, DSR, and storage technologies and then extended through the development of a training curriculum and FFS. Partners (AIATs and extension workers) developed skills in participatory approaches, encouraging farmer decisionmaking and technology choice, and documentation through video, an 'empowering activity for farmers' (Casimero 2012). The approach continued after the 3-year funding came to an end.

In Myanmar, the IMOP started in 2005 forming a multi-institutional grouping, including the MAS as the lead agency, the Ministry of Agriculture and Irrigation, the Department of Agricultural Research and the Seed Division, Plant Protection Department, and Yezin Agricultural University. Emphasis was put on capacity-building of extension personnel, building partnerships with research agencies and the private sector, and briefing of high-level government officials. The integrated approach drew positive feedback from key stakeholders, including policy advisers and raised awareness of IMOP at the policy level. Regular meetings were held with the director general of the Department of Agricultural Planning and with managers of field activities. Annual meetings were held, chaired by the managing director of extension, and attended by the general manager of project planning management and evaluation division. The integrated implementation of activities of four work groups led to greater farmer and multistakeholder participation and strengthened partnerships.

In Vietnam, IRRC influence helped to bring about change in methods of interaction with farmers (Doan, N.P, 22/10/2012). Before the early IPM work of IRRC, information was given to farmers by lecture and leaflets. After the IPM work of IRRC, there was more participatory learning. This was subsequently applied to 3R3G in more depth, and to 1M5R. In the early years of collaboration, interaction was generally with farmers only; later on, it included service providers, pump owners, processors, and companies. Lessons were also learned about the need for follow-up after farmer training. The 1M5R in An Giang builds on good results of 3R3G, which was funded by IRRC in Phase II (Doan, N.P. 22/10/2012). In 2006, the An Giang Department of Agriculture and Rural Development organized a meeting on 3R3G. The chair of the People's Committee invited IRRI to expand the program in An Giang (K.L. Heong 29/06/2012), requesting technology training. Training of trainers was organized, with funding from IRRC and the local government. The 1M5R program was launched in November 2009 and is now ratified as a national technology.

On the question of what activities the NARES would have been doing in the absence of IRRC, in the case of NIA, Philippines, it had been implementing intermittent irrigation and rotational water distribution for some time, but through the influence of IRRC, it was encouraged to take this further: *"We gained more confidence with IRRI showing us that the system is working in other parts of the world. Had we not learned from IRRI, we may have taken another direction"* (NIA, 28/6/2012).

In Vietnam, a senior official in the Ministry of Agriculture voiced a similar opinion, that the benefit of IRRC was their up-to-date knowledge which could be adapted at country level: *'Based on this, Vietnamese science can develop further. We can always do something on our own, but it is not necessarily so good. We cooperate with IRRI for national development…we find our own way, with IRRI support'* (Pham, V.D. 21/10/2012).

10.2 Influence at international level

IRRC's influence on national research and extension programs comes from facilitating interaction and information exchange. There has been cross-country exchange of information among IRRC partners*. 'Every year, we have a workshop in a different country to share our experiences. It's a good chance to share and learn from others. From Thailand, we learned about Thai Rice GAP;, from China, the technology of '3 Controls'; and from Indonesia, ICM.'* (Nguyen, 22/1/2012).

The postharvest platforms in Cambodia, the Philippines, Vietnam, and Myanmar shared information as IRRC funds paid for cross-country visits. IRRC supported capacity-building through training events and encouraging interaction at different levels scientists, extension agents, and private sector (G. Singleton, 23/6/2012).

The regional workshop held in September 2008 documented progress and lessons learned during IRRC Phase II. The '*Research to impact*' book was the major output and the main way of documenting cross-country learning about the processes, methodologies, and strategies employed in addressing challenges of wider scale adoption of NRM technologies in lowland irrigated agroecosystems.

10.3 Leverage and funding synergy

IRRC has created leverage by bringing in other related projects and encouraging a broader perspective across the consortium. Initiatives include:

- Postharvest work with ADB platforms in Cambodia, the Philippines, and Vietnam
- Rodent management/EBRM work funded by ACIAR
- Philippine government's support ICOP with funding
- AWD integrated into the Strengthening Support Project TCPI and TCP II, 2005–07
- Bangladesh's and India's livelihood and crop protection projects linked with IRRC in Phases III and IV
- Indonesian government's support of national outreach efforts

11. Conclusions and recommendations

From the preceding chapters, it is clear that the IRRC has provided a wide-ranging array of impacts in multiple dimensions–from micro-level impacts on farmer livelihoods to national-level agricultural policy influence. Based on these impacts, it can be strongly argued that IRRC has been an effective international platform for strengthening NRM research in rice. The scientific community, research organizations, policymakers, and donors can learn from the IRRC experience documented in this report, most especially with regard to how the institutional structure and partnership efforts of the Consortium contributed to the realized magnitude and breadth of impacts generated.

In this concluding section, we first briefly summarize the major findings from the different analyses conducted above and then offer some lessons learned (i.e., recommendations) based on the assessment of the impacts of IRRC's research and dissemination efforts. We believe that the lessons and insights from this assessment have implications to future NRM research programs in IRRI (and elsewhere), as well as to donor agencies involved in NRM research. Findings from this study also have direct importance to NRM programs interested in documenting the multidimensional impacts of their efforts.

11.1 Brief summary of findings

Economic surplus and poverty analysis. The evidence base that documents economic impact of IRRC technologies is numerous and varied. This body of evidence generally provides an indication of the strong positive economic effects of these technologies to rice farmers in several Asian countries (i.e., higher net income, lower input costs). Qualitative and/or quantitative approaches have been used to determine the economic effects of IRRC technologies.

Overall, the economic surplus analysis of selected IRRC technologies overwhelmingly shows that the improved economic welfare of farmers from adoption of these technologies more than compensates for the research investments made to develop and disseminate them. Even only considering the period that covers the four phases of the project (1997–2012), the rate of returns to total research investment ranges from 6% to 30% (BCRs range from 1:1 to 4:1). If the longer 1997–2016 period is considered (where we project benefits 4 more years to the future), the rate of returns to total IRRC research investments has a larger magnitude ranging from 25% to 43% (or BCRs from 4:1 to 16:1). Given that the economic surplus generated by IRRC technologies is more than the total research investments (from all sources), rate of returns of the research investments from the SDC alone has even higher values (e.g., 14–34% for the 1997–2012 period and 29–46% for the 1997–2016 period). These rates of returns are still lower than typical rate of return estimates for genetic improvement or breeding-based rice research. However, it is important to note that the estimates here only cover a subset of the NRM technologies developed and disseminated by IRRC.

The poverty impact assessment conducted generally indicates that selected IRRC technologies do have the potential to improve the incomes of farmers (i.e., mainly through higher yields or lower costs). However, the evidence shows that, in areas where the IRRC technology users are well below the poverty threshold, the income effect of the technology alone may not provide a sufficient income boost that will allow poor rice farmers to go above the poverty line. But note that the poverty impact assessment in this study is very limited and only considers selected IRRC technologies in particular study sites.

Sociocultural, gender, institutional, and policy impacts. A variety of qualitative and quantitative methods has been used to study and document the sociocultural, gender, institutional, and policy impacts of IRRC technologies. In general, the effects of IRRC technologies on sociocultural indicators (i.e., farmer well-being, livelihoods, community action and cohesion), institutions, and policies have been well-documented and are discussed in various publications. However, with the exception of the *monga* work in Bangladesh and EBRM in Vietnam, overall gender impacts (and disaggregation of impacts by gender) have been limited. Gender has not been mainstreamed into an analysis of different perspectives or differential outcomes from use of technology.

Environmental impacts. There are only a few available studies that were expressly designed to document the environmental impacts of IRRC technologies. Even though there is documentation of possible environment effects of different IRRC technologies, most of the environmental impact evidences are typically based on study participant observations rather than comprehensive scientific studies.

Scientific and human resource development impacts. The scientific publication output of IRRC over the past 15 years has been impressive. A total of 485 publications have been produced through the four phases of the project, and the outputs ranged from peer-reviewed articles and books to conference papers and unpublished theses. These publications have been cited more than 5,000 times. The documented capacity-building efforts also indicate that IRRC had a substantial human resource development impact, especially on NARES staff of partner countries.

Impact pathway analysis. The analysis of impact pathways for the different IRRC work groups shows a wealth of country-specific strategies used for increasing knowledge and access to technologies and for promoting farmer uptake. An important finding is that, in cases where strong multistakeholder groupings were established, involving a range of research and extension partners, actors from government (national and local), NGOs, private sector organizations, and farmers associations, there was more dynamic promotion of the technology and greater impact. Through these groupings, the importance of using multiple channels of dissemination in out-scaling NRM technologies was highlighted. Within these partnerships, local "technology champions" play a key role in the dissemination of technologies and in eventual realization of impact pathways. Appropriate training approaches (i.e., workshops, demonstrations) at different levels are essential for success of technology dissemination and for realizing impact. There are examples of effective cross-country learning for technology development, dissemination, and impact. Early involvement of policymakers in start-up activities and in publicity campaigns was beneficial and support from local authorities, both administrative and political, can speed up dissemination. Notwithstanding these important lessons learned, further understanding of successful impact pathways entails more precise estimates of farmer uptake/adoption and how adoption and impact differ across different groups of stakeholders (i.e., large vs. small farmers, laborers, etc.).

Process evaluation. The process evaluation reveals that IRRC demonstrated a high degree of flexibility and responsiveness to the experiences and lessons learned throughout the four phases of the project. There is strong evidence that IRRC's multistakeholder partnership approach has been successful in allowing them to meet demands of country partners, as well as those of external institutions (i.e., IRRI, donors, and governments). Sharing of lessons learned across countries allowed IRRC to streamline out-scaling and up-scaling of technologies and to identify new research/extension directions that meet farmer needs in partner countries. IRRC's position as a consortium established a wide stakeholder interest group and created a direct connection to country policy and research and extension practice which, in its absence, would have been difficult for IRRI researchers to achieve for multiple countries. Moreover, the continuity of IRRC over its 15-year period has fostered trust among country partners and, in turn, provided the necessary stability to encourage participating researchers to be creative, share ideas, develop concepts, and test new approaches in an interdisciplinary fashion.

Influence analysis. The strong influence of IRRC on the research and extension agendas of partner countries can be seen in the research directions being pursued, the technology transfer practices being implemented, and the kind of policy support generated in these countries. There is ample evidence to show that IRRC has shaped the research and extension priorities of partner countries (see Section 10). This was made possible by allowing the NARES to set their own collaborative research and extension agendas, with IRRC facilitating the process and making sure that these agendas meet the needs of farmers and other major stakeholders. IRRC also influenced national research and extension agendas through professional and technical support and capacity strengthening, primarily through participatory approaches, and by encouraging networking and policy dialogue. The technical and scientific support of IRRC, as well as the international interactions and information exchange among IRRC partners, gave the NARES confidence about the validity of the technologies and allowed them to more strongly pursue avenues that accelerate the research on and dissemination of IRRC technologies in their country. Another important mechanism of influence is through the alumni of IRRI/IRRC-supported training who have moved into positions of policy influence in ministries of agriculture and departments of planning, which in turn provide strong in-country champions who help to facilitate the work of IRRC.

11.2 Lessons learned and recommendations

Evidence of multidimensional impacts. The results of this meta-impact assessment clearly demonstrate that the IRRC has had substantial impacts at different levels and in a variety of dimensions. There are direct economic benefits (i.e., higher yields or lower costs) observed at the farmer and household levels. These economic benefits generally translate into improved farmers' livelihoods and more sustainable rice production at the regional and national levels. A number of IRRC technologies, such as EBRM and AWD, have had strong sociocultural impacts at the local community level, as well as environmental impacts. Agricultural policies at the regional and national levels have also been implemented based on efforts of the IRRC and its partners. Based on these strong documented multidimensional impacts, we can conclude that the IRRC has been an effective international platform for development and dissemination of NRM technologies in irrigated rice-based systems. Agricultural research organizations and agricultural policymakers could learn from the experiences of IRRC in terms of better understanding how a "consortium-based" and "partnership-focused" approach to NRM technology development and dissemination could be effectively implemented. An important challenge for the future is for the local NARES to sustain the advances made with respect to productivity, stability, resilience, and equitability in irrigated rice-based systems, when the levels of IRRC support may not be the same as before.

Impact studies. The IRRC should be lauded for the resources and effort put into documenting the different impacts of the NRM technologies it developed and disseminated. The number of studies that use both qualitative and quantitative methods to analyze the impacts of various technologies in different partner countries is quite impressive.

However, we also noted in this report several areas where these impact studies could be improved. These include

- Investigating the heterogeneity of impacts across different groups of farmers and/or stakeholders. Typically, only the mean impact of the technologies is examined in existing studies. A more refined understanding of the effects of the different IRRC technologies can be achieved when the effects of technologies on different segments of the target populations are examined. Analyzing impacts by gender, by land tenure status, and/or by farm size are some examples of areas where further understanding is needed. Greater emphasis on more explicit scrutiny of environmental impacts is also recommended.
- Using state-of-the-art impact assessment methodologies to examine economic and sociocultural impacts of IRRC technologies and accounting for such issues as selection bias. Based on the existing economic impact evidence reviewed in this report, most of the economic impact studies conducted did not carefully address the issue of selection bias, making it difficult to attribute the economic impact to a particular technology intervention. To be able to undertake these types of methodologies, it is recommended that the "hard" scientists responsible for developing the technologies collaborate with the researcher in charge of impact assessment so that impact studies can be planned before, and conducted during, diffusion and dissemination of a new technology. Note

that this recommendation not only applies to the quantitative methods used; further improvement in the qualitative approaches used in the impact studies is also warranted (i.e., network analysis and utilization of theories of change). Use of more advanced quantitative and qualitative methods may allow for more peer-reviewed publications/articles of the impact assessment studies, which would increase credibility of the results and make it more convincing to donors and policymakers.

- Enhancing consistency in the impact evaluation across work groups and technologies. The presence of researchers within the CU in charge of impact assessment was an excellent decision by IRRC/IRRI administrators and certainly the outputs produced by these researchers made it easier for the meta-impact assessment team to document the multidimensional impacts of IRRC technologies in this report. However, the quality and quantity of studies across technologies still varied widely across technologies/work groups.
- More carefully monitoring the take-up and adoption numbers for at least the "high-potential" IRRC technologies. In conducting the economic surplus analysis, it was apparent that more precise adoption numbers would make the analysis of returns to research investments more reliable. More detailed poverty impact assessment also would rely on the technology adoption numbers collected, as well as the location of adoption. We recognize that availability of resources/funding is critical in the monitoring of adoption numbers, but perhaps local NARES (and funding support from national sources) could be utilized to help augment the tracking of these figures. Adoption number, by itself, is also a good measure that indicates acceptance of the technologies on the ground.

Reflections on the counterfactual. Given the impressive number and variety of impacts from the research and dissemination efforts of IRRC, it is also important at this point to reflect on the counterfactual what would have happened if IRRC had not existed? Would the different technologies have been developed and disseminated anyway (albeit by other institutions/mechanisms aside from IRRC)? This is a difficult question, given that we cannot directly observe this counterfactual scenario and we will have to rely on informed speculations. Nevertheless, reflecting on this issue may be worthwhile at this point.

If the IRRC had not existed, it is likely that some of the technologies discussed in this report would have been developed anyway, but the speed of development/innovation and magnitude of dissemination would have been substantially less. The scientists and researchers in IRRI who are involved in developing NRM technology for irrigated rice would have still been there, even without the institutional structure of IRRC. But the cross-country learning and close collaboration between research work groups and local NARES partners would probably not have been as strong without the IRRC platform. Individual researchers or research groups would have had to cultivate their own relationships/networks with local partners and this may have impeded the development and out-scaling of technologies on the ground. In our view, the institutional structure, the network of partners, and the cross-country learning provided by the IRRC helped accelerate the pace of technology development and dissemination within the partner countries. This institutional structure and support are critical in facilitating the dissemination of research conducted by the different researchers and research groups and, without it, the magnitude of the impact outcomes described in this report may have been different. IRRC's institutional structure that was expressly constructed to emphasize partnerships and close collaboration with local NARES partners is arguably one of the most important elements that facilitated the multidimensional impacts of NRM technologies developed. Previous studies of NRM technologies have also pointed out the role of existing institutions and their structure for effective development and dissemination of NRM technologies (Waibel and Zilberman 2007, Renkow and Byerlee 2010); the present study provides more evidence of this.

Nevertheless, it is also possible that an alternative institutional arrangement (i.e., aside from a consortium-based structure) may have evolved to accomplish the NARES networking and cross-country learning functions observed with the IRRC. Perhaps, a separate outreach office with strong institutional linkages with partner countries and in-house capacity to conduct impact assessment studies (and develop communication materials) would have been able to accomplish the same outcomes as IRRC. But, without further in-depth analysis (i.e., reviewing the literature on the effectiveness and efficiency of alternative institutional structures for research), it is hard to assess whether this type of institutional arrangement would have fared better than the IRRC structure. A more comprehensive assessment of the efficiencies and accomplishments of alternative research and extension institutions is left for future work.

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Appendix 1: Terms of Reference

Terms of Reference for Conducting Impact Assessment of IRRC Technologies

I Background:

Established in 1997 with support from the Swiss Agency for Development and Cooperation (SDC), the Irrigated Rice Research Consortium (IRRC) strives to ensure that rice farmers benefit from technologies arising through research. The SDC continued its strong support of the IRRC through funding a fourth phase of the Consortium through until December 2012. Our target is to assist farmers in irrigated rice-based systems to achieve increased profitability, food security, and environmental sustainability. The Consortium has developed partnerships between national agricultural research and extension systems (NARES) and the International Rice Research Institute (IRRI) in 11 countries. The focus in Phase IV is on Southeast Asia and China. However, there are key activities in Bangladesh that focus on the diffusion of direct seeded rice, and alternate wetting and drying.

The IRRC has helped identify and address regional research needs in irrigated rice. Technologies have been developed and verified in farmers' fields, and pathways explored for their diffusion to end users (farmers, NGOs, private sector, policymakers). With a strong multistakeholder partnership, IRRC is contributing to Millennium Development Goals 1 (eradicate extreme poverty and hunger) and 7 (ensure environmental sustainability) through increased efficiency of resource use (such as land, labor, water, fertilizer, and other inputs) and promotion of ecologically based management of pests and diseases (principally weeds and rodents in this phase), leading to sustained production in an ecologically and environment- friendly context.

Goal: To conduct a meta-impact analysis and a process evaluation of the IRRC. This assessment aims to determine the achievements attained during the four phases of IRRC and how the outcomes of the research has contributed to the following issues in the project (Asian) countries:

(i) Rice/Agricultural policy changes or influence
(ii) Increased rice production at regional and national levels
(iii) Improved livelihoods of smallholder rice farmers, especially increased economic incomes and reduced drudgery for females and youths
(iv) Sociocultural improvements in the life of the smallholder farmers
(v) Environmental impacts

The final consultancy report will document evidence of successful outcomes and impacts, as well as pathways that led to these changes. We also are interested in evidence of limited progress or setbacks, how these were addressed, and the lessons learned.

General Objectives: To assess the multidimensional impacts of the IRRC on the farmer, household, and community at local, regional and national levels and to assess the influence of IRRC, as an international and regional platform for partnership and adaptive research, on the production of knowledge, technology development, dissemination, and farmer adoption of best practices for natural resource management in irrigated rice-based systems. Of particular interest are the economic, sociocultural (including gender), institutional (e.g., capacity building; curriculum development), policy, and environmental impacts of the IRRC.

Specific Objectives

1) To perform a systematic review of the existing evidence about the impacts generated by IRRC technologies (i.e., based on available literature/studies);
2) To conduct impact pathway analysis of various technologies developed by each Work group with an emphasis on determining the primary adoption and dissemination pathways for each country and the IRRC as a whole;

3) To assess the influence of IRRC on the NARES research and extension agenda and activities (in conjunction with the adoption/dissemination pathways identified in specific objective 2);
4) To document and analyze the socio-cultural, institutional (including organizations, and public-private partnerships), environmental, scientific, and policy impacts of
    a. technologies/processes developed by each work group in selected project countries (where the developed technologies have been disseminated and adopted);
    b. the IRRC as a whole;
5) To document financial and economic benefit-cost analyses to estimate the rate of returns and other welfare measures for
    a. the main outputs/technologies developed by each workgroup in four selected project countries (where the developed technologies have been disseminated and adopted);
    b. the IRRC as a whole; and
6) To conduct a process evaluation of the institutional adaptation of the IRRC (phases I-IV) with a focus on its flexibility to move towards new tasks/ skills required for large scale dissemination of its outputs (e.g. policy work, use of media and other extension channels, development of decision tools).

II Terms of Reference

I. Inventory of Impact Evidence, Influence Assessment, and Process Evaluation

A. Inventory of Evidence
Key Research Questions:

- Is there empirical evidence regarding the impacts of technologies and policies developed by IRRC (economic, social, cultural, environmental, and institutional), based on existing studies/literature?
- Are there distributional differences on various dimensions of impacts across countries based on existing studies/literature? How about differences within country across users (i.e., farmer intermediaries, farmers, etc.)?
- What complementary data are needed to calculate economic surplus measures of aggregate impacts?
- What are the major hypothesized influences and impacts that have not yet been assessed?
- How can IRRC impact assessment studies be improved?

B. Impact Pathway Analysis
Key Research Questions:

- For each work group and country, how is/are the technology/ies disseminated by farmer intermediaries, and adopted by farmers. (When did it happen? How did it happen? Why did it happen? What worked? What did not work and why? Who made it happen?)
- What is(are) the "impact pathway(s)" of each technology by country? What is common across countries, and what is different?
- What are the factors enabling or inhibiting the promotion of the technology by country?
- What are the factors enabling or inhibiting the adoption of the technology at the farm level?
- What is the level of adoption of each technology by farmers by country?
- For each technology and country, what are the dissemination pathways (including communication pathways)?
- For each technology and country, what has been the best dissemination pathway (including communication pathways) that led to high adoption levels by farmer intermediaries and the end users (smallholder farmers, millers, etc.).

- How effective is cross-country learning for technology development, dissemination, and impact?

C. Influence Assessment of IRRC

Key Research Questions:

- What are the NARES research and extension agenda and activities in intensive lowland rice-based systems?
- What has been the influence of IRRC on the NARES research and extension agenda/ activities in intensive lowland rice-based systems?
- What are the likely activities the NARES would have been doing in the absence of IRRC?
- What leverage has IRRC generated from NARES countries?
- What is the role of IRRC, as an international and regional platform for partnership and adaptive research, in the production of knowledge, technology development, and dissemination of best practices for natural resource management in irrigated rice-based systems?
- What has been the role of the IRRC in facilitating research and extension policies, farmer adoption and the achievement of impact? Determine to what degree the IRRC Management Unit and the work groups have provided a catalytic role in linking different levels of interaction within a country, between countries, and across the public, private and CSO stakeholders, in the impact pathways.

II. Impact Assessment

Aggregate Impact Assessment

Conduct meta-impact analysis of the achievements that IRRC has done over the past four phases (15 years) with particular attention on assessing the economic, social, cultural, environmental, institutional, scientific and policy impacts.

a) Use of existing farm-level studies (i.e., all the information collected in the Stage I analysis) as input into the quantitative impact assessment methods that utilize the economic surplus framework and complementary methods

Key Research Questions:

- What is the level of adoption of the IRRC technologies in each country based on existing evidence? What is the adoption rate of poor smallholders?
- What are the financial and economic impacts (e.g., NPV, BCR, IRR, ROI, etc.) to the key outputs/technologies developed by each work group with reference to specific countries?
- Relate these economic estimates to the overall investment by SDC and IRRI over the past four phases (15 years)?

b) Analyze the poverty relevance of documented multi-dimensional impacts by technology and country; and for all IRRC regions as a whole.

Key Research Questions:

- What are the characteristics of the adopters of the IRRC technologies?
- What are the implications from the above adopter characteristics to the poor, say via labor demand and food crisis (among others)?

c) Conduct several case studies that demonstrate the policy influences attributable to IRRC

Key Research Questions:

- What are the influences of the IRRC on scientific progress, capacity building, and policy development with respect to the NRM of lowland irrigated rice (e.g., research priorities and funding)?

- Identify recommendations based on the results of the case studies.

Assignment Coverage

The assignment will be carried out for 10.5 months and mainly cover four countries, namely: Bangladesh, Indonesia, Philippines, and Vietnam. However, impact evidence from the following countries may also be included in the analysis as needed: Myanmar, Laos, Cambodia, and China. Much of the work will consist of desk top study of existing reports/studies and easily available/formatted household survey data (or secondary data at more aggregate levels). Field visits will only be supported for the 4 main countries of focus: Bangladesh, Indonesia, Philippines, and Vietnam.

Proposed Personnel (Team)

The structure of the review team is as follows: Team leader: Roderick M. Rejesus (agricultural economist), Team Member 1: Adrienne Martin (Social Anthropologist), and Team Member 2: Phrek Gypmantasiri (Agronomist). The IRRC will assign staff who will help with collation of reports, publications, household data, secondary data, etc., and in the administrative arrangements (through IRRI country offices) for interviews with key NARES, civil society and private sector partners in target partner countries.

Deliverables

This will involve four stages:

- Inception Meeting and Report
  This inception report, which includes the work-plan, must be submitted within 2 months from the commencement of the contract and approved by IRRI/SDC no later than 15 days after submission. (Timeline: Commencement of Contract: May 15, 2012; Inception Report Due: Aug. 1, 2012; IRRI/SDC Approval: No later than Aug. 15, 2012)
- Submission and Presentation of Stage I report (Inventory of Evidence and Influence/Process Evaluation) - 3 months after the approval of the inception report (Timeline: Nov 15, 2012; if inception report is approved by Aug 15). The results from the Stage I report and any preliminary impact assessment results will be presented in the exit workshop of the IRRC Phase IV to be conducted on Nov 21-22, 2012 in Lao, PDR .
- Submission of Draft Final Report - 6 months after the approval of the inception report (Timeline: Feb 15, 2012).
- Submission of the Final Report and final manuscript for publication would be ready on or before March 31, 2013. The draft manuscript will be submitted for publication consideration in the planned special issue of the *Food Security* journal soon after.

Note that this delivery schedule is subject to change when mutually agreed upon by the review team and the IRRC leadership.

Appendix 3: List of Field Visits and Checklist of Questions Asked

Appendix 3.A: List/Description of Field Visits and Interviews

Philippines:

Region 2, P38 24/6/2012: Meeting with farmers' association, p38 Irrigated Service Cooperative (head and secretary of the cooperative, 2 IA support workers)

UPRIIS 25/6/12: Meeting with the president and vice president of the Federation of Irrigators associations; 3 representatives of IAs from top, middle and tail end of the scheme; chairman of one of the IAs and 1 staff member of the IA. Total 7 men.

Pilar, Bohol 27/6/2012: Meeting with farmers (4 men, 2 from downstream and 2 from upstream in the scheme), 3 NIA staff.

LA, Bohol 27/6/12: Meeting with 6 Learning Alliance members, NIA regional office, Tagbilaran.

Upper Sinyawan, 29/6/12: Meeting with farmers' association

NIA/CRS Davao 29/6/2012: Meeting with NIA and CRS

Bangladesh:

Akkelpur 17/10/12: Meeting with farmers in Akkelpur village, Rangpur district. Around 40 men and 10 women farmers present; also 1 staff member from BRRI and 2 from RDRS.

Indonesia: (accompanied by Madonna Casimero and Trina Mendoza)

South Sulawesi, Makassar 15/10/12: Attending communication and wrap-up workshop at Provincial BPTP office. (4 key provincial BPTP staff; district and sub-district extension officers, and key farmer leaders, totaled 20)

Meeting farmers at Maros district and visiting farmer field implementing AWD and LCC (about 6 farmers, 7 extension officers)

South Sulawesi, Makassar 16/10/12: Continued communication and wrap-up workshop: communication materials, video on AWD, response and feedback from farmer leaders and local extension officers on communication materials; formulating plans for disseminating training materials to local extension (Pinrang) and farmer groups (Awolagading) (6 officials, 5 farmer leaders)

Southeast Sulawesi, Kendari. 17/10/12: Farmer group discussion at Bendewuta village, Konawe district, Northwest of Kendari (10 male farmers)

Southeast Sulawesi, Kendari. 18/10/12: Attending FFS graduation and visiting farmer demonstration plots (one ha) at Lapoainda village, Andolo district. (30 farmers of which 9 are female)

Vietnam:

Chan Phu District, 23/10/12: Meeting with farmers (7 men) including the group leader. Also present, the vice chair of the People's Committee, Binh Chanh village, two from the district Plant Protection Department, and one from the District Extension.

Phutan District 23/10/12: Meeting with farmers (6 men, 6 women) including the cooperative leader. Also present – the vice chair of the Phuton People's Committee, the head of Plant Protection in the district, and the vice head of Extension.

Codo District 24/10/12: Meeting with 15 farmers (men) in Trung Thanh village. Also present, the head of Plant Protection in the District.

Other Interviews (IRRC scientists and SDC):

Buresh 26/6/2012: Meeting with Roland Buresh on 26 June 2012 at IRRI.

Heong 29/6/2012: Meeting with KL Heong at IRRI Guest House.

Singleton 22/6/2012: Initial meeting of PCU and the review team at IRRI Guest House.

SDC 6/2012: Meeting with Grant Singleton, David Johnson, Carmen Thoennissen in Bern at SDC office.

Casimero, M.C., June 2012, Interview with Donna Casimero, IRRI Guest House.

Doan, N.P, 22/10/2012, Interview with Doan Ngoch Pho, An Giang Department of Agriculture and Rural Development.

NIA HQ 28/06/2012 National Irrigation Administration, meeting with staff from the Institutional Development Division, and the director of NIA.

Nguyen H.H., 22/10/2012, Interview with Nguyen Han Huan, PPD

Pham, V.D.21/10/2012. Interview with Pham Van Du, HMC.

Appendix 3.B: Checklist of Questions for Key Informant and Field Visit Discussions

IRRC partners - policy level (*influence*)

1. Have there been any changes in policy and implementation strategy relating to the main technology /work group areas of IRRC (e.g., AWD, direct seeding, SSNM/LCC, EBRM, ICM-farmer field schools, storage technology, etc.) in the last 10-15 years?
2. What factors or influences have brought about these changes and how?
3. What is the history of working with IRRI/ IRRC? How did partnerships and collaboration develop over this period? To what extent has this collaboration influenced policy?
4. What would have been the situation without IRRC/ICOP?
5. To what extent are the environmental impacts of IRRC technologies being incorporated into partners' technology dissemination framework? (How important are environmental issues in national rice policy?)

IRRC partners - institutional level (*process, influence, and institutional impacts*)

1. Has the collaborative research process with IRRC had any influence on the structure and interrelationships of local agricultural institutions (NARES)? Has it influenced the research and extension agenda/ activities and resource allocation or changed norms, values and practices? If so, how?
2. To what extent have the IRRC and work groups been able to provide strategic leadership and catalyze stakeholder linkages across the public, private, and CSO sectors? Has there been effective information exchange, capacity building, and shared learning?
3. Has IRRC support helped to leverage funding from partners own resources?

IRRC partners - field level (*outcomes, impacts and impact pathways*)

1. What have been the main changes in rice management practices (pre-and postharvest) in the last 10-15 years? What factors or influences have brought about these changes? What were the challenges in implementing the new technologies and practices? What was the role of IRRC in this change process?
2. How did the partners galvanize community action and cooperation given that incentives differ?
3. How did different organizations (public, private, farmer etc.) adapt to the changes?
4. How were the technologies disseminated? Through what channels, networks and media?
5. What were the outcomes and impacts for farmers/technology users/ agricultural laborers at individual, household and community level?

IRRC partners - field level (*environmental impacts*)

1. How would partners work with farmer groups or organizations to develop systems of monitoring environmental impacts of IRRC technologies?

IRRC partners (*economic impacts*)

1. Do you have some numbers on the degree of adoption or adoption rates of IRRC technologies? Or degree of adoption of the integrated crop management IICM) technology package? Specific adoption numbers (i.e., no. of farmers, or number of hectares) for the following technologies would be helpful if available: SSNM (leaf color chart, or nutrient manager), EBRM, direct seeding (with drum seeder or other), AWD, and SuperBags (hermetic storage).
2. What are their perceived economic impacts of the technologies above (ask where applicable)? Yield effect? Income effect? Cost effect?

3. What are farmer's economic incentives for adopting the IRRC technologies listed above? Potential higher yields? Higher incomes? Cost savings? Less conflict (as in AWD)? Who are the typical adopters (irrigated vs rainfed farmers)?

Farmers/communities (*technology uptake and impact pathways*)

1. How important is rice production in the community (% households growing), other crops grown, importance for income and food security. Other sources of income. % landless?
2. When was the technology (or group of technologies) introduced into the area? What changes have there been? (e.g. variety, planting practice, irrigation management, soil nutrient management, rodent control, storage and processing practices, etc.)
3. Who introduced you to these new practices and technologies? Did men, women and youth participate in technology testing and farmer training? Did implementation involve community action and collaboration (e.g. EBRM)? How were the new practices shared more widely in the community and location?
4. Have adaptations been made by farmers to the technologies? Have some technologies been rejected? By whom and why?

Farmers/communities outcomes and impacts (*socio-cultural and gender impacts)*

1. What are the outcomes from applying the new technologies and practices? (e.g., relating to yields, quality, cropping intensity, water use, labor time (of men and women), fuel savings, rodent, pest and disease management, fertilizer and pesticide use, postharvest loss reduction etc.)
2. What difference has this made? (e.g., to incomes, food supply, market sales, debt reduction, investment, access to agricultural and technical information, employment, etc.) Have there been any impacts on the health of children and adults?
3. What impacts have IRRC supported technologies had on household vulnerability and resilience? e.g. food security in 'hungry' season, with price fluctuations, poor weather etc.
4. Which groups have benefited most? Are some individuals or groups negatively affected—e.g., laborers/ landless; women?
5. In the household, who usually controls agricultural incomes? Who makes decisions on the use of money within the household? Have there been any changes at household level linked to the impacts of new technologies?
6. What have been the impacts at community level—e.g. incidence of conflict linked with NRM; access to natural resources; collective action and joint decision making; changes in attitudes/beliefs.

Farmers/communities (*economic impacts)*

1. What are their perceived economic impacts of the technologies above (ask where applicable)? Yield effect? Income effect? Cost effect?
2. What are farmer's economic incentives for adopting the IRRC technologies listed above? Potential higher yields? Higher incomes? Cost savings? Less conflict (as in AWD)? Who are the typical adopters (irrigated vs. rainfed farmers)?

Appendix Table 2.1: Economic Surplus Spreadsheet Calculation (SDC Cost Only): AWD in the Philippines

Year	εA	Max Yield Change	Gross Cost Change Per Ton	Input cost Change per ha	Input Cost change per ton	Net cost change	Prob of success of yld/cost change	Adoption rate	depreciation rate	deprn factor	K shift	Paddy Rice Price ($/ton) normalized to 2010	Paddy Rice Prodn (tons)	Total Benefits or Change in Total Surplus ($)	SDC Costs WS Workgroup ($) normalized to 2010	Net Benefits ($)	Discounted Total Benefits (5%; t=0 at 2010)	Discounted Total Costs (5% t=0 at 2010)	Discounted net benefits (5% t=0 at 2010)
1997	0.28	0.02	0.05	-0.01	-0.010	0.06	0.50	0.0000	0.000	1.00	0.000000	142.14	11268000	0.00	0.00	0.00	0.00	0.00	0.00
1998	0.28	0.02	0.05	-0.01	-0.010	0.06	0.50	0.0000	0.000	1.00	0.000000	117.31	8554000	0.00	0.00	0.00	0.00	0.00	0.00
1999	0.28	0.02	0.05	-0.01	-0.010	0.06	0.50	0.0000	0.000	1.00	0.000000	123.28	11786600	0.00	0.00	0.00	0.00	0.00	0.00
2000	0.28	0.02	0.05	-0.01	-0.010	0.06	0.50	0.0000	0.000	1.00	0.000000	121.29	12389400	0.00	0.00	0.00	0.00	0.00	0.00
2001	0.28	0.02	0.05	-0.01	-0.010	0.06	0.50	0.0000	0.000	1.00	0.000000	107.44	12954900	0.00	64305.81	-64305.81	0.00	99759.43	-99759.43
2002	0.28	0.02	0.05	-0.01	-0.010	0.06	0.50	0.0012	0.000	1.00	0.000037	117.73	13270700	57930.01	66056.25	-8126.24	85589.00	97595.16	-12006.16
2003	0.28	0.02	0.05	-0.01	-0.010	0.06	0.50	0.0016	0.000	1.00	0.000051	114.92	13499900	78962.59	67572.79	11389.80	111108.29	95081.70	16026.59
2004	0.28	0.02	0.05	-0.01	-0.010	0.06	0.50	0.0022	0.000	1.00	0.000070	124.55	14496800	126120.74	70832.22	55288.53	169013.86	94921.95	74091.91
2005	0.28	0.02	0.05	-0.01	-0.010	0.06	0.50	0.0030	0.000	1.00	0.000096	148.95	14603000	208449.53	75449.74	132999.79	266040.30	96295.11	169745.18
2006	0.28	0.02	0.05	-0.01	-0.010	0.06	0.50	0.0041	0.000	1.00	0.000131	169.18	15326700	340783.89	79591.93	261191.96	414224.95	96744.49	317480.46
2007	0.28	0.02	0.05	-0.01	-0.010	0.06	0.50	0.0057	0.000	1.00	0.000180	207.60	16240200	607244.35	81893.15	525351.20	702961.24	94801.56	608159.68
2008	0.28	0.02	0.05	-0.01	-0.010	0.06	0.50	0.0078	0.000	1.00	0.000247	294.74	16815500	1222334.67	88660.99	1133673.68	1347623.97	97748.74	1249875.23
2009	0.28	0.02	0.05	-0.01	-0.010	0.06	0.50	0.0106	0.000	1.00	0.000337	295.37	16266400	1620688.17	92320.30	1528367.87	1701722.58	96936.32	1604786.26
2010	0.28	0.02	0.05	-0.01	-0.010	0.06	0.50	0.0145	0.000	1.00	0.000461	329.64	15771700	2394788.42	95904.17	2298884.25	2394788.42	95904.17	2298884.25
2011	0.28	0.02	0.05	-0.01	-0.010	0.06	0.50	0.0198	0.000	1.00	0.000628	329.64	15771700	3263210.15	100363.25	3162846.90	3107819.19	95584.04	3012235.15
2012	0.28	0.02	0.05	-0.01	-0.010	0.06	0.50	0.0269	0.020	0.98	0.000836	329.64	15771700	4344983.04	100363.25	4244619.79	3941027.70	91032.42	3849995.28
2013	0.28	0.02	0.05	-0.01	-0.010	0.06	0.50	0.0364	0.040	0.96	0.001108	329.64	15771700	5760459.94		5760459.94	4976101.88	0.00	4976101.88
2014	0.28	0.02	0.05	-0.01	-0.010	0.06	0.50	0.0490	0.060	0.94	0.001460	329.64	15771700	7594189.59		7594189.59	6247758.57	0.00	6247758.57
2015	0.28	0.02	0.05	-0.01	-0.010	0.06	0.50	0.0649	0.080	0.92	0.001892	329.64	15771700	9839383.00		9839383.00	7709414.04	0.00	7709414.04
2016	0.28	0.02	0.05	-0.01	-0.010	0.06	0.50	0.0851	0.100	0.90	0.002428	329.64	15771700	12628008.94		12628008.94	9423214.70	0.00	9423214.70
																Total Discounted Benefits (1997-2012):	14,241,919.50	1,152,405.09	13,089,514.41
																Total Discounted Benefits (1997-2016):	42,598,408.70	1,152,405.09	41,446,003.60
																		BCR (1997-2012):	12.36
																		BCR (1997-2016):	36.96
																		IRR (1997-2012):	0.951
																		IRR (1997-2016):	0.971

Appendix Table 2.2: Economic Surplus Spreadsheet Calculation (SDC Cost Only): EBRM in Vietnam

Year	εA	Max Yield Change	Gross Cost Change Per Ton	Input cost Change per ha	Input Cost change per ton	Net cost change	Prob of success of yld/cost change	Adoption rate	depreciation rate	deprn factor	K shift	Paddy Rice Price ($/ton) normalized 2010	Paddy Rice Prodn (tons)	Total Benefits or Change in Total Surplus ($)	SDC Total Costs LPCE Workgroup ($) normalized to 2010	Net Benefits ($)	Discounted Total Benefits (5%; t=0 at 2010)	Discounted Total Costs (5% t=0 at 2010)	Discounted net benefits (5% t=0 at 2010)
1997	0.31	0.03	0.08	0.05	0.049	0.03	0.50	0.0000	0.000	1.00	0.000000	66.57	27523900	0.00	0.00	0.00	0.00	0.00	0.00
1998	0.31	0.03	0.08	0.05	0.049	0.03	0.50	0.0000	0.000	1.00	0.000000	77.91	29145500	0.00	0.00	0.00	0.00	0.00	0.00
1999	0.31	0.03	0.08	0.05	0.049	0.03	0.50	0.0000	0.000	1.00	0.000000	65.74	31393800	0.00	0.00	0.00	0.00	0.00	0.00
2000	0.31	0.03	0.08	0.05	0.049	0.03	0.50	0.0000	0.000	1.00	0.000000	58.02	32529500	0.00	0.00	0.00	0.00	0.00	0.00
2001	0.31	0.03	0.08	0.05	0.049	0.03	0.50	0.0000	0.000	1.00	0.000000	48.76	32108400	0.00	64869.67	-64869.67	0.00	100634.15	-100634.15
2002	0.31	0.03	0.08	0.05	0.049	0.03	0.50	0.0000	0.000	1.00	0.000000	62.61	34447200	0.00	66635.45	-66635.45	0.00	98450.91	-98450.91
2003	0.31	0.03	0.08	0.05	0.049	0.03	0.50	0.0000	0.000	1.00	0.000000	59.76	34568800	0.00	68165.29	-68165.29	0.00	95915.40	-95915.40
2004	0.31	0.03	0.08	0.05	0.049	0.03	0.50	0.0000	0.000	1.00	0.000000	76.24	36148900	0.00	71453.30	-71453.30	0.00	95754.25	-95754.25
2005	0.31	0.03	0.08	0.05	0.049	0.03	0.50	0.0000	0.000	1.00	0.000000	87.20	35832900	0.00	76111.31	-76111.31	0.00	97139.46	-97139.46
2006	0.31	0.03	0.08	0.05	0.049	0.03	0.50	0.0002	0.000	1.00	0.000002	96.61	35849500	8621.41	80289.82	-71668.41	10479.37	97592.78	-87113.40
2007	0.31	0.03	0.08	0.05	0.049	0.03	0.50	0.0004	0.000	1.00	0.000006	140.07	35942700	28993.03	82611.21	-53618.18	33563.06	95632.81	-62069.75
2008	0.31	0.03	0.08	0.05	0.049	0.03	0.50	0.0008	0.000	1.00	0.000013	228.53	38729800	117678.13	89438.40	28239.73	129740.14	98605.83	31134.31
2009	0.31	0.03	0.08	0.05	0.049	0.03	0.50	0.0019	0.000	1.00	0.000031	228.53	38950200	271930.65	93129.80	178800.85	285527.18	97786.29	187740.89
2010	0.31	0.03	0.08	0.05	0.049	0.03	0.50	0.0044	0.000	1.00	0.000069	228.53	39988900	634581.79	96745.08	537836.70	634581.79	96745.08	537836.70
2011	0.31	0.03	0.08	0.05	0.049	0.03	0.50	0.0097	0.000	1.00	0.000154	228.53	39988900	1408251.97	101243.26	1307008.71	1341192.36	96422.15	1244770.20
2012	0.31	0.03	0.08	0.05	0.049	0.03	0.50	0.0204	0.020	0.98	0.000319	228.53	39988900	2912534.30	101243.26	2811291.04	2641754.47	91830.62	2549923.85
2013	0.31	0.03	0.08	0.05	0.049	0.03	0.50	0.0392	0.040	0.96	0.000599	228.53	39988900	5478390.73		5478390.73	4732439.89	0.00	4732439.89
2014	0.31	0.03	0.08	0.05	0.049	0.03	0.50	0.0650	0.060	0.94	0.000973	228.53	39988900	8897527.82		8897527.82	7320018.16	0.00	7320018.16
2015	0.31	0.03	0.08	0.05	0.049	0.03	0.50	0.0899	0.080	0.92	0.001318	228.53	39988900	12044991.19		12044991.19	9437565.77	0.00	9437565.77
2016	0.31	0.03	0.08	0.05	0.049	0.03	0.50	0.1074	0.100	0.90	0.001540	228.53	39988900	14076751.73		14076751.73	10504288.88	0.00	10504288.88
																Total Discounted Benefits (1997-2012):	5,076,838.36	1,162,509.73	3,914,328.64
																Total Discounted Benefits (1997-2016):	37,071,151.06	1,162,509.73	35,908,641.33

BCR (1997-2012):	4.37
BCR (1997-2016):	31.89
IRR (1997-2012):	0.347
IRR (1997-2016):	0.533

Appendix Table 2.3: Economic Surplus Spreadsheet Calculation (SDC Cost Only): SSNM/LCC in Bangladesh

Year	εA	Max Yield Change	Gross Cost Change Per Ton	Input cost Change per ha	Input Cost change per ton	Net cost change	Prob of success of yld/cost change	Adoption rate	depreciation rate	deprn factor	K shift	Paddy Rice Price ($/ton) normalized 2010	Paddy Rice Prodn (tons)	Total Benefits or Change in Total Surplus ($)	SDC Total Costs PS Workgroup ($) normalized to 2010	Net Benefits ($)	Discounted Total Benefits (5%; t=0 at 2010)	Discounted Total Costs (5% t=0 at 2010)	Discounted net benefits (5% t=0 at 2010)
1997	0.25	0.08	0.32	0.00	0.000	0.32	0.50	0.0000	0.000	1.00	0.000000	54.98	28152000	0.00	175670.64	-175670.64	0.00	331253.19	-331253.19
1998	0.25	0.08	0.32	0.00	0.000	0.32	0.50	0.0000	0.000	1.00	0.000000	66.62	29710000	0.00	191949.50	-191949.50	0.00	344713.73	-344713.73
1999	0.25	0.08	0.32	0.00	0.000	0.32	0.50	0.0000	0.000	1.00	0.000000	68.62	34430000	0.00	203368.23	-203368.23	0.00	347828.68	-347828.68
2000	0.25	0.08	0.32	0.00	0.000	0.32	0.50	0.0000	0.000	1.00	0.000000	62.97	37627500	0.00	211416.20	-211416.20	0.00	344374.72	-344374.72
2001	0.25	0.08	0.32	0.00	0.000	0.32	0.50	0.0000	0.000	1.00	0.000000	58.55	36269000	0.00	222704.28	-222704.28	0.00	345487.43	-345487.43
2002	0.25	0.08	0.32	0.00	0.000	0.32	0.50	0.0000	0.000	1.00	0.000000	63.84	37593000	0.00	228766.39	-228766.39	0.00	337992.15	-337992.15
2003	0.25	0.08	0.32	0.00	0.000	0.32	0.50	0.0000	0.000	1.00	0.000000	61.06	38361400	0.00	234018.48	-234018.48	0.00	329287.50	-329287.50
2004	0.25	0.08	0.32	0.00	0.000	0.32	0.50	0.0000	0.000	1.00	0.000000	92.27	36236000	0.00	245306.55	-245306.55	0.00	328734.24	-328734.24
2005	0.25	0.08	0.32	0.00	0.000	0.32	0.50	0.0000	0.000	1.00	0.000000	99.43	39795600	0.00	261297.99	-261297.99	0.00	333489.81	-333489.81
2006	0.25	0.08	0.32	0.00	0.000	0.32	0.50	0.0000	0.000	1.00	0.000000	102.61	40773000	0.00	275643.25	-275643.25	0.00	335046.09	-335046.09
2007	0.25	0.08	0.32	0.00	0.000	0.32	0.50	0.0000	0.000	1.00	0.000000	123.28	43181000	0.00	283612.84	-283612.84	0.00	328317.31	-328317.31
2008	0.25	0.08	0.32	0.00	0.000	0.32	0.50	0.0019	0.000	1.00	0.000308	152.68	46742000	2200068.17	307051.27	1893016.90	2425575.15	338524.02	2087051.13
2009	0.25	0.08	0.32	0.00	0.000	0.32	0.50	0.0026	0.000	1.00	0.000421	152.68	47724000	3068188.10	319724.22	2748463.88	3221597.50	335710.43	2885887.07
2010	0.25	0.08	0.32	0.00	0.000	0.32	0.50	0.0036	0.000	1.00	0.000575	152.68	49355000	4332939.40	332135.88	4000803.53	4332939.40	332135.88	4000803.53
2011	0.25	0.08	0.32	0.00	0.000	0.32	0.50	0.0049	0.000	1.00	0.000785	152.68	49355000	5914784.06	347578.59	5567205.48	5633127.68	331027.22	5302100.45
2012	0.25	0.08	0.32	0.00	0.000	0.32	0.50	0.0067	0.020	0.98	0.001049	152.68	49355000	7908890.28	347578.59	7561311.69	7173596.63	315264.02	6858332.60
2013	0.25	0.08	0.32	0.00	0.000	0.32	0.50	0.0091	0.040	0.96	0.001402	152.68	49355000	10564084.94		10564084.94	9125653.76	0.00	9125653.76
2014	0.25	0.08	0.32	0.00	0.000	0.32	0.50	0.0124	0.060	0.94	0.001870	152.68	49355000	14092222.89		14092222.89	11593706.65	0.00	11593706.65
2015	0.25	0.08	0.32	0.00	0.000	0.32	0.50	0.0169	0.080	0.92	0.002490	152.68	49355000	18767831.92		18767831.92	14705087.39	0.00	14705087.39
2016	0.25	0.08	0.32	0.00	0.000	0.32	0.50	0.0230	0.100	0.90	0.003309	152.68	49355000	24942717.37		24942717.37	18612639.73	0.00	18612639.73
																Total Discounted Benefits (1997-2012):	22,786,836.36	5,359,186.43	17,427,649.93
																Total Discounted Benefits (1997-2016):	76,823,923.90	5,359,186.43	71,464,737.47
																		BCR (1997-2012):	4.25
																		BCR (1997-2016):	14.33
																		IRR (1997-2012):	0.265
																		IRR (1997-2016):	0.346

Appendix Table 2.4: Economic Surplus Spreadsheet Calculation (SDC Cost Only): DSR/SDV in Bangladesh

Year	εA	Max Yield Change	Gross Cost Change Per Ton	Input cost Change per ha	Input Cost change per ton	Net cost change	Prob of success of yld/cost change	Adoption rate	depreciation rate	deprn factor	K shift	Paddy Rice Price ($/ton) normalized 2010	Paddy Rice Prodn (tons)	Total Benefits or Change in Total Surplus ($)	SDC Total Costs LPCE Workgroup ($) normalized to 2010	Net Benefits ($)	Discounted Total Benefits (5%; t=0 at 2010)	Discounted Total Costs (5% t=0 at 2010)	Discounted net benefits (5% t=0 at 2010)
1997	0.25	0.015	0.06	-0.01	-0.010	0.07	0.50	0.0000000	0.000	1.00	0.000000	54.98	28152000	0.00	0.00	0.00	0.00	0.00	0.00
1998	0.25	0.015	0.06	-0.01	-0.010	0.07	0.50	0.0000000	0.000	1.00	0.000000	66.62	29710000	0.00	0.00	0.00	0.00	0.00	0.00
1999	0.25	0.015	0.06	-0.01	-0.010	0.07	0.50	0.0000000	0.000	1.00	0.000000	68.62	34430000	0.00	0.00	0.00	0.00	0.00	0.00
2000	0.25	0.015	0.06	-0.01	-0.010	0.07	0.50	0.0000000	0.000	1.00	0.000000	62.97	37627500	0.00	0.00	0.00	0.00	0.00	0.00
2001	0.25	0.015	0.06	-0.01	-0.010	0.07	0.50	0.0000000	0.000	1.00	0.000000	58.55	36269000	0.00	64869.67	-64869.67	0.00	100634.15	-100634.15
2002	0.25	0.015	0.06	-0.01	-0.010	0.07	0.50	0.0000000	0.000	1.00	0.000000	63.84	37593000	0.00	66635.45	-66635.45	0.00	98450.91	-98450.91
2003	0.25	0.015	0.06	-0.01	-0.010	0.07	0.50	0.0000000	0.000	1.00	0.000000	61.06	38361400	0.00	68165.29	-68165.29	0.00	95915.40	-95915.40
2004	0.25	0.015	0.06	-0.01	-0.010	0.07	0.50	0.0007954	0.000	1.00	0.000028	92.27	36236000	92890.89	71453.30	21437.60	124482.68	95754.25	28728.43
2005	0.25	0.015	0.06	-0.01	-0.010	0.07	0.50	0.0010591	0.000	1.00	0.000037	99.43	39795600	146374.46	76111.31	70263.15	186815.02	97139.46	89675.56
2006	0.25	0.015	0.06	-0.01	-0.010	0.07	0.50	0.0014097	0.000	1.00	0.000049	102.61	40773000	205999.92	80289.82	125710.10	250394.19	97592.78	152801.42
2007	0.25	0.015	0.06	-0.01	-0.010	0.07	0.50	0.0018755	0.000	1.00	0.000066	123.28	43181000	348709.23	82611.21	266098.02	403674.53	95632.81	308041.72
2008	0.25	0.015	0.06	-0.01	-0.010	0.07	0.50	0.0024936	0.000	1.00	0.000087	152.68	46742000	621530.71	89438.40	532092.32	685237.61	98605.83	586631.78
2009	0.25	0.015	0.06	-0.01	-0.010	0.07	0.50	0.0033127	0.000	1.00	0.000116	152.68	47724000	843046.01	93129.80	749916.21	885198.31	97786.29	787412.02
2010	0.25	0.015	0.06	-0.01	-0.010	0.07	0.50	0.0043962	0.000	0.95	0.000146	152.68	49355000	1099148.92	96745.08	1002403.84	1099148.92	96745.08	1002403.84
2011	0.25	0.015	0.06	-0.01	-0.010	0.07	0.50	0.0058255	0.000	0.90	0.000183	152.68	49355000	1379875.24	101243.26	1278631.98	1314166.90	96422.15	1217744.74
2012	0.25	0.015	0.06	-0.01	-0.010	0.07	0.50	0.0073969	0.020	0.85	0.000220	152.68	49355000	1654743.87	101243.26	1553500.61	1500901.47	91830.62	1409070.85
2013	0.25	0.015	0.06	-0.01	-0.010	0.07	0.50	0.0093525	0.040	0.80	0.000261	152.68	49355000	1969177.14		1969177.14	1701049.25	0.00	1701049.25
2014	0.25	0.015	0.06	-0.01	-0.010	0.07	0.50	0.0117647	0.060	0.75	0.000308	152.68	49355000	2322262.03		2322262.03	1910530.72	0.00	1910530.72
2015	0.25	0.015	0.06	-0.01	-0.010	0.07	0.50	0.0147066	0.080	0.70	0.000360	152.68	49355000	2709451.11		2709451.11	2122925.84	0.00	2122925.84
2016	0.25	0.015	0.06	-0.01	-0.010	0.07	0.50	0.0182436	0.100	0.65	0.000414	152.68	49355000	3121036.932		3121036.93	2328965.81	0.00	2328965.81

	Discounted Total Benefits	Discounted Total Costs	Discounted net benefits
Total Discounted Benefits (1997-2012):	6,450,019.63	1,162,509.73	5,287,509.90
Total Discounted Benefits (1997-2016):	14,513,491.25	1,162,509.73	13,350,981.52

BCR (1997-2012):	5.55
BCR (1997-2016):	12.48
IRR (1997-2012):	0.567
IRR (1997-2016):	0.603

Appendix Table 2.5: Economic Surplus Spreadsheet Calculation (SDC Cost Only): AR in the Philippines

Year	εA	Max Yield Change	Gross Cost Change Per Ton	Input cost Change per ha	Input Cost change per ton	Net cost change	Prob of success of yld/cost change	Adoption rate	depreciati on rate	deprn factor	K shift	Paddy Rice Price ($/ton) normalized to 2010	Paddy Rice Prodn (tons)	Total Benefits or Change in Total Surplus ($)	Total SDC Costs WS Workgroup ($) normalized to 2010	Net Benefits ($)	Discounted Total Benefits (5%; t=0 at 2010)	Discounted Total Costs (5% t=0 at 2010)	Discounted net benefits (5% t=0 at 2010)
1997	0.28	-0.15	-0.54	-0.50	-0.588	0.05	0.50	0.0000	0.000	1.00	0.000000	142.14	11268000	0.00	0.00	0.00	0.00	0.00	0.00
1998	0.28	-0.15	-0.54	-0.50	-0.588	0.05	0.50	0.0000	0.000	1.00	0.000000	117.31	8554000	0.00	0.00	0.00	0.00	0.00	0.00
1999	0.28	-0.15	-0.54	-0.50	-0.588	0.05	0.50	0.0000	0.000	1.00	0.000000	123.28	11786600	0.00	0.00	0.00	0.00	0.00	0.00
2000	0.28	-0.15	-0.54	-0.50	-0.588	0.05	0.50	0.0000	0.000	1.00	0.000000	121.29	12389400	0.00	0.00	0.00	0.00	0.00	0.00
2001	0.28	-0.15	-0.54	-0.50	-0.588	0.05	0.50	0.0000	0.000	1.00	0.000000	107.44	12954900	0.00	64305.81	-64305.81	0.00	99759.43	-99759.43
2002	0.28	-0.15	-0.54	-0.50	-0.588	0.05	0.50	0.0000	0.000	1.00	0.000000	117.73	13270700	0.00	66056.25	-66056.25	0.00	97595.16	-97595.16
2003	0.28	-0.15	-0.54	-0.50	-0.588	0.05	0.50	0.0000	0.000	1.00	0.000000	114.92	13499900	0.00	67572.79	-67572.79	0.00	95081.70	-95081.70
2004	0.28	-0.15	-0.54	-0.50	-0.588	0.05	0.50	0.0000	0.000	1.00	0.000000	124.55	14496800	0.00	70832.22	-70832.22	0.00	94921.95	-94921.95
2005	0.28	-0.15	-0.54	-0.50	-0.588	0.05	0.50	0.0000	0.000	1.00	0.000000	148.95	14603000	0.00	75449.74	-75449.74	0.00	96295.11	-96295.11
2006	0.28	-0.15	-0.54	-0.50	-0.588	0.05	0.50	0.0002	0.000	1.00	0.000004	169.18	15326700	11450.50	79591.93	-68141.43	13918.16	96744.49	-82826.33
2007	0.28	-0.15	-0.54	-0.50	-0.588	0.05	0.50	0.0002	0.000	1.00	0.000006	207.60	16240200	19767.27	81893.15	-62125.88	22883.08	94801.56	-71918.47
2008	0.28	-0.15	-0.54	-0.50	-0.588	0.05	0.50	0.0003	0.000	1.00	0.000008	294.74	16815500	38567.66	88660.99	-50093.33	42520.85	97748.74	-55227.90
2009	0.28	-0.15	-0.54	-0.50	-0.588	0.05	0.50	0.0004	0.000	1.00	0.000010	295.37	16266400	49599.66	92320.30	-42720.64	52079.65	96936.32	-44856.67
2010	0.28	-0.15	-0.54	-0.50	-0.588	0.05	0.50	0.0005	0.000	1.00	0.000014	329.64	15771700	71154.68	95904.17	-24749.49	71154.68	95904.17	-24749.49
2011	0.28	-0.15	-0.54	-0.50	-0.588	0.05	0.50	0.0007	0.000	1.00	0.000018	329.64	15771700	94255.31	100363.25	-6107.93	89766.96	95584.04	-5817.08
2012	0.28	-0.15	-0.54	-0.50	-0.588	0.05	0.50	0.0009	0.020	0.98	0.000024	329.64	15771700	122222.86	100363.25	21859.61	110859.74	91032.42	19827.31
2013	0.28	-0.15	-0.54	-0.50	-0.588	0.05	0.50	0.0012	0.040	0.96	0.000030	329.64	15771700	158191.67		158191.67	136651.91	0.00	136651.91
2014	0.28	-0.15	-0.54	-0.50	-0.588	0.05	0.50	0.0016	0.060	0.94	0.000039	329.64	15771700	204264.57		204264.57	168048.96	0.00	168048.96
2015	0.28	-0.15	-0.54	-0.50	-0.588	0.05	0.50	0.0021	0.080	0.92	0.000050	329.64	15771700	260346.19		260346.19	203988.06	0.00	203988.06
2016	0.28	-0.15	-0.54	-0.50	-0.588	0.05	0.50	0.0027	0.100	0.90	0.000064	329.64	15771700	330553.47		330553.47	246664.09	0.00	246664.09

Total Discounted Benefits (1997-2012):	403,183.11	1,152,405.09	(749,221.98)
Total Discounted Benefits (1997-2016):	1,158,536.13	1,152,405.09	6,131.04

BCR (1997-2012):	0.35
BCR (1997-2016):	1.01
IRR (1997-2012):	negative
IRR (1997-2016):	0.05

Appendix Table 2.6: Economic Surplus Spreadsheet Calculation (SDC Cost Only): HSS in the Philippines

Year	εA	Max Yield Change	Gross Cost Change Per Ton	Input cost Change per ha	Input Cost change per ton	Net cost change	Prob of success of yld/cost change	Adoption rate	depreciation rate	deprn factor	K shift	Seed Rice Price ($/ton) normalized to 2010	Seed Rice Prodn (tons)	Total Benefits or Change in Total Surplus ($)	SDC Costs PP Workgroup ($) normalized to 2010	Net Benefits ($)	Discounted Total Benefits (5%; t=0 at 2010)	Discounted Total Costs (5% t=0 at 2010)	Discounted net benefits (5% t=0 at 2010)
1997	0.28	0.06	0.21	0.00	0.000	0.21	0.50	0.0000	0.000	1.00	0.000000	430.74	171000	0.00	0.00	0.00	0.00	0.00	0.00
1998	0.28	0.06	0.21	0.00	0.000	0.21	0.50	0.0000	0.000	1.00	0.000000	339.21	191000	0.00	0.00	0.00	0.00	0.00	0.00
1999	0.28	0.06	0.21	0.00	0.000	0.21	0.50	0.0000	0.000	1.00	0.000000	375.94	191000	0.00	0.00	0.00	0.00	0.00	0.00
2000	0.28	0.06	0.21	0.00	0.000	0.21	0.50	0.0000	0.000	1.00	0.000000	345.71	193000	0.00	0.00	0.00	0.00	0.00	0.00
2001	0.28	0.06	0.21	0.00	0.000	0.21	0.50	0.0000	0.000	1.00	0.000000	315.60	195000	0.00	0.00	0.00	0.00	0.00	0.00
2002	0.28	0.06	0.21	0.00	0.000	0.21	0.50	0.0000	0.000	1.00	0.000000	320.36	192000	0.00	0.00	0.00	0.00	0.00	0.00
2003	0.28	0.06	0.21	0.00	0.000	0.21	0.50	0.0000	0.000	1.00	0.000000	311.99	201000	0.00	15318.84	-15318.84	0.00	21555.15	-21555.15
2004	0.28	0.06	0.21	0.00	0.000	0.21	0.50	0.0000	0.000	1.00	0.000000	316.31	206000	0.00	16057.76	-16057.76	0.00	21518.93	-21518.93
2005	0.28	0.06	0.21	0.00	0.000	0.21	0.50	0.0000	0.000	1.00	0.000000	342.74	204000	0.00	17104.56	-17104.56	0.00	21830.23	-21830.23
2006	0.28	0.06	0.21	0.00	0.000	0.21	0.50	0.0000	0.000	1.00	0.000000	388.19	204000	0.00	18043.60	-18043.60	0.00	21932.10	-21932.10
2007	0.28	0.06	0.21	0.00	0.000	0.21	0.50	0.0000	0.000	1.00	0.000000	444.07	204000	0.00	18565.28	-18565.28	0.00	21491.64	-21491.64
2008	0.28	0.06	0.21	0.00	0.000	0.21	0.50	0.0000	0.000	1.00	0.000000	500.62	204000	0.00	20099.56	-20099.56	0.00	22159.77	-22159.77
2009	0.28	0.06	0.21	0.00	0.000	0.21	0.50	0.0000	0.000	1.00	0.000000	484.55	204000	0.00	20929.13	-20929.13	0.00	21975.59	-21975.59
2010	0.28	0.06	0.21	0.00	0.000	0.21	0.50	0.0000	0.000	1.00	0.000000	532.03	204000	0.00	21741.60	-21741.60	0.00	21741.60	-21741.60
2011	0.28	0.06	0.21	0.00	0.000	0.21	0.50	0.0194	0.000	1.00	0.002081	532.03	204000	225955.78	22752.48	203203.30	215195.98	21669.03	193526.95
2012	0.28	0.06	0.21	0.00	0.000	0.21	0.50	0.0235	0.020	0.98	0.002471	532.03	204000	268290.54	22752.48	245538.06	243347.43	20637.17	222710.26
2013	0.28	0.06	0.21	0.00	0.000	0.21	0.50	0.0285	0.040	0.96	0.002930	532.03	204000	318145.50		318145.50	274826.04	0.00	274826.04
2014	0.28	0.06	0.21	0.00	0.000	0.21	0.50	0.0344	0.060	0.94	0.003469	532.03	204000	376703.10		376703.10	309914.57	0.00	309914.57
2015	0.28	0.06	0.21	0.00	0.000	0.21	0.50	0.0412	0.080	0.92	0.004059	532.03	204000	440816.15		440816.15	345390.99	0.00	345390.99
2016	0.28	0.06	0.21	0.00	0.000	0.21	0.50	0.0492	0.100	0.90	0.004740	532.03	204000	514759.55		514759.55	384121.50	0.00	384121.50

Total Discounted Benefits (1997-2012):	458,543.40	216,511.20	242,032.21
Total Discounted Benefits (1997-2016):	1,772,796.51	216,511.20	1,556,285.31
BCR (1997-2012):			2.12
BCR (1997-2016):			8.19
IRR (1997-2012):			0.233
IRR (1997-2016):			0.414