Consultative Group on International Agricultural Research
SCIENCE COUNCIL
Standing Panel on Impact Assessment (SPIA)

Natural Resources Management Research Impacts: Evidence from the CGIAR

SCIENCE COUNCIL SECRETARIAT
October 2006

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Foreword

This is the final report of the Standing Panel on Impact Assessment (SPIA). Convened by the Science Council (SC) of the Consultative Group on International Agricultural Research (CGIAR), the Panel assessed the impacts of the CGIAR's natural resources management research.

In 2003, the then SPIA Chair, Hans Gregersen, was asked by the CGIAR Director to develop an initiative that would assess the impacts of past investments in natural resources management research (NRMR) in the CGIAR system (hereafter, CG system), and improve the system's capacity to conduct such assessments in the future. This request was in response to formal concerns on the dearth of documented credible evidence that NRMR substantively contributes to the CGIAR mission to combat poverty, enhance food security and protect the environment.[1] SPIA responded by assessing three elements: case studies of CGIAR NRMR, NRMR impacts from a systemwide program and further development of NRMR impact assessment methods.

For the first element, SPIA commissioned five impact assessment case studies on research by five CGIAR centers and their partners. The aim was to generate evidence from a variety of NRMR types commonly undertaken by the CGIAR. Case studies were selected on the basis of the quality of proposals submitted by all the centers. SPIA provided modest support for implementing the five winning proposals. Two more centers volunteered case studies for inclusion in the exercise, on the understanding that the centers would meet all the expenses and that the two case studies would undergo the same rigorous peer review as the original five. The full case studies and methodology will be published by CAB International (CABI) in 2006 in a book entitled *The Impact of Natural Resource Management Research: Studies from the CGIAR*. Some of the case studies have already been published by centers in more detail.

For the second element, SPIA picked one of the oldest systemwide programs in the CG system – the Alternatives to Slash-and-Burn Programme (ASB). ASB's research focuses on natural resource management–poverty links and impacts on the livelihoods of poor people who live in forest margins.

The third element involved two activities and outputs: (i) development of a paper by the Center Directors' Committee on the state-of-the-art NRMR impact assessment in the centers; and, (ii) development of improved approaches to, and methods for assessing the impacts of, NRMR. The latter activity is ongoing and part of a longer term SPIA project to develop, with the center impact assessment focal points, more comprehensive strategic guidelines for impact assessment in the CGIAR.[2]

1 See for example World Bank/OED (2003), Raitzer (2003), and Kelley and Gregersen (2004).

2 These guidelines were first suggested at the SPIA-sponsored systemwide meeting on impact assessment in Rome in 2000 (see TAC 2001a). At the time, it was agreed that developing the guidelines was a longer-term activity best undertaken when a wider array of good assessments were in hand to ensure the guidelines were practical and based on CG experience.

Acknowledgements

A natural resources economist of international renown, Professor David Zilberman from the University of California, Berkeley, USA, served as a methodology consultant for SPIA. He provided critical guidance on methodology and the case studies.

This initiative and the final report document benefited from the input and involvement of many individuals. We would particularly like to recognize and thank former SPIA member, Hermann Waibel, who acted as the SPIA point person for this project and diligently steered and advised on the case studies. We also thank the following people: former SC/SPIA members, Alain deJanvry and Dick Harwood; current members, Flavio Avila, Mywish Maredia and Prabhu Pingali; Science Council Secretariat staff, Tim Kelley and Ruben Echeverria; SPIA consultants, David Zilberman and David Raitzer and the center case study leaders: Tim Dalton, Nancy Johnson, and Nina Lilja (CIAT); Mike Spilsbury (CIFOR); Vijay Laxmi Pandey and Olaf Erenstein (CIMMYT); Kamel Shideed and Veronique Alary (ICARDA); Meredith Giordano (IWMI); Olu Ajayi and Frank Place (ICRAF); and Madan Dey and Patrick Kambewa (WorldFish). We are grateful to Sam Fujisaka and Doug White, who wrote an insightful piece on the state-of-the-art of NRMR impact assessment in the CGIAR. We also appreciate inputs from Adel El Beltagy and Joachim Voss, who interacted with us throughout. Finally, we thank the four anonymous peer reviewers who diligently reviewed the seven case studies and provided the case study teams with insightful and useful suggestions.

H.G. Gregersen
Past Chairman
SPIA

J.G. Ryan
Chairman
SPIA

Acronyms

AFSED	Arab Fund for Socioeconomic Development
ASB	Alternatives to Slash-and-Burn Programme
BCR	benefit–cost ratio
C&I	Criteria and indicators
CABI	CAB International
CAPRi	CGIAR Program on Collective Action and Property Rights
CAR	Corrective action request
CDC	Center Directors' Committee
CG	Consultative Group
CGE	Computable General Equilibrium
CGI	Crop germplasm improvement
CGIAR	Consultative Group on International Agricultural Research
CIAT	Centro Internacional de Agricultura Tropical (International Center for Tropical Agriculture)
CIFOR	Center for International Forestry Research
CIMMYT	Centro Internacional de Mejoramiento de Maíz y Trigo (International Maize and Wheat Improvement Center)
CSR	Cropping systems research
EIRR	Economic internal rate of return
FAO	Food and Agriculture Organization of the United Nations
FIRR	Financial internal rate of return
FPR	Farmer participatory research
FSC	Forest Stewardship Council
FSR	Farming systems research
GIS	Geographic information system
GNP	Gross national product
GTAP	Global Trade Analysis Project
IAA	Integrated aquaculture–agriculture
IARC	International agricultural research center
IBSRAM	International Board for Soil Research and Management
ICARDA	International Center for Agricultural Research in the Dry Areas
ICRAF	World Agroforestry Centre
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IDRC	International Development Research Centre
IFAD	International Fund for Agricultural Development
IFDC	International Fertilizer Development Center
IFPRI	International Food Policy Research Institute
IGP	Indo-Gangetic Plains
IIMI	International Irrigation Management Institute (now IWMI)
IITA	International Institute for Tropical Agriculture
ILRI	International Livestock Research Institute
IMPSA	Irrigation Management Policy Support Activity
IMT	Irrigation management transfer
INRM	Integrated natural resources management

INRMR	Integrated natural resources management research
IPG	International public good
IPGRI	International Plant Genetic Resources Institute
IPM	Integrated pest management
IRR	Internal rate of return
IRRI	International Rice Research Institute
ISNAR	International Services for National Agricultural Research
ISP	Information service provider
IWMI	International Water Management Institute
M&M	Mashreq/Maghreb
MDG	Millennium Development Goal
MEA	Millennium Ecosystem Assessment
NARS	National agricultural research system
NGO	Non-governmental organization
NPV	Net present value
NRM	Natural resources management
NRMR	Natural resources management research
R&D	Research and development
RBM	Results-based management
RT	Reduced tillage
RWC	Rice–Wheat Consortium
S&W	Soil and water
SC	Science Council of the CGIAR
SCUAF	Soil Change Under Agroforestry
SFM	Sustainable forest management
SPIA	Standing Panel on Impact Assessment
TAC	Technical Advisory Committee (now Science Council)
TI	Tornqvist Index
WANA	West Asia and North Africa
WARDA	Africa Rice Center (formerly West African Rice Development Association)
WorldFish	WorldFish Center (formerly International Center for Living Aquatic Resources Management, ICLARM)
WUA	Water users' association
ZT	Zero tillage

Summary

This document presents the results of SPIA's initiative to assess the impacts of past investments in NRMR in the CG system. NRMR encompasses research on land, water and biodiversity resources management. It focuses on generating knowledge that results in technology options and how to sustainably enhance the productivity and stability of ecosystem resources. The initiative was a response to concerns on the dearth of documented credible evidence that NRMR substantially contributes to realizing the CGIAR mission on poverty, food security and the environment.

SPIA commissioned five impact assessment case studies associated with the research of five CG centers. Two more centers volunteered case studies for inclusion in the overall exercise, on the understanding that their case studies would undergo the same rigorous peer review as the original five. The seven case studies are the main focus of the SPIA NRMR impact assessment initiative. This report also carries results from the Alternatives to Slash-and-Burn Programme (ASB), included for its systemwide reach. However, the report only provides summaries of, and commentary on, the case studies. The complete case studies will appear in a forthcoming book to be published by CABI.

The seven impact assessments included case studies from Centro Internacional de Agricultura Tropical (CIAT; the International Center for Tropical Agriculture), Center for International Forestry Research (CIFOR), Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT; the International Maize and Wheat Improvement Center), International Center for Agricultural Research in the Dry Areas (ICARDA), World Agroforestry Centre (ICRAF), International Water Management Institute (IWMI) and WorldFish Center (WorldFish). The seven are highly diverse on several accounts. They cover a range of geographical regions, with two projects in sub-Saharan Africa, one in North Africa, two in Asia, and one with global coverage. Both macro- and micro-oriented research projects are included. Here, macro-oriented refers to projects related to policy and institutions while micro-oriented projects relate to commodities and farm-level technology. Most of the research considered in the cases started in the mid-1980s or early 1990s, meaning there was a reasonable interval between research and impact assessment. The total CGIAR investment in these research projects exceeded US$18 million. All the projects significantly involved national agricultural research systems (NARS) and other partners.

The case studies varied in clearly and credibly defining, and then quantitatively assessing, impacts. In the two policy-oriented cases (CIFOR and IWMI), it was only possible to identify the impact pathways; the cases could identify, but not quantify, impacts. For the five cases where quantification of benefits and costs was possible and internal rates of return (IRR) were calculated, it was concluded that NRMR is likely to produce benefits that significantly exceed costs (when *ex ante* projections are included) and, therefore, those investments can be considered fully justified. While the IRRs do not reach the levels achieved in general for much of the CGIAR's crop breeding research, it should be noted that the IRRs of the NRMR projects in this sample were calculated without estimating positive spill-over environmental benefits, which probably outstrip benefits from crop germplasm improvement (CGI) research, but that is subject to further research. Some of the NRM projects produced findings for fostering incremental improvements in policies or management practices. However, due to methodological challenges, it was not possible to conduct quantitative assessments of economic benefits. There is need for a methodology that will clearly

identify and quantify the various potential impacts that were excluded in the present exercise. And while this methodology is under development, there is an urgent need for further conceptual and empirical analyses.

While the results from these case studies suggest returns on NRMR are lower than returns from CGI, meaningful cross-comparison is not possible: there is a large discrepancy in measurement and volume of documentation between the two types of research. Seven cases of NRMR impacts are unequal comparators for hundreds of CGI studies. Also needed are research methods that take into account the unique aspects of NRMR. Therefore this exercise should mark a beginning, rather than an end, of more comprehensive assessment of the impact of NRMR.

1. Introduction

CGI research is still a major component of CG research. However, during the past decade, NRMR has gained prominence in terms of budget allocation and priority setting. CGIAR investments in NRMR have increased substantially both within the older commodity-oriented centers such as International Rice Research Institute (IRRI) and CIMMYT, and the newer resource management centers such as CIFOR, IWMI, ICRAF and WorldFish (see Barrett, 2002; Kelley and Gregersen, 2005). These investments are in response to increased concerns about the environmental and NRM foundations of agriculture. About 20% of the CGIAR budget is now allocated to NRM-related research.

NRMR in the CGIAR includes agronomy-related themes such as soil and nutrient management, irrigation and land cover management, water harvesting, and so on. NRMR strongly emphasizes maintaining or increasing natural resource productivity, a complementing CGI to tap the benefits of new cultivars. While NRMR is sometimes equated with ecological research in other contexts, within the CG system the term is much broader and includes productivity-oriented research.

In terms of this report, NRMR encompasses "research on land, water and biodiversity resources management that is focused on producing knowledge that results in technology options, information and methods or processes that enhance the productivity and stability of ecosystem resources" (Kelley and Gregersen, 2005). Whereas research results are for most part international public goods, the results are generally not applicable across national boundaries (cf. Harwood et al., 2005; 2006). The primary clients of the research are departments of agriculture, forestry and fisheries, farmers, foresters, fisherfolk, rural communities and, for much of the research, policy-makers.

NRMR outputs include recommendations for crop management in addition to procedures and decision rules for farmers, resource managers, extension agents, and regional and national policy-makers. Successful NRMR projects can lead to the development of micro-level innovations such as zero tillage (ZT), optimal intercropping mixes, or integrated farming. However, NRMR in the CGIAR has moved beyond field, plot and farm level (Fujisaka and White, 2004) to regional resource management. It sometimes involves various public and private stakeholders when dealing with policy questions related to the sustainable use of natural resources. Thus, NRMR also generates many macro-level innovations that include management concepts for collective action (e.g. management guidelines for water users' associations (WUA), rules for the management of common property resources such as forests, water bodies, fish and rangeland resources); and regional, national and international policies. NRM policy research targets higher-level decision-makers and usually has larger-scale effects.

The following synopsis of the history of NRMR in the CGIAR is based on a review of a number of CGIAR Technical Advisory Committee (TAC) documents (Barrett, 2002; Kelley and Gregersen, 2005; TAC, 1987, 1988, 1990a,b, 1991, 1995a,b, 1996, 1997, 1999a,b, 2000, 2001a). TAC evolved into the Science Council in 2003.

NRMR in the CGIAR through to 1989

There was a gradual evolution of CGIAR thinking on NRMR and a substantial broadening of activities in this area up until 1989. In 1990, the CGIAR agreed to expand the system to include a number of natural resources-related research areas such as forestry, agroforestry and fisheries. It also agreed to expand water-related research. Following is a brief overview of the situation prior to 1989.

Through the 1960s, NRMR focused almost exclusively on agricultural productivity related to food crops. This included efficient use of fertilizer and other nutrient sources, effective pesticide use, water distribution networks and crop adaptation to drought stress. There was little specific research on the reduction of environmental impacts, although the thinking in the CGIAR was moving in that direction.

Through the 1970s and 1980s, CGIAR NRMR broadened somewhat and a farming systems focus was added to the research agenda. Some programs researched entire farming systems, including animal feed and other components. Others focused on the 'mandate' crops in a farming systems context. These efforts broadened the crops grown and their agronomic management. Varietal selection was often done, but genetic improvement by breeding was not included for those 'companion' crops. Farmer participatory methods became central since most of the work was conducted on-farm, by farmers. In all cases, system research was based on mandate crops, i.e. upland rice, irrigated lowland rice, cassava, maize, etc. Economic production research increasingly extended beyond individual crops to include systems impact on farm-family incomes, labor use and food security. Water research emphasized water management and operations at district level. Research on genetic improvement and related agronomic practices continued for the mandate crops (TAC, 2001a).

The concept of sustainability came into the TAC and CGIAR language in 1987, when sustainability and NRM concerns came to the fore. A 1988 paper entitled *Sustainable Agricultural Production: Implications for International Agricultural Research* (TAC, 1988) gave the following key definition: "Sustainable agriculture should involve the successful management of resources for agriculture to satisfy changing human needs while maintaining or enhancing the quality of the environment and conserving natural resources."

1990 and beyond: expansion into broader and more integrated NRMR

The 1989 CGIAR meeting in Canberra, Australia, was a turning point that broadened the NRM-focused mandate for the CGIAR. The meeting accepted a proposal to include research centers working on forestry, agroforestry, water management and fisheries. In 1990, the role of existing non-CGIAR, international NRM-focused centers were reviewed and options for adding forestry to the system were considered. Such centers were the International Board for Soil Research and Management (IBSRAM), International Fertilizer Development Center (IFDC), International Irrigation Management Institute (IIMI; now the International Water Management Institute, IWMI) and the International Council for Research in Agroforestry (ICRAF; now the World Agroforestry Centre). At the same time, TAC reviewed the weaknesses in CGIAR NRMR and the need to broaden the CGIAR NRM mandate. With the exception of IFDC, all the centers above were added to the CG system and a new center created – the Center for International Forestry Research (CIFOR).

At the time, the ecoregional approach was emerging – several centers could jointly work on integrated crop and natural resources questions within broad ecoregionally focused policy contexts. At its annual meeting in 1990, the CGIAR endorsed the concept. This broadened the mandate beyond geographical areas delineated by commodity systems (e.g. upland rice, lowland rainfed rice, etc.) to areas delineated by non-commodity factors.

Research in the CGIAR was evolving to embrace soil- and water-related NRMR, which are still the core of NRMR in the CG system. A decade ago, the scenario was as described below (TAC, 1997).

In 1996, the CG system allocated about US$49 million, or a little over one-sixth of its total resources, to soils and water (S&W) research. Budget allocations to S&W by centers were between 5 and 40%. More than one-third (35–40%) of the total CGIAR investment in S&W research was for irrigated lands and rainfed lowlands, considered to be well-endowed lands. Fragile or marginal lands, which included warm semi-arid savannas and forest margins, each received about 15%, while the cool semi-arid highlands and hillsides had 5% each. The balance went to policy and other research that cannot be easily attributed to any ecosystem. On average, centers devoted about three-quarters of their S&W efforts to on-site research. The larger part of the balance appears to have been devoted to the policy and management aspects of other natural resources. This implies that there was very little off-site research which is an important component of integrated NRMR.

On average centers allocated two-thirds of their S&W budget to applied research, with a range between 50 and 90%. This allocation, coupled with the previous conclusion, suggests a strong concentration of research efforts on location-specific production systems. Most of these systems produced very few international public goods (IPGs). Many of the centers recognized then that to meet the IPG requirements in location-specific research, comparative research across locations and countries was an imperative. Available data does not however clarify the extent to which centers explicitly built this need into their programs.

TAC also made the first formal call for an integrated natural resources management research (INRMR) approach based on S&W resource management (TAC, 1997). The S&W paper emphasized that:

> *"…the CGIAR System could benefit from introduction of a more consistent, systematic and environmentally sensitive integrated natural resources management (INRM) framework for research. This framework would serve two main purposes. One would be to provide a logical framework for linking the various natural resources management activities in the system. The other would be to provide a better means of showing the rest of the world how the system is addressing the interrelated set of environmental and natural resources issues that are of concern when moving towards sustainable agricultural, forestry and fisheries production. Such a framework would involve four sets of interrelated linkages:*
>
> - *Links between productivity-enhancing and resource-conserving research (e.g crop improvement and natural resources management).*
> - *Spatial or landscape level linkages (e.g upstream–downstream linkages in a watershed management framework).*
> - *Temporal linkages (e.g. links between present and future, or sustainability considerations).*
> - *Linkages between research and the diffusion/adoption of results from such research.*
>
> *Research within this INRM framework incorporates a broad spectrum of disciplines and activities outside the soil and water focus of this study, including those related to forestry, fisheries and genetic resources. These other areas of activity are fully as important and critical to the successful use of an INRM framework as an integrating tool. Thus, they will need to be incorporated into a more operational INRM framework and approach. One example of an INRM framework focusing on the spatial (in this case watershed) linkages is provided by an integrated watershed management framework[3]."*

Since 1996, there have been several key meetings and significant decisions on NRMR in the CGIAR. All have led to the conclusion that a broad integrated approach is needed. Such an approach links natural resources to people and policies. It also recognizes the explicit links between NRM and sustainability,

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[3] A detailed model is presented in Annex I of the S&W study.

and the links between the biophysical aspects of natural resources and strong socioeconomic and political pressures on natural resource ownership, management, and use.

The growing interest in INRMR in the CGIAR has taken a slightly different and broader path than that initially envisioned by TAC (see quote above). This broad research paradigm emphasizes the nexus of productivity enhancement – environmental protection and human development – as a multiple research objective across different temporal and spatial scales, from farm to landscape (Maredia and Pingali, 2001; Sayer and Campbell, 2001; Turkelboom et al., 2003). This is in line with parallel the integrated watershed management paradigm which has been in use for many years (TAC, 1997; TAC, 2001b; Brooks et al., 2003).

The INRM paradigm has many welcome features. It addresses a range of very important previously neglected dimensions on social and livelihood security impacts. However, there are also concerns about INRM. Its highly conceptual definition makes specific and quantitative impact assessment problematic. Kelley and Gregersen (2005) raise a number of other issues about INRM, especially on assessment and evaluation.

And while INRMR is more inclusive, comprehensive and process-oriented than NRMR, the concept is still too new for the full range of impacts to be measured. One of the fundamental issues that will soon generate debate is what impacts are to be measured for INRMR.[4] If it is the more conventional quantitative measures or indicators, then the impact assessment challenges with INRMR are substantial. As indicated by the cases in this publication, this conclusion also holds for the more focused, narrowly defined NRMR.

CGIAR investments in NRMR[5]

It is difficult to precisely quantify the cumulative level of CGIAR investments in NRM-type research activities for two reasons. First, as noted above, there is a shift in thinking by some within the CG system regarding what NRM and what INRMR actually encompass. The more one moves towards the INRM concept, the more one comes up against a problem of identifying specific resource allocations. Thus, for example, a significant portion of INRMR could also be labeled as policy research within the more conventional definitions used in the system. Second, the official CGIAR activity definitions have changed over time, and those definitions encompass different and changing aspects of NRM-related research. For example, of the five principal CGIAR activities used for classification purposes between 1992 and 2001, two of these – 'protecting the environment' and 'increasing productivity through production systems development and management' – captured different aspects of NRMR. The CGIAR investment allocated to 'protecting the environment' amounted to almost US$500 million (in nominal dollar values) between 1992 and 2001 – based on an average investment share of 16.5%. Over the same period, investments in 'production systems development and management' accounted for roughly US$630 million (averaging 21% of the total investment). Certainly not all of this can be defined strictly under NRMR, but these figures offer some indication of the significant level of investment in NRM-related research since 1992[6]. Appendix I shows the historical investment figures by CGIAR activity and by centers.

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4 While the use of impact assessment as a learning tool for those doing research is quite clear in the case of INRM , INRM thinking is less clear about the accountability function of impact assessment for investors in the research.

5 This section draws on Kelley and Gregersen (2005).

6 Since 2002, the CGIAR reports only by Output category (germplasm improvement; germplasm collection; sustainable production; policy; enhancing NARS), and no longer by CGIAR activity. Thus, the figures could not be meaningfully updated beyond 2002.

CGIAR investments in 'increasing productivity' have fallen from 47% of the total in 1994 to 34% in 2002. Within this main activity, investments in the sub-activity 'germplasm enhancement and breeding' have fallen from 23% (1994) to 18% (2001), while those for sub-activity 'production systems development and management' have fallen from 24 to 17%.[7] At the same time, CGIAR investments in 'protecting the environment' rose from 15 to 18% and for 'improving policies' from 10 to 15%. Thus, there is a trend in CGIAR investment away from productivity-enhancing type activities, for which there are proven impacts on poverty. This has raised questions about the current direction and focus of the CGIAR (World Bank, 2003).

From 1994 through 2005, investments across the then 16 CG centers show a similar trend. Many of the major commodity centers and the ecoregional centers have seen their investments fall significantly, both in nominal and real terms, consistent with the trend towards less investment in crop germplasm and increasing productivity. When viewed in real terms, i.e. after adjusting for inflation, the impact of these reduced resources are even more significant. The centers which expanded during this period were usually those that focused on NRMR, particularly environmental protection aspects and policy. Thus, during the period between 1996 and 2004, IWMI's annual budget rose from US$9.7 million to US$23.0 million; WorldFish's from US$8.0 to US$14.8 million; ICRAF's from US$17.1 to US$29.1 million; CIFOR's from US$8.0 to US$14.8 million; International Food Policy Research Institute's (IFPRI's) from US$14.5 to US$30.6 million; and International Plant Genetic Resources Institute's (IPGRI's) from US$14.5 to US$33.9 million.

Although the CGIAR activity 'protecting the environment' has been one of the fastest growing areas, there has been very limited documented impact. As noted by the World Bank (2003), NRMR in the CGIAR is under-evaluated and requires more accountability. 'Under-evaluated' relates to four distinct aspects of CGIAR NRMR: productivity or efficiency of resource use; science quality; comparative advantage; and impacts on the ground.

Therefore, there is an urgent need to document the impacts of NRMR within the CG system, hence the SPIA NRMR impact assessment initiative. It only represents a start and a snapshot in time of the impacts of selected types of NRMR projects commonly undertaken by the CGIAR centers with their partners. And since NRMR is an important component of the agricultural development research agenda, it is imperative to provide a comprehensive picture of its impacts.

Organization of the report

Chapter 2 summarizes the seven center-based case studies of NRMR impacts, followed by an SPIA perspective on the results and lessons learned.[8] A summary of the impacts and lessons learned from the assessment of the Alternatives to Slash and Burn (ASB) Systemwide Programme is also included. Chapter 3 reviews ongoing work in developing methodology and strategic guidelines for assessing NRMR impacts and discusses the centers' perspective on where the CG system is with respect to NRMR impact assessment. Chapter 4 discusses how the centers and the SC/SPIA can improve the overall approach to NRMR impact assessment within the CG system.

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7 The two largest components within the production systems sub-activity, cropping systems and livestock systems, saw their investment shares fall the most, from 16% to 9% and from 6% to 4%, respectively. At the same time, investments in tree systems fluctuated around 3% while investments in fish systems actually rose.

8 The detailed studies are to appear in a forthcoming book to be published by CABI in 2007.

2. The Case Studies

The major objective of the SPIA initiative was to gain some insight into the actual impacts of CGIAR investments in NRMR. Resources were provided to five centers (CIAT, CIFOR, CIMMYT, ICARDA and WorldFish) to undertake credible empirical assessments of the impacts of past NRMR activities. Two other centers, IWMI and ICRAF, participated in the initiative using their own resources, bringing the total number of case studies to seven. Table 2.1 lists the studies, centers, and the lead staff.

Table 2.1 SPIA initiative case studies

CGIAR Center	Lead staff	Topic
CIAT	Tim Dalton Nancy Johnson Nina Lilja	Impact of participatory natural resource management research in cassava-based cropping systems in Vietnam and Thailand
CIFOR	Mike Spilsbury	The sustainability of forest management: Assessing the impact of CIFOR criteria and indicators research
CIMMYT	Olaf Erenstein Vijay Laxmi Pandey	Assessing the impact of zero tillage in India's rice–wheat systems
ICARDA	Veronique Alary Kamel Shideed	NRM technologies in crop–livestock production systems in arid and semi-arid areas of Morocco and Tunisia
IWMI	Meredith Giordano	Assessing the outcomes of IWMI's research and interventions on irrigation management transfer
ICRAF	Olu Ajayi Frank Place	Fertilizer trees: their development, socioeconomic and ecological impacts in southern Africa
WorldFish	Madan Dey Patrick Kambewa	Impact of the development and dissemination of integrated aquaculture: agriculture technologies in Malawi

SPIA guided the case studies in much the same way as the study on the impacts of crop germplasm improvement research (Evenson and Gollin, 2003). Hermann Waibel, an SPIA member, was in charge of interaction with the centers and worked closely with the SPIA chair, other SPIA members and the SC Secretariat.

Eleven centers responded to the call for proposals in mid-2003. Using established criteria such as the importance of the research, technical quality of the proposal and theme addressed, five proposals were selected for funding.[9] At a later stage, two additional centers volunteered case studies with the agreement

[9] Funds were only available for five case studies.

that these case studies would follow the same guidelines and go through the same peer-review process as the five SPIA-funded ones.

Drafts of the cases were submitted to SPIA in late 2004/early 2005 and reviewed by four external peer reviewers who provided an extensive commentary on each of them. In most cases, the reviewers recommended publication after revision of the papers. SPIA members also reviewed the case studies and helped respective centers to prepare second drafts.

The final workshop for the initiative was held at IRRI in The Philippines from 13–15 June 2005, as a joint meeting with the CGIAR INRM Task Force. The workshop involved a wide range of stakeholders including environmental economists, social scientists and some users of NRM impact assessments. The aims of the workshop were to: (i) disseminate results; (ii) summarize, conclude and compare methods and findings; and (iii) discuss drafts with individual case study teams. Details on the IRRI meeting are available in the final report of the workshop.[10]

Extensively revised drafts were produced based on the peer reviews and discussions with SPIA. These drafts were submitted to SPIA between September and October 2005. The drafts provide the basis for the following summary of the cases and their results, as well as SPIA comments on lessons learned. The full case studies will be published as chapters in a forthcoming CABI book entitled *The Impact of Natural Resource Management Research: Studies from the CGIAR*. In this document, extended abstracts of the seven case studies are presented.

CIAT case study: Impact of participatory natural resource management research in cassava-based cropping systems in Vietnam and Thailand

Between 1994 and 2003, CIAT, in collaboration with national agricultural research partners in Thailand and Vietnam, implemented a Nippon Foundation-funded project called 'Improving the Sustainability of Cassava-based Cropping Systems in Asia'. The purpose of the project was to address the problem of the observed widespread non-adoption of soil conservation and fertility management technologies in cassava production in Asia. Conservation technologies such as contour lines and hedgerows; management technologies such as intercropping, manure and mineral fertilizer use; and genetic improvement technologies such as improved cassava varieties were included in the project. Hence, the nature of the NRMR was that of applied, adaptive research for already-existing NRM technologies and principles. However, farmer adoption was low. CIAT, together with NARS researchers and extension agents, worked with farmers in selected project villages. The farmer participatory research (FPR) methodology included conducting on-farm experiments to identify, test and adjust promising natural resource conservation and productivity enhancement cassava technologies. Therefore, the project encompassed a broader research paradigm that falls under the category of INRM.

The impact study was conducted in 2003 in Vietnam and Thailand. Data were collected from 800 farm households. In both countries, eight villages were selected comprising four project and four control villages. In the project villages, CIAT and NARS partners had already implemented FPR activities. The control villages had similar natural resource and socioeconomic conditions. In the control villages, the national extension services promoted technology and advised farmers according to their standard operating procedure, thus providing a counterfactual for the FPR component of the project villages. The

[10] Report of the combined workshop of the Standing Panel on Impact Assessment and the 6th meeting of the CGIAR Task Force on Integrated Natural Resources Management, held at IRRI headquarters, Los Baños, The Philippines. 13–15 June 2005. (http://www.icarda.cgiar.org/INRMsite/FinalReportINRMTaskForceMeeting.pdf)

data collection protocol followed the focus group methodology, i.e. focus group participants filled out survey forms on wealth, socioeconomic status and cassava production inputs, outputs and technologies. Recall questions were used to establish the area under cassava and cassava yields before the project to enable comparisons after interventions.

Impact assessment framework

Household theory served as the general conceptual framework to measure impacts of technology adoption and knowledge. A household utility function for measuring outputs was formulated. The methodology allowed measurement of single or multiple farm products, and both commodity and non-commodity outputs. Knowledge was included as a stock resource to be enhanced by project participation. Model estimation was only possible in a reduced form since the parameters of the equations were not directly observable. First, as a proxy for knowledge, a participation dummy was used. Second, the impact of participation on non-commodity outputs was captured through the adoption of soil conservation practices. Third, the wage effect was measured by separating the productivity impact of technology variables from the knowledge variable, i.e. the participation dummy.

Adoption and outcomes

Analysis showed that the overall level of adoption was high for varieties and fertilizer but was lower for soil conservation practices such as intercropping. The differences in conservation practices between participants and non-participants were more pronounced than between varieties and fertilizer. Adoption levels were different in Thailand and Vietnam, with the latter having lower levels of adoption. Only about half of the project participants in Vietnam adopted improved varieties, in contrast to almost all of the participants in Thailand. Differences between participants and non-participants were smaller in Thailand.

The case study's impact analysis showed that cassava technologies and knowledge significantly affected behavioral and productivity variables. The following outcomes were noted:

- Adoption of improved cassava varieties significantly contributed to expansion of cassava area and increased cassava yields.
- Farmers with larger cassava areas tended to expand them less than farmers with smaller areas.
- Adoption of the contour ridging technology led to lower area expansions both for cassava and total farmland area.
- Female household heads tended to expand farmland area more than male household heads.
- Adoption of hedgerows positively affected cassava yields.
- There were significant positive spill-over effects from participants to non-participants in project villages.
- Yield gains were significantly higher in Vietnam than in Thailand.
- Project participation had a significant effect on yield.

Welfare analysis and rate of return

Total costs included the research and development (R&D) costs for CIAT and NARS, compensation for farmers' costs of experimentation and research participation. The total R&D and adoption costs from 1994 to 2003 were US$3.96 million. These costs were equally distributed over the lifespan of the project.

The project benefits were derived from the total yield effects estimated in the simultaneous equation system that aggregated the technology and knowledge effects, and weighted them with adoption rates. The resulting shift in cassava output was then valued at domestic market prices for the year 2003. To estimate the cumulative benefits over the 10-year project period, the usual logistic adoption curve was used, assuming that annual benefits were a fraction of the 2003 figure equivalent to the number of farmers trained by year. Based on these data, the IRR was calculated at 41.2%. Various scenario analyses revealed that the rate of return of the R&D investment was indeed a safe bet considering that the most conservative scenarios still yielded an IRR of 20%. Since the IRR does not include the environmental benefits attributable to the project from reduced soil degradation, the calculated IRR is most likely a lower bound.

Lessons learned

The CIAT case study is an example of an INRM-type project that focused on the complementarities between NRM and genetic improvement research. The study is unique since it provides a methodology that can separate technology effects from knowledge effects assumed from FPR. Unfortunately no knowledge data were collected, e.g. knowledge tests for participants and non-participants before and after project implementation. A baseline survey would have helped to develop a better understanding of the mechanisms through which FPR can change behavior and increase productivity. Finally, the rate of return was limited to a financial analysis, thus ignoring differences between domestic and world prices. A valuation of expected environmental benefits would have strengthened the case.

The study leaves the question of up-scaling the FPR approach open. Since the R&D investment is relatively small and the yield effects high, there is a good rate of return. But, does this justify recommending that extension services in Thailand and Vietnam should adopt the FPR approach on a broad scale? More needs to be known about the quality of the FPR method, should CIAT support come to an end. However, evidence from a complementary study implies that the CIAT project strengthened the FPR research capacity of the national research system (see Howeler, 2004).

Overall, the case study demonstrates the need to plan for *ex post* impact assessment during the early phase of an NRM R&D project.

CIFOR case study: The sustainability of forest management – assessing the impact of CIFOR criteria and indicators research

Many researchers have worked on the development of criteria and indicators (C&I) for sustainable forest management (SFM). Among other uses, C&I have a role in SFM certification programs. CIFOR was one of the first organizations to undertake major, long-term comparative research in this area, having started its Phase I research in August 1994 and Phase II in February 1996. Phase II, which ended in 1999, broadened the work to include research on a variety of sustainability assessment tools. The total cost of the research program was approximately US$3.3 million.

The research involved the development of C&I for the various dimensions of SFM, and then testing these C&Is in the field in diverse conditions. The main outputs from the research are in CIFOR's C&I Toolbox Series.[11] The series includes a comprehensive set of eight manuals and decision-support software tools that guide users through the complexities of assessing the sustainability of natural and planted forests. In addition to the toolbox series, researchers produced journal articles, books and book chapters, software, course materials, policy advice and technical support. Thus, the output of the program was knowledge

[11] http://www.cifor.org/acm/pub/toolbox.html

and information on methods and conditions of sustainability, and on appropriate use of basic C&I and certification tools of global applicability, including computer-based tools.

The CIFOR project started when certification was in its infancy. By the end of the overall research program in January 1999, more than 10 million hectares of forest had been certified worldwide, rising to more than 45 million hectares by October 2004.

Impact assessment framework

The case study researchers had no illusions that they could assess the ultimate impacts of the research in terms of income changes and environmental benefits. Instead they commenced on an exercise to trace impact pathways that helped to target clients and their particular needs. They then analyzed the target clients in more detail through documentation, interviews and other means to determine the uptake of CIFOR research outputs. Within the overall assessment framework, it was envisioned that researchers, foresters, conservationists, certifiers and others would use the tools developed by CIFOR and partners to achieve more sustainable forest management, e.g. through forest certification and auditing practices. It was also envisioned that better forest management would in turn lead to better forest health and improved sustainable incomes for forest dwellers and owners.

Thus, this case study focuses primarily on specific certification impact pathways and examines the extent to which certification bodies, such as the Forest Stewardship Council (FSC) and national standards development processes made use of the CIFOR C&I research. An analysis drawn from information published in public certification assessment reports shows patterns of improvement in the management of FSC-certified forests in developing countries. These improvements are linked to CIFOR's research contributions.

Three main impact pathways provided the framework for the assessment. All three eventually lead to forest certification audits using C&I-based standards, changes in forest management as a result of the audits and CIFOR mission-relevant benefits.

Adoption and outcomes

To determine the uptake of CIFOR's research by certifiers, key staff in certification agencies were interviewed. Key staff were those who were employed at the time when certification standards were being developed. The interviews sought to ascertain the role that CIFOR C&I research played in the development of these standards, and the likely outcome of the certification process in the absence of CIFOR C&I research. In addition, project documentation (reports, meeting minutes and emails), published documents and internet resources were examined for evidence of FSC certifiers making use of CIFOR's C&I research.

Formal recognition of use of the CIFOR C&I has been acknowledged by many of the key certification agencies, including the pioneers in certification – SmartWood and the FSC – and many other groups. The CIFOR study makes an important qualification (in this case applying to SmartWood, but relevant to other groups) that it is "unlikely that the certification standards would have developed very differently, though perhaps in some aspects they would have developed less rapidly and possibly less effectively (e.g. with regard to social C&I and effective methods for stakeholder consultation)." In other words, in some cases, the benefit of CIFOR's research was earlier adoption and in others, development of improved standards. The time saving is, of course, a benefit that can be attributed to the research, under the assumption that it leads earlier to environmental improvement or loss prevention and eventually to impacts on livelihoods of the poor.

It appears that independent field tests done by CIFOR and the work that CIFOR did on certification and social issues related to forest-dependent communities were of particular value to the certification groups. The bottom line is that over 79%, or 37.1 million hectares of forest have been certified by companies that acknowledge some use of CIFOR's C&I research in their certification standards or audit processes.

Much of CIFOR's research uptake was in developed countries, but there was also substantial uptake in some major forested developing countries, (e.g. China and Thailand). Evidence of uptake of CIFOR C&I in national initiatives in developing countries was sought largely from publicly available documents, from key informants and from correspondence records of the project.

Indications of impact

Standards applied by certification bodies directly lead to on-the-ground changes in the management of forests through audit processes, i.e. there are impacts at the forest level, both in a biophysical sense and on people who depend on the forest for their livelihood, for fuel and other products. However, there are many difficulties in comparing forest management impacts with and without certification. The case study addresses many of these difficulties and the researchers concluded that: "It is possible to examine the causal effects of FSC certification in terms of changes to on-the-ground forest management by examining the specific improvements in forest management that forest owners or managers were required to make in response to the certification auditing process. These changes provide a means of examining 'before' and 'after' situations in certified forests." The case study then points out the reasons why using such audits will systematically lead to an underestimation of the certification-related improvements in forest management. In other words, the benefits will be on the conservative side.

Quantitative attribution of CIFOR's research contribution to certification standards proved problematic, although it is clear that CIFOR research helped to improve the standards and audit processes applied, especially to social issues in developing countries. As a result, substantial areas of forest have been certified. Issues that are closely associated with CIFOR research contributions to certification standards commonly feature in corrective action requests (CARs) that result from certification audits, therefore resulting in improved management practices over several million hectares of forest.

Through analysis of CARs, which are part of the documentation in public certification assessment reports, the case study concluded that "...forest management improved with respect to a broad array of forest management, environmental, social, cultural and economic issues because the regulatory nature of the certification process provides this as a guarantee through third-party forest auditors. It is clear that many of the changes on the ground in certified forest are consistent with the CGIAR mission of protecting the environment. Less certain is how these outcomes translate into livelihood benefits. However, given the assumed counterfactual of forest management without certification failing to make these improvements, it is reasonable to assert that the consideration of local stakeholder interests is generally higher in certified forest than it would otherwise have been."

The case study assesses the literature on the impacts of certification, and also on how CIFOR's C&I research has had an impact through other pathways, e.g. international forest policy changes and direct uptake in development assistance initiatives.

Lessons learned

The main lesson from this case study is that it is possible to trace fairly far down the impact pathways associated with this type of research. A plausible link has been made between this type of international policy-focused NRMR and improvements in forest management. The case study comes close to estimating on-the-ground impacts e.g. improvements in the sustainability of forest management, although the attribution issue remains problematic. With high and low estimates of on-the-ground impacts in hand, it would be possible to move on to look at economic impacts by associating the outputs from the improved management with specific groups of forest users and owners. However, the cost of going further down the impact pathway than was done in this case study would be high.

CIMMYT case study: Assessing the impact of zero tillage in India's rice–wheat systems

The point of departure for ZT technology was the observed slowdown in productivity growth in the rice–wheat systems of India. Traditional crop cultivation practices in rice–wheat systems degrade soil and water resources and thereby threaten the sustainability of the system. Evidence from long-term experiments shows that crop yields are stagnating and sometimes declining. The Rice–Wheat Consortium (RWC) of the Indo-Gangetic Plains (IGP) has developed and promoted a number of resource-conserving technologies that increase farm-level productivity, conserve natural resources and are less polluting than traditional practices. The most widely adopted resource-conserving technology in the IGP, particularly in India, is ZT. It allows wheat to be sown immediately after the rice harvest. Thus, ZT makes use of residual moisture for wheat germination and reduces the number of field operations for crop establishment. The core component of the technology is the use of a seeding machine that is sometimes combined with a device for fertilizer application.

Contrary to classic research activities, e.g. in plant genetic improvement, CIMMYT's role with regard to ZT in India was not to develop a fundamentally new technology or discover new scientific principles, but rather to make the diffusion process faster and more efficient. CIMMYT facilitated technology introduction by helping the NARS to design experiments for technology testing and local adaptation. Constraints were identified alongside demonstrating technical feasibility and economic efficiency to the user. The main research input was CIMMYT's expertise in designing and implementing on-farm experiments. Its status as an independent international organization helped to facilitate negotiations with the private sector and government decision-makers. CIMMYT's social capital allowed it to assume the role of an honest broker, thereby lowering transaction costs and reducing uncertainty about the use of the technology in India.

The uniqueness of this NRMR project lies in the fact that local adaptation and improvement of ZT seeding machines were implemented as a participatory process involving farmers, scientists and manufacturers. It is therefore an excellent example of FPR defined as part of marketing private technologies.

Impact assessment framework

The classic consumer–producer surplus model framework was followed. Welfare effects were modeled using a closed-economy framework with linear supply and demand functions and a parallel research-induced supply shift. The resulting sum of producer and consumer surplus was used to estimate the rate of return on investment. The parameters of the supply shift were largely based on secondary data including on-station and on-farm trial data and focus group interviews. The focus group interviews compared adopters and non-adopters differentiated by gender, and revealed that ZT had a socioeconomic impact in terms of yield increases and cost reductions.

A social rate of return was estimated by converting farm prices to export parity prices using the nominal protection coefficient for wheat. A ceiling was applied for a maximum adoption level during a 30-year project period. The present value of benefits was calculated using the social discount rate prevailing in India.

The counterfactual was defined as a situation where adoption will also take place without CIMMYT's intervention. Technology adoption was assumed to follow the usual logistic adoption curve (without the project, there would be a lag time of 5 years). To achieve this gain in time, a US$3.5 million investment by CIMMYT and RWC was necessary; however, at the same time, some of the NARS research and extension costs were saved.

Impact analysis was limited to the direct economic effects only, but included a description of the documented environmental benefits.

Adoption and outcomes

Adoption of the technology was defined through the use of the ZT drilling machine. Since some of the farmers who used the machine nevertheless practiced some tillage or reduced tillage (RT), adoption is considered to be a combination of full and partial adoption. Given that agroclimatic and socioeconomic constraints prevent the adoption of ZT/RT technology in the entire IGP area, an adoption ceiling of 33% of the wheat area, equivalent to 3.43 million hectares was assumed. A logistic curve based on observed adoption patterns was fitted to the ZT/RT adoption estimates reported by experts. Project-induced adoption was defined as a shift in the adoption curve representing a 5-year lag.

The following outcomes can be attributed to the technology, based on secondary and survey information during the course of the impact assessment study. Zero-tillage:

- Reduces the number of field operation technologies from an average of seven to one, translating to 8–12 hours per hectare saved in tractor time
- Reduces water usage by about 100 mm, or approximately 1 million litres per hectare – a saving of 20–35%
- Improves soil quality in various dimensions, including soil structure, soil fertility and soil biological properties
- Typically reduces the incidence of weeds in the wheat crop – primarily due to the early emergence of wheat and reduced soil disturbance and
- Leads to an increase in wheat yield of 6–10% on average and a reduction in the variable costs of wheat production of 5–10% due to (i) timely sowing, (ii) increased input use efficiency, and (iii) more effective weed control by herbicides.

Welfare analysis and rate of return

The benefits generated by the US$3.5 million investments made by RWC and CIMMYT consist of consumer and producer surplus and some savings of NARS costs. The present value of the benefit stream was calculated over a 30-year project period with a social discount rate of 5%. Using conservative benefit estimates based on the outcome parameters from secondary data verified in focus group interviews, the ZT R&D program yielded a net present value (NPV) of US$94 million; equivalent to a benefit–cost ratio (BCR) of 39 and an IRR of 57%. The discounted cumulative economic surplus amounts to US$96 million, which dwarfs the discounted incremental costs of US$2.5 million. The economic surplus primarily benefited consumers, at 65%, compared to producers, at 35%. Assuming a more optimistic scenario, with ZT-inducing 10% yield gains and 10% cost savings, this leads to an IRR of 66%. Thus, CIMMYT's and RWC's R&D investment in facilitating the adaptation and adoption process of ZT in India compares well with the performance of other CGIAR investments.

Lessons learned

This case study shows that a CG center – in this case CIMMYT – can achieve tremendous impact in promoting NRM technologies by playing the role of a technically competent, honest broker and making use of its social and human capital in the right place and at the right time. Investment in NRMR can yield high returns in helping a country gain time in the introduction of a technology. The CIMMYT–RWC ZT/RT project achieved such a high rate of return because it addressed the scaling-up problem, which many NRM projects face when developing and promoting NRM technologies. The institutional and physical infrastructure for scaling-up was in place and there was a private sector incentive to cooperate since the technology is embodied in a private good. The missing element was trust and guidance for the various actors in the change process. It is safe to assume that the net social and economic benefits of the project would be considerably higher if the environmental benefits were monetized. This case study highlights the comparative advantage of a CG center helping a country to speed up technology diffusion. It also raises the issue of the international public goods nature of the output from this project. Although there are transferable messages in terms of how to manage a technology diffusion process, a more rigorous analysis of the general and reproducible lessons from this case must still be determined.

Finally, this case study also illustrates the importance of incorporating impact assessment studies into the early phase of a project. Relying almost solely on secondary data verified by a few focus group interviews inhibits the use of econometric techniques of impact assessment. Thus, there is still some degree of uncertainty associated with the benefit estimates generated in this study.

ICARDA case study: NRM technologies in crop–livestock production systems in arid and semi-arid areas of Morocco and Tunisia

Crop–livestock systems are predominant farm enterprises in the West Asia and North Africa (WANA) region. In these systems, the major household income is generated from small ruminant production. The Mashreq/Maghreb (M&M) project was initiated and designed as an adaptive research program for the development of integrated crop–livestock production systems in low rainfall areas of WANA. The M&M project was funded by the International Fund for Agricultural Development (IFAD), the Arab Fund for Economic and Social Development (AFSED), the CGIAR Program on Collective Action and Property Rights (CAPRi), and the International Development Research Centre (IDRC). Research at ICARDA and collaborating NARS has led to the development of technologies that can enhance and stabilize production by supplying animal feed and reducing soil erosion. These technologies take the form of alternative cropping systems designed to increase feed availability under low rainfall and in marginal lands. One example is the use of fodder shrubs like *Atriplex* and spineless cactus together with other annual crops in alley cropping systems.

The ICARDA case study presents an assessment of the benefits of investment in R&D for these NRM technologies by ICARDA and its collaborating NARS in Morocco and Tunisia. The analysis takes the form of two separate case studies, each of which uses a slightly different methodological approach. However, common lessons can be drawn from both.

Impact assessment framework

The common theoretical framework on which these studies are based is cost–benefit analysis. This framework follows a theoretical discussion of the role of subsidies in promoting sustainable technologies in marginal areas. It provides a formal method for valuation of subsidies in cost–benefit analyses where environmental benefits cannot be monetized. The framework also bridges environmental and farm-level benefits, thus helping to isolate factors that determine the private and social rates of return of the technology.

In the case of Tunisia, a multi-faceted methodological approach was used. First, impact indicators were identified and the interaction among the technology's economic, social, agronomic and environmental effects were assessed using a community-level, multi-period mathematical programming model. Second, the rate and the degree of adoption were assessed from project records. Econometric analysis was carried out to identify the determinants of adoption. These were used for the projection of the future adoption rate. Third, the rate of return of adopting the technology from the farmer's perspective and the economic rate of return on the project investment were calculated.

In the case of Morocco, a biophysical simulation model called Soil Change Under Agroforestry (SCUAF) was used to assess the biophysical and economic effects of the NRM technology. SCUAF was calibrated using data from field trials and farm household surveys of both the traditional barley farming system and the newly introduced *Atriplex* alley cropping in selected communities of the study area. The biophysical module of the SCUAF model generates yield and erosion outcomes for both cropping systems. These results are combined with a simple economic module to generate the net revenues over time. Using the opportunity costs of capital as the discount rate and applying the Excel @risk procedure allows the calculation of cumulative distribution functions of the net present value and internal rate of return of the NRM technology. To document the adoption status of the alley cropping technology in terms of the rate and degree of its adoption and factors affecting the adoption process, a survey of 100 farmers was conducted. Factors affecting the adoption indicators, and estimates on the net impact of the technology were computed using econometric analysis.

Adoption and outcomes

Tunisia. The adoption of cactus-alley cropping has been measured using two indicators: i) the proportion of adopters in the total population (adoption rate); and ii) the total area under the new technology relative to the total potential area (adoption degree). In 2002, the adoption rate was found to be slightly above 30% and adoption degree at 29%. A generally observed pattern was that adoption of cactus-alley cropping increases with farm and herd size. It was also observed that farmers without animals adopt the technology because of incentives provided by a development project. Other determinants of technology adoption were farmer age and irrigation availability. The mathematical programming model provided additional insights into the role played by government subsidies in adoption. Farmers with good resource endowments (land and irrigation) and stable off-farm income were more likely to adopt the technology than those with less favorable conditions. The results also show similar adoption rates between the scenario with subsidies and the scenario with both subsidies and good information on expected yields for annual crops.

The effects of the technology on productivity were estimated through on-farm experiments. Biomass yields in cactus-alley cropping increased by 57% compared with yields in a traditional barley-cropping system. This is because of higher grain yields of barley fodder grass and straw, in addition to the output of cactus pads and fruits. The increased supply of animal feed led to a reduction in feed costs of 13%.

Morocco. The adoption data were taken from extension records, which revealed 24% of the land in the target community in 2003 was devoted to *Atriplex* alley cropping. The corresponding adoption rate was 33%, with larger-scale farmers and farmers with livestock representing the majority of adopters. On average, adopters assigned nearly 27% of their farmland to *Atriplex* alley cropping but this varied considerably across farms. Overall, the area planted with *Atriplex* has increased by 6% annually since 1999. The productivity effects of the technology were estimated through a Cobb Douglas production function derived from the survey data obtained from adopters and non-adopters. Results showed that barley yield increased by 0.16 tonnes per hectare and the straw yield by 1.06 tonnes per hectare. Only the latter was significant. A second outcome of alley cropping was that due to the increase in feed supply, farmers increased flock size. The calculations suggest that alley cropping increased the number of small ruminants by 25% among technology adopters compared with non-adopters. Furthermore, the reduction in feed cost was calculated at 11–70%, with an average value of 33%. This cost reduction was due to the substitution of expensive commercial feed such as wheat bran and sugarbeet pulp with *Atriplex* biomass and barley straw.

Welfare analysis and rate of return

Tunisia. The financial internal rate of return (FIRR) of investing in cactus alley farming, i.e. the rate of return for a farmer who received the subsidy, was calculated at 53%. The FIRR for a farmer who had to pay the full costs of cactus establishment came down to 17%. Hence the subsidy makes a big difference to the farm-level economics of the NRM technology. If all R&D costs associated with ICARDA and the NARS activities are included, the economic internal rate of return (EIRR) is 16%, assuming that adoption will have reached 96,000 hectares after 22 years. This calculation assumes that all resource costs are accounted for and that no difference exits between financial and economic prices of inputs and outputs. Taking into account the uncertainty in the parameters that determine the rate of return, the application of the Excel @risk procedure showed that the results are firm. The chance of getting an IRR of more than 4% was found to be 95%.

Morocco. The IRR calculation was based on the assumption that changes in barley production (determined by the reduction of soil erosion due to planting of *Atriplex*) would not affect the market equilibrium price of barley. This means that only the producers' welfare was considered; the environmental benefits of the technology, such as reduction of soil erosion and improved soil fertility, were considered as additional net benefits. The discounted values of net benefits streams were compared with the discounted value of cost using a discount rate of 10%, which is equivalent to the interest rate on borrowing from commercial banks. Based on a constant adoption rate at the 2005 level, an estimated IRR of 29% was calculated for 2015, the project termination year These results support the economic feasibility of research investment in *Atriplex* technology. To randomize the calculated IRR, stochastic simulation was conducted using Excel @risk. This simulation gave a mode of 25% under risky conditions, further supporting the profitability of *Atriplex* alley cropping.

Using an opportunity cost approach, the monetary value of the environmental benefits of *Atriplex* alley cropping – such as reduced soil erosion and improved soil organic carbon – was estimated at US$425 per hectare, which is well above the incentives of US$250–300 per hectare provided to farmers by the development project. These opportunities would be foregone without the investment in *Atriplex* R&D.

Lessons learned

There are at least three lessons that can be drawn from this study.

- First, the development of the cactus/*Atriplex* alley cropping in the WANA region has encouraged the governments of Morocco and Tunisia to invest in agriculture in dry areas. By increasing and stabilizing fodder reserves, cactus/*Atriplex* alley cropping can help mitigate drought. The technology is therefore an effective risk-hedging strategy for drylands. The benefits are expected to spur adoption by farmers in similar agroecological zones in Morocco, Tunisia and other countries.

- Second, the study has shown that assessing the impact of NRMR requires methodological approaches beyond conventional economic and biophysical models. It is necessary to capture the holistic nature of the problem by integrating economic, environmental and social aspects. For example, dynamic and recursive programming and econometric models proved to be useful tools for generating the appropriate indicators to assess the *ex post* impact of NRMR. Further assessment of the long-term environmental impacts of NRM technologies is most accurate when simulation models are used.

Unfortunately, these are not readily available. Future research should focus on developing more efficient biophysical models adaptable to marginal lands in the dry areas.

- Third, future research on the impact of NRM R&D in dry areas requires pre-intervention baseline data in project and control areas in order to apply more advanced methods of analysis. Land tenure is another issue that needs more attention because secure tenure is a key determinant in the adoption of, and investment in, NRM technologies in the dry areas.

IWMI case study: Assessing the outcomes of IWMI's research and interventions on irrigation management transfer

There is mounting evidence of the under-performance of publicly owned irrigation schemes, which has put irrigation management transfer (IMT) on the research agenda. The underlying hypothesis was that the transfer of management responsibilities to farmer organizations would improve the management of irrigation systems, leading to higher productivity and sustainability.

IWMI's role included reviewing and analyzing the experiences and impacts of past IMT processes; advising policy-makers in planning and implementing IMT; technical support to governments implementing IMT programs; and, the development of generic IMT guidelines. Over a period spanning more than 15 years, IWMI launched a series of projects at global, regional and national level to review and analyze past IMT experiences and impacts; develop a series of products, including policy and operational recommendations to assist governments and local institutions; and, in collaboration with the Food and Agriculture Organization of the United Nations (FAO), produce an 'international public good' in the form of generic guidelines for IMT in general, and for the establishment of water users' associations (WUAs) in particular. IWMI's role was not to advocate turnover, privatization and self-management of irrigation systems but to play the role of an independent advisor and honest broker that could objectively assess the results and identify effective institutional strategies.

The paper documents the extent to which IWMI's peer-reviewed publications; technical papers and reports; expertise; advisory capacity in the technical and policy fields; and implementation of IMT projects have been used by relevant government and non-governmental partners.

The study team analyzed IWMI's contributions through bibliometric assessments using the Web of Science, Google Scholar and an analysis of website downloads of IWMI's IMT research outputs.

Impact assessment framework

This study does not include the assessment of welfare effects and a rate of return analysis on IWMI's investments in IMT research. The nature of this NRM project was to generate information and knowledge but IWMI had no control over the application of the information it generated. The study concentrates on measuring the outcomes of the NRMR for the overall IMT knowledge base and on IMT policy and operations in specific countries. The project outputs include reduced transaction costs associated with IMT planning and implementation; reduced probability of misguided interventions; and increased likelihood of successful IMT reforms. Against this background, IWMI hypothesized three areas of outcome of its research and interventions: (i) awareness of new IMT research results among its developing country clients; (ii) application of better policies; and (iii) better techniques in irrigation management.

The methodology includes the following components: (i) internal review of the knowledge generated by IWMI on IMT through publications, workshop proceedings and presentations; (ii) assessing the demand, use and estimated implications of IWMI's IMT research at various scales and by and for various users; (iii) bibliometric and website download (webmetric) analyses to measure the general influence of, and demand for, IWMI's IMT research products; and, (iv) structured questionnaire surveys for clients where IWMI's involvement was more explicit through action research or project implementation.

Adoption and outcomes

The bibliometric assessment using the Web of Science, Google Scholar and an analysis of website downloads of IWMI's IMT research outputs revealed the following:

- By July 2005, 50% (126) of IWMI's 251 IMT outputs were registered on the IWMI website (www.iwmi.cgiar.org). For these 126 outputs, a Google Scholar search documented 527 total citations; of which 65% (or 345) were from non-IWMI authors.
- The largest number of citations was for IWMI's Research Report series (107, excluding IWMI citations) and peer-reviewed journal articles (81, excluding IWMI citations). The single most cited publication was IWMI's IMT synthesis report (Vermillion, 1997), which received 25 citations from non-IWMI authors.
- An assessment of downloads from the IWMI website for the period January 2000 to July 2005 showed that 18 IIMI/IWMI research reports and five IWMI working papers on IMT published between 1996 and 2003, ranked within the top 50 monthly downloads from the IWMI website, with over 29,000 total downloads of these 23 publications during the period.
- For the period October–December 2003, CGNET provided information service provider (ISP) addresses, country and city information of IWMI's web users. During this period, over 1100 downloads of IWMI IMT research reports (853) and working papers (283) were recorded from institutions and individuals in developed countries (70%) and developing countries/countries in transition (30%). Over 170 downloads were from universities and research organizations, of which approximately one-third were from developing countries/countries in transition.
- A total of 5700 copies of the IWMI/FAO IMT guidelines have been distributed since 1999. This includes 4100 copies in English alone, with an additional 1600 in Spanish, French and Russian. A survey revealed half of the respondents were aware of the IWMI/FAO IMT guidelines.
- IWMI's guidelines on the establishment of water user associations in Central Asia were disseminated primarily through the IWMI website. Results indicate that since the release of the guidelines in March 2004, they have consistently ranked in the top ten downloads each month, with downloads per month of the English version averaging 475. Nearly all respondents to a user survey in Central Asia were aware of the WUA, Social Mobilization and Institutional Development guidelines.
- The Asian Development Bank has drawn from IWMI's WUA guidelines to prepare WUA training manuals. The Bank has also recommended the guidelines to the Aga Khan Foundation's Microfinance and Social Development Support Project and to CARE in Tajikistan.

Indications of impact

The study provides evidence of substantial and continuing demand for IWMI's IMT research. Examples include Cambodia, India, Pakistan and South Africa. Direct and indirect data sources also indicate that IWMI policy and operational-level interventions have contributed positively to IMT decision-making at national and global level. Although evidence of IWMI's policy advisories on IMT translating into field-level productivity impact was not available, it is worth mentioning that the direction of observed policy change was consistent with IWMI recommendations. Also, IWMI continues to receive requests to assist in subsequent IMT by former client countries, indicating advice given was valued. There is evidence of IWMI 's policy advice being adopted by Nepal, Sri Lanka and Pakistan. The following three examples are indicators from Sri Lanka:

- First, the government amended the Agrarian Services Act and the Irrigation Ordinance to legalize the role of farmer organizations in all major and minor irrigation schemes.
- Second, the Mahaweli Authority, the country's largest multi-purpose water resources development project, is currently being restructured.
- Third, following IWMI's recommendation based on the Irrigation Management Policy Support Activity (IMPSA), the government took action in 2000 to establish the National Water Resources Council to formulate a comprehensive water policy stipulating holistic and sustainable water management.

Other examples outside Sri Lanka include the following:

- In Nepal, IWMI's recommendations have been incorporated into the country's new Irrigation Regulation 2056.
- Following IWMI's pilot interventions to establish water user federations in Pakistan, the Sindh provincial government adopted IWMI's model in the three study canals and the lessons from the pilot study have informed the formation of IMT policy elsewhere in the province.
- Results from a preliminary questionnaire survey in Central Asia suggest the respondents have used the WUA guidelines to establish over 250 WUAs.

Lessons learned

This case study shows that in NRMR projects, one must distinguish between projects with a micro emphasis and projects with a macro emphasis. For micro-projects that focus on management practices that directly increase farm productivity, conventional cost–benefit analysis approaches may be suitable to assess project impacts. However, for NRM-related macro-projects to develop strategies and procedures for better NRM within a region, sector or a country, different metrics of analysis may be required. The IWMI IMT project is an example of an NRM macro-project.

The case studies discussed in the IWMI report show the demand for the results of IWMI's research and technical information. However, IWMI faces two challenges relating to the impact assessment of NRM policy projects:

- Establishing what would have happened to IMT in the absence of IWMI's research and synthesis. Would other organizations have filled the gap?
- Establishing what productivity and efficiency gains are attributable to stronger farmer participation in the management of irrigation schemes as per IWMI's intervention for technical, policy and institutional change.

One key lesson, consistent with the NRMR micro-projects, is that proper *ex post* evaluation requires careful planning and monitoring before, during and after the project lifecycle.

ICRAF case study: Fertilizer trees – their development, socioeconomic and ecological impacts in southern Africa

Low soil fertility is a major biophysical constraint to increasing agricultural productivity in Africa. Mounting pressure on the land has led to shorter fallow periods. The generally low level of mineral fertilizer use – often because it is unavailable or expensive and farmers lack access to credit — causes severe nutrient depletion of soils. Since the beginning of the 1990s, ICRAF, in partnership with institutions in southern Africa, has developed soil-fertility management technologies that use on-farm resources to replenish soil fertility. One such NRM technology is fertilizer tree fallows. This involves planting fast-growing plant species that are (usually) nitrogen-fixing, that produce easily decomposable biomass, that are compatible with cereal crops in rotation and that are adapted to the climatic and soil conditions of the *miombo* woodland ecology of southern Africa. The *miombo* woodland covers most of southern, central and eastern Africa. It forms a closed deciduous non-spinescent woodland with a shrub layer variable in density and composition.

The fertilizer tree project had two main phases. The first phase which started in 1986 emphasized research on the agronomic aspects of tree fallows. Such aspects include species selection and provenances; tree establishment; rotation periods and configurations of trees and crops; and methods of cutting and incorporating tree biomass into the soil.

The second phase, from around 1997, concentrated on secondary problems associated with the technology, such as the management of emerging pests in the fallow species and up-scaling the technology. These latter issues included improving the effectiveness of seed and nursery systems, developing institutional mechanisms for managing potential conflicts between tree growing and animal grazing, and identifying best-bet locations for testing and promoting improved fallows. Due to the virtual absence of effective service delivery systems, ICRAF supported extension, such as producing extension materials and facilitating farmer visits to experiment and demonstration plots. ICRAF also helped organizations involved in improved fallows to network for information exchange and provided fund-raising assistance.

In addition to these R&D investments by ICRAF, trials in farmers' fields led to the adaptation of the technology. Hence, farmers put in their own resources and contributed to technology development with their own innovations, such as methods of planting tree fallow seedlings directly into bush fallows, tree pruning and the use of vegetative planting material.

Impact assessment framework

The study follows a comprehensive descriptive approach. Part of this account is based on a general cost–benefit framework that attempts to identify the private and social costs and benefits of tree fallows. Using the conventional economic surplus model, theoretical deliberations are submitted with a view to developing hypotheses for the short-term production and price effects, and the longer-term interaction effects between the demand for environmental services and the price of maize. However, no methodology to test these theoretical hypotheses has been developed.

There is also an impact assessment framework, which starts out with an exhaustive description of the technology R&D process, including the results of a farmer-based adaptation of the technology. Drawing from a broad-based literature review, it then summarizes numerous studies that investigated the factors enabling or inhibiting adoption of tree fallows. The adoption studies followed various methodological approaches ranging from purely descriptive methods to more advanced econometric modeling using logit and tobit models.

To assess farm-level impacts, primary data were collected from farmers' fields on a weekly basis throughout the 2002/2003 agricultural season in Zambia. These data were used to calculate the net present values of five soil fertility management options including three tree fallow variants and two counterfactual scenarios.

A financial rate of return calculation aggregates the observed farm-level benefits and projecting adoption until 2014. ICRAF's R&D investment was based on rough estimates from project records. In addition to the rate of return analysis, an ample description of the long-term ecosystem and environmental effects based on literature data and ICRAF experiments was provided.

Adoption and farm-level outcomes

About 77,500 farmers had a sown fallow in their field in 2003. A good number of these farmers were reached and recorded by a World Vision project targeting 90,000 households. Their study found that 27% of households had planted an improved fallow by 2003, after 3 years of development efforts. In just 3 years, the percentage of farmers using improved fallows equaled that of farmers using manure (26%). Furthermore, farmers had planted improved fallows in other collaborating countries including Malawi, Mozambique, Tanzania and Zimbabwe.

Dis-adoption of tree fallows was low; 71% of farmers who planted fertilizer tree fallows in 1996/97 continued to plant them over the next 3 years.

The average size of fields cultivated by farmers increased from 0.07 hectare in 1997 to 0.20 hectare in 2003. However, the distribution of the field size varied widely, ranging from 0.01–0.78 hectare per farmer.

The analysis of farm-level net benefits of fertilizer tree fallows shows that these are more profitable than the common farmer practice of no nutrient inputs. However fertilizer tree fallows cannot compete with recommended rates of mineral fertilizer based on the 50% subsidy on chemical fertilizer in Zambia. Accounting for the full costs of fertilizer narrows the gap between chemical fertilizer and tree fallows but still makes the former more profitable. Hence, the economics of tree fallows is location-specific, i.e. in areas where transport costs of fertilizer are high, the tree fallow options outperform the fertilizer option.

Additional benefits of the tree fallow technology included mitigating yield risks, i.e. farmers who used mineral fertilizer lost more invested resources than those who invested in tree fallows. The fallows also enhanced the soil's ability to retain moisture during drought years by improving the soil structure and organic matter content.

Welfare analysis and rate of return

The total financial benefits due to the technology were calculated at nearly US$2 million by 2005–2006. On the cost side, during the 1989–2004 period, the average annual cost in R&D for soil fertility ranged between US$230,000 and US$350,000. Costs were assumed to increase slightly over time due to inflation, but to diminish around 2010. Development costs of two tree fallow implementation projects in the late 1990s and early 2000s were included and costs of US$70,000 were assumed annually until the end of the project period. The IRR depends on the assumed duration of the project. Since the research lag was considerable due to the long R&D period, for a 20–year time horizon (1988–2008), the IRR is only 3.2%. However, if the time period is expanded to 25 years, the IRR rises to 15.2%, and further to 20.8 % for a project ending in 2018.

Other quantified benefits were:

- Improved food security through the provision of 57–114 extra person days of maize consumption per household.
- Improved soil fertility, soil aggregation, enhanced water infiltration and water holding capacity, as well as reduced water runoff and soil erosion. Fallow systems increase the percentage of water-stable aggregates with a diameter greater than 2 mm compared with continuous maize cultivation.
- Positive N balance in the 2 years of cropping provided proper tree fallow management (i.e. 2 years of fallow followed by 2 years of cropping).
- On average, provision of an additional 11% of fuelwood, which helped to reduce the exploitation of trees from the communally-owned *miombo* woodlands and thus reduced deforestation.

- Positive effect on carbon sequestration with 2.5 to 3.6 t/ha sequestered. Rotational woodlots offered the highest potential to sequester carbon both in the soil and in above-ground biomass.

Lessons learned
There were four main lessons:

- Fertilizer tree fallows are a profitable option for increasing maize production for African farmers without proper access to fertilizer.
- The technology is likely to be transitory for some farmers and more lasting for others depending on economic development in rural Africa.
- In the absence of effective service delivery systems, international agricultural research centers may have to invest in extension activities to promote technology adoption.
- Impact assessment of complex NRM technologies that start out with a purely agronomic perspective is difficult, since the necessary data need to be collected on a real-time basis.

WorldFish case study: Impact of the development and dissemination of integrated aquaculture–agriculture technologies in Malawi

Since the start of the 1970s, several donor organizations have tried to introduce aquaculture to rural farmers in Malawi. However, these projects had little success: farmers discontinued fish production as soon as subsidies were terminated. Furthermore, there was no diffusion of the technology outside project areas.

From 1986 until the mid-1990s, the WorldFish Center, in collaboration with the Department of Fisheries in Malawi, implemented an R&D project to introduce an FPR approach. The project emphasized the concept of integrated aquaculture–agriculture (IAA), which uses farm waste, crop by-products and other natural resources from the farm environment as nutrient inputs for fishponds. Farmers participated in the evaluation and adaptation of IAA technologies.

The outputs of the project were:

- Generation of integrated aquaculture–agriculture production technologies
- Development of a technology-transfer approach for small-scale aquaculture in Africa.

An impact study to assess the *ex post* impact of this NRMR project was conducted in 2003. The impact study measured the effects of these two project outputs on:

- The degree of IAA technology adoption and diffusion
- Farm income
- Household health
- Welfare effects of increased fish supply on the Malawian economy.

In addition, a qualitative description of the institutional impact of the technology transfer approach is given.

Impact assessment framework
The theoretical basis for assessing the impact of the project is household theory. It is hypothesized that the technology-transfer approach improves the understanding of farmers about the interactions of their

agroecology and farming systems and thus stimulates them to adopt the IAA technology. It also permits more efficient use of farm inputs and thus raises total factor productivity. In addition, IAA requires efficient use of on-farm and natural resource inputs, resulting in better natural resource management and enhancing biodiversity. Increased farm productivity arising from higher output and optimal use of inputs translates into higher farm income and better health.

The basis for comparison is small-scale farm households that in principle could have adopted IAA technology but chose not to.

Data were collected in early 2004 using a survey. The six-site study covered IAA-adopting and non-adopting farmers. In each of six study sites, 30 IAA and 30 non-IAA (i.e. 'control') respondents were selected representing agroecological conditions with good potential for fish farming and typical socioeconomic conditions for rural Malawi. Out of these 360 sample farmers, 315 were available for interview. In addition, data from a small sample of farmer project participants were monitored and a household health survey of 545 respondents (including IAA and non-IAA farms) was undertaken.

The analysis applied a comprehensive impact assessment framework and included an adoption study. It also explored impact pathways with land-use changes, input use efficiency, total factor productivity, farm profitability and farm income. To describe the adoption process, a two-stage logit function adoption model was used. The first step captured the adoption decision and the second one the intensity of adoption as measured by the level of integration of aquaculture with other farm enterprises. Land-use changes were measured using frequency statistics. The concept of interspatial total factor productivity using the Tornqvist Index (TI) was used to account for the multi-output multi-input setting of the IAA system. Profitability was compared using descriptive statistics, while the income effects were measured by applying a two-stage instrumental variable approach. Predicted probability of adoption was used as a variable to measure the effect of farm income. In addition, a stochastic production and technical efficiency function was estimated that could provide some indication of the IAA technology transfer approach on the technical efficiency of input use.

At the household level, descriptive statistics and parametric tests were used to assess the impact of IAA adoption on the food consumption pattern and the household's nutritional status.

The welfare effects of the project on the Malawian economy were estimated by calculating the economic surplus using a multi-commodity model. The increase in consumer and producer surplus was used as a measure of gross benefit. Accounting for the R&D investment and taking into consideration the effect of other aquaculture projects on fish output, the IRR was calculated.

Adoption and outcomes
Results of the adoption model showed that the decision to adopt IAA is influenced by a few factors, namely: (i) access to extension; (ii) the intensity of IAA training; (iii) endowment of land; and (iv) farmer age. Conversely, the degree of aquaculture integration, which could be a proxy measure of the success of the participatory technology-transfer concept, was found to be influenced by: (i) irrigation access; (ii) gender; (iii) educational level of the household head; and, (iv) endowment of land. Hence, the adoption decision is influenced by the project variables, but the level of aquaculture integration is driven by factors external to the project's transfer concept. While the study provided a good understanding of the adoption process, no adoption data were provided regarding the scale of adoption.

Farm-level impacts can be summarized as follows:

- IAA farmers grow more high-value crops (e.g. vegetables) in combination around their fishponds.
- Total factor productivity of IAA adopters exceeds those of non-adopters by 11%.
- Labor input of IAA adopters exceeds those of non-adopters by 25%.
- Average farm profits per unit area owned by IAA adopters are more than double those of non-adopters.
- Net farm income of IAA adopters exceeds those of non-adopters by 60%.
- Fish accounts for slightly more than 10% of net farm income of IAA adopters.
- A 1% increase in IAA adoption increases net farm income per hectare by 0.9%.
- Farm size has a negative effect on net farm income per hectare, while it positively affects the IAA adoption decision.
- IAA adopters are technically more efficient than non-adopters.
- IAA adopters consume more animal protein than non-adopters.
- No significant impact of IAA adoption on the nutritional status of children below 5 years of age could be demonstrated. However this may emerge in the longer term.

Welfare effects and rate of return

Project benefits and costs were calculated based on a number of assumptions. The cost of IAA technology development by WorldFish from 1986–1994 was around US$1.5 million. The WorldFish project costs were specified on an annual basis. Another US$100,000 per year for the collaborating NARS was added to the costs. From 1994 onwards, a constant annual cost of US$100,000 was assumed to reflect the cost of dissemination activities by the government and various NGOs.

The supply impact of R&D on IAA in Malawi was estimated from the increases in aquaculture production. Twenty-five percent is attributed to growth in demand; the remainder is divided equally between yield increase and area growth. Assuming that two-thirds of the observed growth in aquaculture production is attributable to the WorldFish project, this translates into a net present value (NPV) of US$3,056 million, and an internal rate of return of 12.2%. Most of the benefits (60%) go to consumers through lower fish prices.

Lessons learned

This case study is an excellent example of a comprehensive impact assessment framework that used a combination of methodological tools to assess the impact of a complex NRM R&D project. The combination of an integrated multi-output, multi-input technology with a new technology transfer model presented a particular challenge: equating the two types of project outcome to adoption, farm level, household level and economy-wide welfare impact was a complex task. The study provided a possible avenue for measuring the impact of such types of NRM projects while also illustrating their limitations. A major stumbling block is the difficulty of effectively integrating the results of the different partial analyses. Furthermore, the lack of baseline data did not permit significant empirical attribution of the impacts.

The demonstrated welfare effects are based on conservative assumptions. Advancing the financial project analysis toward an economic analysis using shadow prices (the real prices if distortions are removed) might lead to a higher rate of return.

SPIA synthesis of the case studies and lessons learned

The seven case studies are highly diverse, as shown in Table 2.2. They cover a range of geographical regions, with two projects in sub-Saharan Africa, one in North Africa, two in Asia and, one with global coverage. Both macro- (policy and institutions related) and micro-oriented (commodity and farm-level technology focused) research projects are included. Most of the research commenced in the mid 1980s or early 1990s, such that a reasonable time period had transpired to allow for lag times between research and impacts.

Investment was often difficult to quantify since the research was mostly multi-dimensional and sometimes embedded in other activities in the center. As a result, the figures in the table are estimates based on center and NARS records, and expert judgments. In several cases, the term 'research investment' also includes some investments in extension. Sometimes centers engage in dissemination and extension to introduce and spread NRM technology. These projects involved significant involvement by NARS and other partners, which further complicated costing. The attribution problem is significant in some cases.

Most of the micro-studies used a neoclassical economics framework that followed the examples given by CGIAR investment in CGI research (Evenson and Gollin, 2003). Typically, the researchers started out with an adoption study, and then proceeded to investigate the productivity and income effects of the NRM technology by a production function or household model. All these micro-studies applied a welfare economics framework to calculate a financial or economic rate of return on the R&D investment. Three of the micro-studies (CIAT, CIMMYT and WorldFish) also calculated the distribution of the project benefits among producers and consumers. However, none was able to examine the overall impacts on the poor since baseline data were not available and sample sizes of the studies were insufficient to produce valid results.

The methodology used for the micro-studies was not applicable for the macro-studies. In both the CIFOR and IWMI cases, it was not possible to identify the economic benefits of CIFOR's certification or IWMI's

Table 2.2 Overview of NRMR projects

Center	Project type	Countries	Period	Investment (million US$)[1]
CIAT	Cassava productivity enhancement, soil conservation technologies and farmer participatory research	Thailand, Vietnam	1993–2004	4.0
CIFOR	Criteria and indicators of sustainable forest management	Global	1994–1999	3.3
CIMMYT	Zero tillage in rice–wheat systems	India	1990–present	3.5
ICARDA	Alley cropping with cactus/*Atriplex*	Morocco, Tunisia	1995–2002	< 1.0
IWMI	Irrigation management transfer	South Asia, Central Asia	1992–present	Not specified
ICRAF	Tree fallows in maize	Zambia	1986–2002	~3.5
WorldFish	Integrated agriculture–aquaculture	Malawi	1986–mid 1990s	1.5

[1] Nominal values

information and policy advice. It was also not possible to clearly identify a counterfactual. Both these research projects had heterogeneous impact pathways. Attribution was complicated because of the difficulty in isolating contributions from other parties. The analyses therefore concentrated on providing a thorough description and quantification of the demand for the particular NRM technology, through application of interviews, user surveys, bibliometric techniques and webmetric searches. The different conceptual frameworks and analytical approaches for the case studies are presented in Table 2.3.

The CIMMYT project established an effective public–private sector partnership that helped to achieve a large-scale impact expected to reach over three million hectares (currently about 800,000 ha). However, the coverage of the project at the final stage was based on *ex ante* analysis using adoption models. Likewise, all analyses of rates of return had an element of *ex ante* since benefits were assumed to continue beyond the date of project termination.

Table 2.4 summarizes the impact assessment results for the projects. Most IRRs were of the same magnitude as found in many other agriculture R&D projects. For example, Raitzer (2003) calculated an IRR of 15% of CGIAR investments where *ex post* impact was empirically attributable to the research. Evenson (1991) in a review of rates of return for agricultural research in Africa found it to be 37% on average. However, this figure can be judged as too optimistic since this study tended to underestimate the research costs. Furthermore, the IRR of the NRMR projects in the current study were calculated using conservative assumptions, e.g. excluding spill-over effects and environmental benefits.

For two of the three case studies (CIMMYT and WorldFish) where producer and consumer surpluses were calculated, it was found that NRMR projects benefit consumers relatively more than producers. In these two cases, the elasticity of demand for the commodities involved was low.

Box 1 lists a number of lessons learned from the case studies. The studies demonstrate that, at least in cases where benefits can be quantified, CGIAR investment in NRMR has paid off. However, the case

Table 2.3 Conceptual framework and methodologies

Center	Conceptual framework	Major methodologies used
CIAT	Household production and welfare theory	Simultaneous equations of adoption and productivity change, consumer and producer surplus, rate of return
CIFOR	Institutional economics and information theory	Impact pathway and client analysis
CIMMYT	Production and welfare theory	Statistical and descriptive analyses, partial budgets, consumer and producer surplus, rate of return
ICARDA	Production and welfare theory	Mathematical programming, ecological modeling, adoption and production functions, stochastic simulation
IWMI	Institutional economics and information theory	Bibliometric and webmetric analyses, client surveys
ICRAF	Production and welfare theory	Literature analysis, partial budget, rate of return
WorldFish	Household production and welfare theory	Adoption functions, total factor productivity, stochastic production frontiers and technical efficiency analysis, descriptive statistics for income and profit, consumer and producer surplus, rate of return

Table 2.4 Impact results of NRM projects

Center	Scale (actual (A)[1] and predicted (P)[2]) Land area	Number of users	Consumer (C) and producer (P) surplus	Internal rate of return (IRR)	Other documented impacts
CIAT		8 villages, 2800 t cassava per village per year (A)	P: 100%	~ 40%	Knowledge and institutional learning
CIFOR	45 million ha of forest under certification (P)		n.c.	n.c.	Cost savings for certifiers
CIMMYT	0.82 million ha (A) 3.4 million ha (P)		C: 65% P: 35%	57%	Conservation of water and energy resources
ICARDA	*Tunisia:* 470 ha (A) 96,000 ha (P) *Morocco:* 1650 ha (A) 350,000 ha (P)		n.c.	*Tunisia:* 16% *Morocco:* 48%	Reduction of soil erosion Net environmental benefit: US$131 per ha
IWMI		50,000 downloads in five years (A), 7500 copies of IMT guidelines (A)	n.c.	n.c.	Demand for policy advice
ICRAF	Approximately 77,000 farmers (A)		n.c.	15% (over a 25-year period)	Carbon sequestration Risk reduction Reduced soil erosion
WorldFish		1000 t of fish per year (A) 15,000 t per year (P)[3]	C: 60% P: 40%	12%	Household nutrition

1 *ex post* evidence of adoption by the end of the data collection of the study, i.e., around 2002/2003
n.c. Not calculated
2 Predicted adoption on national level outside the project intervention area
3 Calculated on the basis of the observed annual growth rate up to 2016

studies' IRRs do not reach the level achieved for CGI research, mainly because of the difficulty and cost of scaling up NRMR outcomes. On the other hand, NRMR is likely to have additional environmental benefits. Where appropriate, the case studies identified environmental benefits, but in most cases, they were not quantified, and hence, excluded.

Another observation from the seven cases is that NRMR includes involvement in extension. This raises the question of the comparative advantage of the CGIAR in extension-type activities. The question is: 'How can the Centers make sure that their NRM technologies become adopted if delivery systems are largely dysfunctional or even absent?' The uptake of agroforestry innovations in many countries has faced this constraint. Unlike CGI, NRMR lacks champions in both the private and public sectors, who understand the research and are eager to extend its results.

Box 1: Lessons learned and food for thought

The rates of return of these specific NRMR projects are sufficient to justify the investment; but the rates are not at the upper end of the spectrum of rates of return associated with agricultural research, e.g. CGI.

Rates of return would likely be higher if environmental benefits were included.

More effort is needed to quantify and value environmental benefits.

Costs of adoption are often difficult to quantify (farmer-time, learning).

Lack of baseline data leads to assumptions, especially regarding the counterfactual.

NRM projects include micro- (technology) and macro- (policy) projects.

Micro-projects in NRMR are often small and local, although in some cases, there are comparative studies across regions and countries that can produce more general knowledge.

Quantification of benefits for macro-projects in NRMR was not possible in the two case studies attempted (CIFOR and IWMI). Such quantification requires new models and methods.

Issues related to institutionalizing impact assessment for NRMR in centers need to be addressed.

Another concern is data. The centers do not plan projects using explicit *ex ante* impact projections, and none of the cases had a baseline survey. Hence, it was not possible to use analytical models that could have significantly reduced the counterfactual problem, and, to some extent, the attribution problem. Similarly, studies that apply non-market valuations of environmental goods and services are not widespread in the CGIAR. None of the NRM case studies incorporated this dimension in their research, perhaps because of poor data availability in developing countries. However, it is increasingly evident that to reach meaningful conclusions about the impacts of some types of NRMR, these data cannot be ignored. What is also absent is empirical evidence of impact on poverty reduction, e.g. using a methodology suggested by Alwang and Siegel (2003). In a few cases, *ad hoc* attempts have been made, but the database was insufficient to take this very far.

Finally, it is necessary to explore and develop new theoretical frameworks and methodologies for assessing the impact of NRMR through policy impact pathways. A dynamic model that includes learning and adaptation is imperative in order to better assess the adoption of recommendations from NRM policy research; to measure reductions in transaction costs; to measure increases in productivity and gains in time; and to reduce the number of misguided policy interventions in a multi-agent setting.

There is evidence of positive economic impact from the wide variety of NRMR assessed in the case studies, with IRRs that for the most part should be acceptable to most investors in the CG system's research. At the same time, the case studies have raised a new set of questions and issues that not only require the centers to do more of the same type of assessment, but also to analyze a broader set of NRMR impacts and not just economic impacts.

Impacts of the systemwide Programme on Alternatives to Slash-and-Burn: A synthesis of a recent assessment

One of the components of the SPIA NRMR impacts initiative was an assessment of the impacts of one particular systemwide program. ASB – the oldest NRM-focused research program in the CG system – was chosen as a typical case study. The CGIAR SC commissioned an evaluation and impact assessment of ASB in 2004. A three-member panel carried out the review between late 2004 and mid-2005. The impact assessment aspects of the review are summarized in this report.[12]

ASB has been in operation as a CG systemwide program since 1994. It has an ecoregional focus on the forest–agriculture margin in the humid tropics, with benchmark sites in six countries (Brazil, Cameroon, Indonesia, Peru, Thailand and The Philippines). Its goal is to raise the productivity and income of rural households in the humid tropics while at the same time decreasing deforestation, or at least maintaining it at the same level. ASB approaches this goal through an INRM strategy, emphasizing long-term engagement of researchers with local communities and policy-makers at various levels. ASB comprises a partnership of more than 80 institutions from around the world, including research institutes, NGOs, universities, community organizations, farmers' groups, and other local, national, and international partners. ICRAF is the convening center.

The challenge of measuring impact

The difficulties of assessing ultimate impacts in complex, multi-disciplinary, multi-stakeholder INRM programs operating at different scales and across regions are formidable. They include identifying unambiguous cause-and-effect chains in environments where typically there is a multitude of entities and forces contributing to impact; time lags between research results and eventual variations in valuable aspects; and the lack of widely-accepted standardized indicators to quantify these variations. Even if these indicators were available, the all-encompassing nature of INRM programs would require unambiguous assessment and long-term tracking of a number of variables. In reality however, reliable data are difficult to obtain. Time lags for impact to occur may be considerable in programs such as ASB; and such programs may be too 'young' to exhibit their whole array of potential impacts in the 11-year period. In addition, the different biophysical, cultural, political and economic conditions surrounding individual experiences makes it difficult to make generalizations on broader scales of impact.

The approach

The Panel used a three-pronged approach to assess the ultimate impacts of ASB. First, it sought to establish how ASB's domain has changed over the last decade, independent of the program's role in bringing about these changes. Next, the panel examined correlations between changes advocated by ASB and actual changes, thus establishing the possibility that ASB played a role in bringing about the said changes. Finally, the panel drew on previous analysis of uptake and outcomes to determine whether there was an underlying plausible causal connection in the observed correlations. This was done in the context of ASB's impact in three major areas: (i) knowledge, (ii) technology and policy, and (iii) capacity-building. No attempt was made to assess ultimate impacts on the poor who live along forest margins.

The results-based management (RBM) framework used by the Panel to assess ASB is very appropriate. The impact pathway was clearly spelled out and elements disaggregated in the context of a succession of components internal to program elements (input, activity and output) and external to program elements (uptake, outcome and impact). A number of innovative methods and metrics were also used to quantitatively and qualitatively document ASB's influence and outcomes.

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[12] See http://www.sciencecouncil.cgiar.org/meetings/meeting/SC4/ASB_Review FINALb.pdf for the full external review report.

Main results
The review found that ASB employs INRM approaches to produce research-based knowledge relevant to its core mission in a highly innovative, effective and efficient manner. The review team found the quantity and mix of ASB's outputs as generally appropriate for the evolving character of the program.

Uptake. The uptake of ASB products by independent publishers and by website users has been substantial and (suitably normalized) on a par with, or somewhat greater than, levels achieved by other CGIAR units. The great demand for program leaders to speak and participate in high-level international committees exceeds capacity. The program itself embodies a capacity for research and development that makes it an increasingly attractive partner for other institutions. Relatively fewer people sign up for ASB's training programs than to other CGIAR training programs. However, ASB's lecture notes are in high demand.

Outcomes. ASB results are treated as influential outputs by communities specializing in the ASB domain around the world. Particularly recognized are its research results in pan-tropical research methods, soil science, the analysis of benefit trade-offs among alternative land uses and cross-sectoral policy guidance. In the action realm, ASB is widely acknowledged to have contributed directly to the design of innovative policies, legislation and institutions across its pan-tropic domain. On capacity-building, a significant outcome of ASB's activities over the last decade has been the creation of an important and at least partially replicable capacity for harnessing research on sustainable development in the ASB domain. Nevertheless, while ASB is known to work in broader fields of development and conservation, its outputs, which are truly international public goods, are not as widely cited or utilized. This shortfall is likely to be remedied, in part, by the release in 2006 of several excellent synthesis outputs. It also represents an excellent opportunity for high returns on future dissemination investments.

Impact on knowledge. ASB has greatly contributed to the world's knowledge of human–environment interactions on the forest margins of humid tropics. Its research has had a significant impact on contemporary understanding and policy emphasis regarding the promotion of sustainable agricultural development based on environmentally sound NRM. Researchers and institutions that work on poverty alleviation and conservation in the humid tropics recognize ASB as a world leader in integrated, interdisciplinary research on the human and environmental consequences of land-use choices. Citation analyses and other objective measures show that ASB results are treated as influential international public goods by researchers in human–environment systems.

Every major difference identified between the world in 1992 and the world today in terms of understanding the underlying human–environment interactions at the forest margin in the humid tropics reflects a change that ASB has actively promoted. These changes include emphasizing the importance of smallholder land management; acknowledging the multiple actors in land-use change, and the multiple services provided to those actors by land; and, more generally, recognizing the complex dynamism of the ASB domain. ASB's systematic, science-grounded approaches have helped to transform existing anecdotal understanding at specific locales into globally accepted scientific knowledge of an entire ecoregion. Despite relative weaknesses in certain areas of modeling and institutional analysis, the program has set the standard and established a model for integrating natural and social science approaches in response to complex NRM problems.

Thus, there is credible evidence that ASB has created a truly international public good of reliable knowledge regarding the functioning of human–environment systems in tropical forest margins around the world. It has achieved this by generating comparable, co-located data across its benchmark sites and using its Global Coordinating Office to undertake across-site syntheses. The SC regards this as a valuable template to help guide future system priorities and strategies.

Impact on technology and policy. ASB results touching on technology and policy correlate well with some but not all of the observed changes in management and policy that have occurred over the last decade. The program was one of the first to systematically demonstrate what is now generally understood to be the error of assuming that increases in smallholder productivity would *ipso facto* reduce rates of deforestation and forest degradation. ASB built on these early insights to lead the way in scientifically characterizing the trade-offs across different stakeholder interests inherent in different land-use decisions. The 'ASB matrix' created and calibrated by the program, has become globally accepted as a state-of-the-art scientific framework for supporting decision-making on land-use alternatives. More broadly, ASB has helped to 'globalize' policy approaches to human–environment dynamics in tropical forest margins, showing that actions must be concerted to reflect global economic and environmental interdependencies.

ASB impacts are less clear with respect to other major changes that have affected international approaches to technological innovation and policy-making in the program's domain. For example, although ASB outputs acknowledge the need for engaging an increasing variety of actors in efforts to manage landscape use at the forest margin, there is little evidence of ASB leadership in this area. ASB does not seem to have played a leading role in the growing recognition of the suite of governmental reforms, including the control of corruption, necessary for creating an environment in which market forces and other incentives can realize their potential. Generally, the lack of appropriate mechanisms for tracking and targeting its technology and policy outputs into action and impact make it difficult to evaluate ASB's on-the-ground impact.

There are several areas where ASB has had significant local impacts on technology adoption and policy change, and where considerable potential exists for these impacts to spread in time across the pan-tropic domain. Two specific examples are the introduction of a forage legume, *Arachis pintoi*, to arrest pasture degradation in the Amazon and the ASB-supported regulatory reforms over land rights in Indonesia. However, the potential spread of such local innovations is contingent on governmental reforms and development partners.

Impact on capacity. ASB has made substantial contributions to some but not all of the major changes that have occurred over the last decade in the world's capacity to address questions of sustainable land use at the forest–agriculture margin in the humid tropics. The program's greatest impact on capacity is paradoxically also the least tangible, but not in all cases. As demonstrated by the role assigned to ASB in the Millennium Ecosystem Assessment (MEA), the program has created the world's pre-eminent system for the comparative scientific investigation of human–environment interactions in its domain.

Beyond this overall impact on capacity, through its benchmark system of standardized methods , ASB has contributed to the emergence of today's vastly improved global capacity to measure changes in land use and their implications in tropical forest margins. The program plays a lesser, but nonetheless important, role in the world's maturing ability to explain and predict those changes. With respect to local impacts, ASB has substantially enhanced and hastened the development of capacity in the NARS and international agricultural research centers (IARCs) working closely with ASB. However, it remains to be seen whether this capacity can be sustained or transferred to other organizations that have not been intimately involved with ASB.

While the panel's report gives ASB high marks for capacity-building, it acknowledges the difficulty of measuring the effects of capacity-building activities. Indeed, the report does not really provide sufficient evidence to allow a conclusion that ASB has been very successful in this area.

ASB and the CGIAR in the R&D continuum. The most conspicuous capacity need that ASB has failed to meet is scaling up R&D results into major development initiatives. In the review team's opinion, the

CGIAR has been “somewhat ambivalent, with a resulting lack of clarity regarding who has responsibility for the production of potentially global public goods, and who has responsibility for the transformation of that potential into widely diffused change on the ground” (Science Council Secretariat, 2006). Thus, ASB’s major shortcoming is its inability to mobilize resources to extend its results more widely across the forest margins of the tropics. This raises the issue of the program’s appropriate location in the research–development continuum. Related to this is the fact that many of ASB’s research and innovation results take a long time to yield impacts and require considerable development investments. In order to generate development benefits, attributes of research results which could be politically appealing and economically attractive to governments or financial institutions should be especially highlighted, so the necessary complementary development investment takes place. This issue is not limited to ASB but is more generic. A thorough discussion among CGIAR stakeholders regarding the appropriate location of CGIAR work in the research–development continuum is needed.

SPIA concluded that overall, by developing more environmentally sensitive routes to some of the conditions necessary for increasing the incomes of poor people living on forest margins in the tropics, ASB has had a solid presence and has impacted positively on knowledge and practice. The study also shows that in the absence of an *a priori* impact assessment framework, which the program did not have at its outset, it is exceedingly difficult to trace the impacts of an INRM program beyond the output and, in some cases, the outcome point. SPIA also concluded that a major issue when deriving impacts from this type of program is determining the appropriate position of the program – in terms of influence and presence – on the impact pathway. This, of course, raises the fundamental question on the role of this type of NRMR program in relation to the roles of other actors.

3. Methods Development: Conceptual and Analytical Considerations in Measuring Impacts from NRMR

A small part of the funding for this initiative was devoted to improving NRMR impact assessment methods. The methods development component of the initiative is linked to ongoing SPIA and CG preparation of strategic guidelines for impact assessment. For this reason, the discussion of methods in this report stems from a work-in-progress, and is only intended to highlight some of the key issues and methodological challenges in measuring NRMR impacts.

Two main activities are involved in this part of the overall initiative:

- First, the Center Directors' Committee (CDC), through its task force on INRM, was requested to prepare an overview paper on the centers' perspective of where the CG system stood in terms of NRMR impact assessment. The CGIAR provided funds for this activity, and two consultants were hired to draft a paper which was later discussed and approved by the CDC (See highlights from this paper in the next section).
- Second, a recognized international expert in the field of NRM impact assessment, David Zilberman of the University of California, Berkeley, USA, was hired as a consultant to assist on this component of the study. Zilberman worked with the case study teams and helped them develop strategic guidelines for NRM impact assessment. The results of his work will be integrated with ongoing SPIA methods and strategic guidelines development activities. Zilberman worked closely with a former SPIA member, Hermann Waibel, and other SPIA members. Some highlights of the ongoing work on approaches and methods are presented in the section below on 'NRMR impact assessment methodology development'.

NRMR impact assessment in the CGIAR: Center Directors Committee paper on *ex post* methods to measure natural resource management research impacts

One aspect of the overall initiative involved the CDC producing a paper on their perspective of the state of NRMR impact assessment in the centers. Two consultants, Sam Fujisaka and Douglas White, produced a paper, which was then reviewed by the centers and finalized for submission to SPIA. The paper:

- Categorizes four overlapping types of NRMR and their associated impact assessment methods
- Provides examples of *ex post* impact assessment of the different categories of NRMR/INRM
- Summarizes each center's description of their methods and approaches
- Considers the implications of impact assessment methods in terms of questions or issues addressed
- Suggests a way forward for the centers.

Key points of this paper are summarized in Appendix II; the full paper is available on the Internet[13] and from the SC library.

Two clear points arise from this analysis: (a) the wide variety of activities included within the NRMR framework; and, (b) the wide variety of impact assessment approaches used and how some of them fall

[13] http://www.icarda.cgiar.org/INRMsite/

short in terms of producing credible and rigorous quantitative measures of impact. The centers differ widely in the level of NRM impact assessment they undertake and their capacity to carry out such assessment. In other words, the CG system is in a state of flux when it comes to NRM impact assessment.

Fujisaka and White (2004) make a number of important conclusions and recommendations that are outlined in Chapter 4. The authors point out that:

- The section of this paper 'Wisdom from the practitioners' downplays what apparently is a point of contention. Accordingly, one view supports economic impact assessment and calls for more economic methods development: "Approaches are needed that capture environmental services and other (non-yield) outputs from NRM/INRMR such as maintenance and loss reduction, risk reduction, quality improvement, reduction of negative environmental externalities and compatibility with off-farm laboor schedules." (Kelley and Gregersen, 2005).
- The contending view supports the process orientation of INRM and downplays the econometric approaches: "…current 'best practice' economic evaluation methods commonly used in the CGIAR system, which attempt to establish a linear link between a project's outputs and wider level impacts, ignore complexity" (Douthwaite et al., 2004).

They go on to say: 'We conclude with many others that different mixes of methods (including economic) are necessary to deal with the different types of impacts sought by INRMR.' SPIA concurs fully with this conclusion. We believe that a number of different approaches are needed, depending on the purpose of the assessment, the nature of the impacts and the research being assessed. The seven case studies included in this initiative illustrate a wide set of approaches that are appropriate depending on the type of research and the purpose of the assessment.

NRMR impact assessment methodology development[14]

The SPIA initiative focuses on drawing out specific methodological lessons and issues related to NRMR impact assessment. This section provides some insight into the broader sets of issues and challenges encountered in this task. These insights are an important input for the broader strategic guidelines that SPIA and center partners are developing. The guidelines will explore basic issues such as the criteria for plausibility in impact assessments, attribution, development of counterfactuals, range of indicators of impact, logframe and impact pathways analysis, relationship between *ex ante* and *ex post* impact assessment, and issues related to credibility, feasibility, transparency, communication and use of results.

Much of the methodological development of impact assessment in the CGIAR occurred within the context of the big successes of the Green Revolution, and thus was focused on appropriate methods for documenting the economic benefits derived from CGI research (Evenson and Gollin, 2003). These methods rely primarily on the use of standard neoclassical market approaches that measure the economic surplus generated by shifts in the supply function. These shifts are derived from adoption of new, higher-yielding varieties of rice, wheat, maize and other crops. Unlike CGI research, NRMR projects generally target more complex objectives than raising yields or improving crop quality and thus require both expansion of the existing methodologies and development of new ones.

The following discussion emphasizes the direction of expansion of existing methods to meet the needs of NRMR projects. It also identifies the new direction of methodologies to accommodate unique features of

[14] Constitutes work in progress by SPIA consultant Prof. David Zilberman and Hermann Waibel, with input from the other SPIA members.

NRMR. (See the Chapter 1 for the scope of NRMR used here). First, the measures and indicators of impact are listed, and some basic issues arising from the nature of NRMR are discussed. The methodologies of NRMR economic impact assessment, illustrated by some examples from the CGIAR case studies, are given. Finally, some conclusions regarding further requirements of NRMR impact assessment are drawn.

In evaluating NRMR, it is helpful to distinguish between research and innovation categories. First, innovations may vary by scale. In particular, micro-level and macro-level innovations may require different measurements and analyses for impact assessment. Second, it is useful to differentiate between specialized and integrated NRMR and innovations, as discussed in the introduction. INRMR includes elements of both micro-level and macro-level innovations. For example, INRMR projects may refine technologies such as zero tillage to adapt it to spatial variations and also investigate changes in policies conducive to technology diffusion. Assessment of INRMR projects requires a combination of methods that captures the impact of various components as well as the impact of the project as a whole.

Measures and indicators of impact of NRMR

While it is desirable to have a small number of impact measures of NRMR projects that are effective across the board, the use of various measures based on modeling capability and especially data availability are often necessary. At a minimum, the following measures of impact are relevant for NRMR: adoption, productivity, risk and vulnerability, efficiency, equity, resource sustainability, farmer knowledge and general equilibrium effects.

Adoption. Quantitative measures of the scale and scope of adoption, both in relative and absolute terms, are crucial in assessing impacts. The land shares (and the actual areas) of new technologies, as well as the share of farmers who adopt new technologies over time, are important NRM adoption measures for cropping systems. Such measures have been used in all CG system NRM crop innovation studies. When a technology has several components, e.g. integrated pest management (IPM), which includes non-chemical methods of control and monitoring, it is useful to have measures of adoption for each of the components. Intensity of adoption can be measured by input use per unit of land, e.g. how many times a new treatment has been applied per season. One of the key results of impact assessments is the identification of factors that affect adoption. Thus, it is important to have measures of adoption corresponding to different economic and ecological conditions. For example, the CIAT adoption study of improved varieties and soil management technologies of cassava, the CIMMYT study of ZT in rice–wheat systems, and the ICRAF study of tree fallows in maize relate adoption patterns to land quality. Indeed, the seven case studies emphasize the statistical explanation of adoption patterns. Unfortunately, in some of the studies only cross-section surveys were available. The analysis would have improved had there been data on the evolution of adoption over time.

An obvious measure of adoption of macro NRM innovations is the extent to which policy-makers follow research recommendations in, for example, water policy reform or land or forest regulations. Both the CIFOR and IWMI projects provided evidence of adoption of the policies they recommended. However, policy-making is affected by many sources of information, and policy research is an evolving project. Therefore, bibliographical measures (e.g. citations) can be used as proxies for the use of NRMR results among academic audiences. In turn, academic information may influence policy-makers although they rarely cite the sources used in the process of making decisions.

Several authors in Pardey and Smith (2004) suggest that interviewing policy-makers to assess their sources of information is valuable for identifying the influence of research results on policy research. Because of the nature of NRM policy research projects, it may be difficult to quantify the adoption of their results. This is especially relevant for cases where NRMR results are used to prevent introduction of inappropriate policies. And while macro NRM projects do not always trigger change, they speed up the adoption of both a new technology and new policies. Thus, their effect is a shift of the adoption curve or a modification of its shape.

Productivity. Agricultural producers generally adopt management innovations in crops and livestock only if positive productivity and income effects can be realized. Some NRM technologies can increase the productivity of the natural resources used as inputs. For example, IPM enables producers to reduce pesticide inputs without compromising yields. The CIAT project enhanced soil quality and increased the productivity of other resources by reducing soil erosion. The ICARDA projects included elements that enhance soil quality, which led to enhanced productivity of livestock systems. Other NRM projects replace external inputs with low-cost, on-farm resources. For example, the ICRAF projects substituted expensive fertilizers with local tree cuttings. Hence, NRM micro-level innovations can be input-reducing or output-increasing. Furthermore, NRM projects may introduce feedback and re-use systems that can turn waste into by-products. For example, the WorldFish project promoted integrated farming by introducing fishponds in small-scale farms. Residues of vegetable production became fish food; the fish in turn, produced residues that were used as fertilizers for vegetables. Production function and total factor productivity analysis are common methodological tools that can be used to assess the productivity effects of NRM technologies. However, these tools have to be modified to adjust to the specific conditions and problems at hand. Analysis of productivity of NRM systems requires better tools for analyzing the productivity of multiple cropping systems.

Improved productivity by means of NRM systems may not always be reflected in increased output per unit of land. The CIAT project shows that with improved technology, more marginal land enters the production bracket, resulting however in a reduction when output per hectare are computed. Thus, the analysis of NRM projects must recognize heterogeneity of land quality, human capital and environmental conditions, which may lead to different manifestations of the higher production capacity introduced by NRM innovations.

Risk and vulnerability. Sometimes, NRM technologies reduce the yield variability rather than raise the yield potential. For example, balanced nutrient management, improved water management, effective harvesting techniques, or diversified farm enterprises may enhance the response to covariate and idiosyncratic external shocks from ecological or market forces. Thus, an income-smoothing effect can be achieved, and the probability of a household falling below a critical level of income or consumption can be reduced. The concepts of certainty equivalence and poverty thresholds (Ligon and Schechter, 2003; Barrett, 2002) can be used to describe these NRM impact measures. For example, the ICARDA project made a major contribution to preventing damage caused by sandstorms, and the CIAT project reduced vulnerability to rainstorms. Cost-reduction effects of NRM technologies are also apparent Thus, many of the projects resulted in improved food security, and their value was higher when food prices and purchased input prices were higher. For example, the outcomes of the ICRAF project prove most valuable in periods of fertilizer shortages or high prices.

Efficiency. Efficiency is a major criterion in assessing project impacts. Several indicators, including the IRR, the NPV and the benefit–cost ratio (BCR) of a research project can be used to measure efficiency. Therefore, information is required on the costs and values of all the inputs used in the research development and diffusion process, and the outputs affected by the project. In many cases, the correct assessment of efficiency effects must take into account the monetized value of the environmental benefit, which may be quite significant in NRM projects. However, some of the data may not be available or reliable. In particular, reliable data on quantities and values of change in natural resource stocks or environmental amenities are sometimes missing. Therefore, it may be useful to calculate the expected NPV of market benefit (measures of cost-effectiveness) and to present it together with physical measures or other evidence of environmental and natural resource impacts. In other cases, the calculation of rate of return, or other efficiency measures, may be constrained by a lack of data on the cost of the research effort, as well as by problems associated with attributing success to a specific project, as opposed to other projects. In these cases, it is at least possible to compute the overall gain in economic surplus (benefit) resulting from the R&D effort, without computing the rate of return that requires knowledge of research costs and attribution.

The seven case studies attempted to provide efficiency measures, and the rates of return were respectable in most cases but below the spectacular rates of return of crop improvement projects reported by Huffman and Evenson (2005). One possible explanation for the lower rate of return of NRM projects is that these projects required the establishment of a specialized network of delivery and extension, while crop-breeding systems that produce new varieties can rely on existing public and private networks of distribution. The return on research projects depends on the existence and efficiency of marketing and distribution networks. When these networks are lacking, either extra costs are incurred for outreach and extension, or the rate of adoption and the overall impacts are lower than under an ideal system. In addition, NRM projects can have positive non-market effects, which are often neither quantified nor valued owing to lack of data.

Distributional effects. The modeling framework mentioned above allows for the assessment of policy impact on distinct groups such as consumers, producers and governments in various locations. A more refined distribution analysis can be developed based on welfare economic models. Alternative measures of distributional effects estimate the impact of the research on poverty. They include changes in the Gini coefficient and static poverty measures, such as changes in the share of the population below the poverty line (i.e. the headcount ratio and poverty depth, or the poverty gap). It may be useful to break the distributional measure across regions to overcome heterogeneity and to identify regions that are strongly affected by the NRM technology. Recently, there has been a growing tendency to assess impact on poverty, measured by the extent to which projects help to raise the well-being of poor smallholder farmers above a threshold of one or two US dollars per day. Furthermore, the effect of research projects on gender adds another aspect to the distributional measures. For example, in the CIAT project, female-headed households introduced new technologies to relatively more land than households headed by males. In general, the analysis of the impact of the seven case studies suggests that the micro-level projects in particular are beneficial to poor stakeholders, although none of the projects conducted a formal analysis using poverty measures. For example, in the WorldFish study, it was found that a better supply of animal protein improved the nutritional status of children in the longer term. It was also found that 60% of the benefits go to poor consumers due to lower fish prices. Clearly, adding quantitative analysis of poverty impact by formally adopting the standard poverty measures must be given more attention in future.

Environmental and natural resource effects. Typically, many NRMR projects emphasize improvements of environmental quality and reduction of resource management problems. Therefore, it is imperative to have measures of impact on the environment whenever possible. One of the challenges of conducting these studies was to obtain useful quantitative indicators of the natural resource stock and environmental quality.

Several of the NRM projects provided some quantitative indication of environmental benefits, although these were rarely expressed in monetary terms. The only exception is the ICARDA project where the benefits of soil erosion abatement were calculated at US$425 per hectare when applying the replacement cost approach. In some of the other studies, physical effects had been quantified. For example, the ICRAF project calculated the positive effects of the NRM technology on carbon sequestration to be between 2.5 and 3.6 tonnes per hectare. This is a quantified contribution to slowing global warming. The CIMMYT project showed savings in fuel energy through a reduction of 8–12 hours per hectare of tractor time, with consequences for climate change as well. It also showed savings of about one million litres of water per hectare, in addition to demonstrated but unquantified improvements in soil quality, such as soil biological properties, soil fertility and soil structure. The adoption of contour ridging in the CIAT cassava project reduced soil erosion and improved water quality, but quantification of the benefits could not be carried out due to lack of complementary biophysical measurements. Development of effective monetary indicators of benefits and corresponding baseline data collection efforts before/without the project compared with after/with the project is a major priority if a more comprehensive assessment of the value of NRMR projects is to be developed.

Farmer knowledge and human capital. Adoption of innovation requires choices of technology and their adaptation to specific situations. Farmers with higher levels of human capital, including knowledge and the ability to deal with disequilibrium, are more likely to adopt new technologies (Schultz, 1975). Knowledge and skills are especially important in relatively complex NRM technologies. Indeed, lack of farmer knowledge and understanding of the ecosystem and the natural resource interactions required can be a reason for non-adoption, for example in the case of pest management technologies (Feder et al., 2004). Rosenberg (1982) argued that the introduction of new technologies leads to learning and experimentation, which, in turn enhance the gains from adoption (learning by using). Several studies (e.g. Godtland et al., 2004; Tripp et al., 2005) suggest that this phenomenon especially applies to IPM technologies. Learning by using contributes to the build-up of human capital, both in terms of specific knowledge and improved skills. In the NRM case studies, the CIAT and WorldFish projects included these effects in their analyses. In the CIAT project, knowledge was treated like a stock resource in the context of a household model and was measured using participation in on-farm experimentation as a proxy. The WorldFish project established evidence of higher technical efficiency by adopters of integrated aquaculture–agriculture technologies. The build-up of human capital is a manifestation of empowerment as one of the by-products of NRM innovations (Shiferaw et al., 2004) and therefore needs to be explicitly recognized.

General equilibrium effects. NRM projects that increase productivity and reduce environmental effects may have a secondary effect through macro-economic multipliers, and may have an impact on employment levels as well as health. These issues were hardly addressed by the seven case studies, even though the WorldFish project provided initial indicators of nutritional and health benefits. It is useful to provide parallel systems of impacts: i) measures of economic surplus that allow direct evaluation of efficiency and distributional effects, and (ii) systems that rely on computable general equilibrium or social accounting metrics to assess overall effects, including secondary impacts.

Assessment of secondary effects may be especially important in macro-projects. These projects are likely to have economy-wide effects and large-scale impacts on variables such as employment or even overall gross national product (GNP) growth – all of interest to policy-makers. The CIFOR and IWMI case studies were both unable to demonstrate such multiplier effects in quantitative terms. They nevertheless enabled researchers to draw some conclusions. For example, in the case of the IWMI project, the more rapid and more widespread farmer participation in irrigation management had positive effects on government budgets and efficiency in managing irrigation schemes.

In the CIFOR project, it was pointed out that certification schemes for sustainable forest management using CIFOR research outputs were adopted for over 37 million hectares of forest worldwide, leading to biophysical impacts and livelihood improvements for forest-dependent people. Computable General Equilibrium (CGE) and Global Trade Analysis Project (GTAP) models might be considered for future impact assessment of macro-projects that go beyond national borders and contribute to international and global public goods of NRMR (Ryan, 2006).

NRMR impact assessment methodologies

The works of Huffman and Evenson (2005), Alston et al. (1999), and the literature on innovation in agriculture (Sunding and Zilberman, 2001) provide a theoretical and analytical framework for analyzing the adoption and impact of micro-level innovations. The methodological analysis used by the SPIA initiative involved an adaptation of existing methodologies relating to both micro- and macro-level innovations that rendered them appropriate for assessing the impacts of NRMR in the CG system. The major challenge is developing the methodologies for analyzing the adoption and impacts of macro-level innovations.

It is useful if impact assessments of research investments can quantify research benefits, since economic values are universally understood and provide consistent metrics for impact. The research effort of the CG centers focuses on technical, managerial or institutional innovations that modify behavior. 'Adoption' is defined as choice of alternative technology, practice or policy. Therefore, good modeling of adoption of technologies and practices at the micro level and of policies at the macro level are crucial building blocks in the process of quantifying the impacts of NRM projects.

While micro NRM projects result in new technologies and management rules that farmers can directly adopt, macro projects develop policies and institutions that change the incentives and conditions faced by individual decision-makers and, in turn, lead to changes of behavior, including the adoption of new practices. Thus, understanding adoption at the micro level is an important element in modeling the impacts of macro NRM projects. However, in macro-projects, it is also important to model the factors that lead policy-makers to adopt new policies and to consider some of the complexities of the political reality that affects political choices and outcomes. Therefore, models that analyze the impacts of micro-projects are discussed separately from those that analyze the impacts of macro NRM projects. Impact assessment of INRM projects requires a model that combines micro- and macro-level innovations in a complementary manner.

What follows is an overview of micro- and macro-level NRM innovations, their impacts and assessment of these impacts. Two fundamental issues of impact assessment that apply equally to NRMR projects are discussed: (i) deriving counterfactuals, and, (ii) attribution. Modeling frameworks for analyzing both the generation and adoption of NRM innovations are also considered. Possible metrics for NRMR impact assessment studies are developed, followed by the analysis of attribution problems and how to resolve them. Finally, some of the main issues in data collection and estimation for effective NRM impact studies are discussed.

What difference do NRMR projects make? The counterfactual and attribution issues

Impact assessment studies should answer two basic questions:

- Counterfactual: What would have happened if the project had not been undertaken at all or if it had been undertaken later?
- Attribution: How much of the benefits generated by the innovation are attributable to the different actors involved in R&D and implementation?

The first question is especially pertinent to NRMR projects that do not lead to an embodied innovation but to a management technique or a policy change. The second question is crucial in assessing the actual contribution of specific NRMR projects and pertinent to CG centers.

Counterfactual situations. To address the first question, the NRMR impact study has to justify the choice of a realistic counterfactual scenario that recognizes the possibility of alternative developments in the absence of the research project. There is a growing emphasis on the use of statistical analyses that compare with control groups the performance of groups that were affected or treated by the policy or management practices. The econometrics of these types of analysis is quite advanced (Imbens, 2004; Imbens and Angrist, 2004). Ryan and Meng (2004) recently used such experimental evaluation approaches in Bangladesh to assess the impacts of policy research by IFPRI on food for education programs.

When using treatment and control groups, it is imperative to have appropriate project design and implementation methods that will generate data to assess the relative impacts of a new technology or innovation requires. That means that in some cases, several villages or farmers are selected at the beginning of the project. Some of them are subject to new policies, while others are not subjected to the new policies. This approach should be especially valuable for policies where theory cannot provide strong *a priori* assessment of their impacts. In such cases, comparison versus control groups become very valuable.

Attribution. A major challenge of any impact assessment study is to assign benefits to each of the actors responsible for the various activities along the research-to-impact pathway. An NRMR project relies on prior knowledge and its success is affected by many factors, including local extension. Sometimes a CG center may just speed up the onset and introduction of innovations rather than start new innovations. Ideally, the NRMR project can be assigned the incremental benefits that it provides, but in most cases, it is difficult to compute the precise contribution. When it is clear that a given innovation would not have been developed or evolved without the CGIAR's effort, and where there is minimal or no input from other research organizations, or from national extension, then the NRMR project may be credited with all the benefits. In other cases, it may be reasonable to assume that the NRMR effort may have accelerated (by x number of years) the introduction of a technology that would otherwise have been introduced later. In this case, the benefits of, say, the first x years should be attributed to the NRMR. This approach was first applied by Ryan (2004) to assess the impact of liberalization of the rice market in Vietnam. In the CIMMYT study, the center adopted a technology that had previously been introduced by the local authorities and Monsanto without success. The benefit CIMMYT brought was accelerating adoption by 5 years. In some cases, it may be practical to simply assign the research a fraction of the benefits. For example, in assigning royalties for innovation, frequently the surplus is divided equally among universities that conduct the innovation, the companies that develop the product, the companies that undertake the research from which the innovation is based and the marketers. While equal attribution is not advocated, every study should have a discussion that will justify the principles and assumptions in attribution.

Micro-projects: impact assessment issues and approaches

Generation of innovations and transfer of knowledge. The CGIAR centers conduct research that leads to improved, higher-yielding varieties of crops for species (and countries) bypassed by private sector R&D investment. Studies of the impacts of most CGI research assume that the linear model of innovation systems approximates reality. However, the NARS, extension systems and private seed companies are responsible for national and local adaptation and marketing of new varieties. This generally linear model is relevant for the generation and adoption of research-derived micro-level NRM innovations. However, due to local specificity and the need for adaptation, knowledge of the local ecosystem is typically more important when introducing improved NRM practices than it might be when introducing improved crop germplasm. These NRM technologies are frequently not embodied in a single product (such as seed) but instead depend on management practices that may require significant adaptation of the technology to local conditions and individual user groups. For the above reasons, FPR approaches are often preferred for this kind of NRMR. FPR can help overcome the problems of heterogeneity and poor infrastructure and can ensure adoption. The linear or top-down approach to research is being questioned in NRMR and in some kinds of breeding research. SPIA is planning a review of the impacts of FPR in the CGIAR.

These particular features of innovations derived from NRMR may affect their cost structure, for instance, increased research expenditure at locations outside the CGIAR centers. The features may also suggest that NRMR success and costs depend on the availability and quality of extension and on the local service providers that have to introduce the technologies to their final users. In order to facilitate adoption of NRM innovations in locations with weak local outreach, the CGIAR may have to conduct demonstrations during the pilot phase – but only in close association with development partners, who can assume the major role in extension once the technology has been accepted. Still, the need to conduct location-specific research and to develop outreach mechanisms to introduce some NRM micro-level innovations may increase costs and reduce rates of return on investment in research.

Modeling technology adoption. Early studies on adoption, following the seminal work of Griliches (1958), modeled it as a process of imitation among homogenous economic agents. However, as the survey by Sunding and Zilberman (2001) shows, much of the literature on adoption of micro-level innovations in agriculture is based on the threshold approach, where decision-makers are heterogeneous and differences in timing and extent of adoption of a new innovation reflect differences among the decision-makers and their circumstances. This approach explains the S-shaped diffusion curve. Diffusion is the aggregate level of adoption and is measured by the percentage adopting a technology at a given time. The approach justifies the use of discrete choice models to quantify the factors that affect adoption.

Adoption models that follow the threshold approach have several components

Sources of heterogeneity. As Sunding and Zilberman (2001) report, differences in the size of operation explains the differences in the adoption of non-divisible innovations; differences in location and output prices explain differences in adoption of some seed varieties; and differences in human capital cause differences in the time and extent of adoption of computers and many other technologies. When it comes to NRM technologies, differences in land quality, or prices of inputs such as water, explain differences in technology adoption. Statistical analysis can identify the variables that explain differences in the adoption of micro NRM technologies. They include economic variables (prices of input), agroecological variables (land quality) and farm characteristics.

Micro-level decision rules. The threshold models of adoption assume that adoption decisions are made by those who control micro units (smallholder farmers). Many of the models assume that these decision-makers are profit maximizers, others model them as risk-averse, and recent studies use the real-option approach of Dixit and Pindyck (1994) to model adoption as dynamic choices under uncertainty. Other models of adoption may consider the choice within a household model where families make both production and consumption choices. Different behavioral assumptions may result in different hypotheses on factors affecting adoption and adoption intensities. The micro-models in this research assume that decision-makers pursue profits and in some cases aim to reduce risks.

Policies and other parameters. The adoption choices of the micro-units are affected by economic and technical parameters. The key variables include prices, support policies, marketing efforts and climatic and agronomic conditions. There is ample evidence that price-support policies provide major incentives for increasing supply-enhancing policies. Subsidies were important in enhancing the adoption of ICARDA's alley-cropping technology. Adoption of NRM innovation is likely to be enhanced by resource and environmental policies. Water trading that leads to a price increase for farmers may result in the adoption of water conservation. Extension and marketing efforts are also crucial to enhancing adoption. Farmers may be uncertain about the performance of a new technology and its fit with their circumstances. Demonstrations and assurances from a trusted dealer or extension agent may increase their likelihood of adopting. The lack of well-functioning markets for NRM technologies may disadvantage these technologies when compared with seed technologies.

Aggregation procedures and price determination. The model first determines the optimal choices for each type of unit and then, given the policy parameters and the distributions of the micro-units, computes the aggregate supply of outputs and the demand for inputs. This determines the prices of outputs and inputs. These prices then allow the derivation of the equilibrium levels of adoption and externalities.

Dynamic processes: The levels of adoption may change over time because of dynamic processes that affect the industry. These processes include learning by using and learning by doing: the former increases productivity for the input used while the latter lowers the cost of the technology given increasing diffusion. There may also be external network factors increasing benefits from the technology over time as the number of adopters rises, thus triggering further adoption. In some cases, the dynamics of natural resources themselves can be a driving force for the adoption of an NRM technology. Shah et al. (1995) show how the decline of groundwater stock due to pumping increases water price over time, leading to adoption of conservation technologies. Pesticide resistance is one reason to adopt NRM technologies like IPM. Xabadia et al. (2004) have introduced an adoption model of a resource conservation technology in response to policies aimed at controlling stock pollution.

As already explained, modeling frameworks that are appropriate for NRM micro-level innovations sometimes require clever formulations that incorporate biological or physical factors into economic models. Modeling NRM techniques is more complex than, for example, building micro-economic models for new seed varieties, which assume the technology modifies existing production or the profit function in a simple manner (e.g. multiple shifts). Conservation technologies increase input-use efficiency and reduce residues (Khanna and Zilberman, 2001). A pest control strategy is modeled as damage control agents (Lichtenberg and Zilberman, 1986). Models of new livestock management systems must incorporate livestock population dynamics and livestock–environment interactions. The micro-modeling of NRM technologies is challenging and should incorporate the dynamics and heterogeneity of natural resources, production and pollution. To be useful, adoption modeling of NRM technologies should be based on interdisciplinary dialogue, in which economists work with other scientists to identify critical factors affecting adoption of a micro-level innovation for each situation.

Modeling impact. The standard approach for measuring an impact has been partial equilibrium models, in which new technologies lower unit costs and expand supply, resulting in increased quantities and lower prices of a homogenous product. Sometimes these models are modified to consider innovations that improve quality. As NRM micro-level innovations frequently affect other dimensions besides yield and cost, more complex models are required to assess impact. For example, NRM innovations may increase the stock of farmer knowledge and understanding of ecosystem functions, which can lead to higher efficiency of existing technologies and better technology choices in the future. Impact assessment frameworks appropriate for assessing NRM micro-level innovations are needed so that a range of other objectives can be considered. Examples include reducing economic and human health risks, improving environmental quality and conserving natural resources.

While the rate of return is the major criterion used to justify a project, it should not be taken as the exclusive measure of impact assessment. The Millennium Development Goals (MDGs) introduce a poverty focus on all development projects including research and thus put emphasis on the distributional effects of projects.

Macro-projects: Impact assessment issues and approaches related to NRM policy research

Macro NRMR projects can draw upon prior knowledge of impact assessment in social science and policy research. Unfortunately, literature on research impacts – in terms of its influence on policy and responses to it – is very sparse. A recent exception is the book by Pardey and Smith (2004), which primarily investigates methods of assessing social science research, which includes economics and policy research. Timmer (2004) argues that it is especially difficult to assess the impact of policy research because many of the findings are not formally published and communicated. Furthermore, the effectiveness of policy researchers sometimes depends on their being discrete. Norton and Alwang (2004) argue that understanding the impact of policy research requires knowledge of the exact institutions through which decisions are made. Gardner (2004) argues that while problems of attribution may be especially difficult in analyzing the impact of policy research, the basic methods of welfare and rate-of-return analysis that are used for micro-level innovations can be applied to assess the impact of macro-level policy research.

While the focus of impact assessment of research is on adoption of the innovation by final users, we should note that a new micro-level innovation has to be adopted at several levels before it can be used. The basic innovation from R&D must first be adopted by a technology manufacturer and/or an extension agent before filtering to final users. Similarly, the introduction of natural resources policy innovations is a complex process. These policies often affect property rights and are subject to political pressure from affected groups. Ulrich et al. (1986) have recognized that different interest groups have different rates of returns from proposed policy changes (e.g. forest certification standards, pollution regulations, water pricing, banning certain chemical pesticides, etc.), and that the estimation of these varying rates of returns can explain adoption. Furthermore, using notions of stochastic dominance, it is possible to identify situations where policies have overall welfare-improving effects, as compared to policies that improve the welfare of some groups while hurting others.

A policy innovation can trigger several waves of adoption. Once policy-makers introduce policy change, a political process starts. Political and legislative processes may result in policy outcomes that can be quite different from the ideas of the original innovation. Also, once legislation has been implemented, it may result in behavioral modifications that lead to adoption of new technologies. For example, the IWMI project has helped to introduce market incentives for the management of irrigation projects and water resources. The exact legislation based on these ideas may vary by location, but once it is introduced, it is likely to lead to the adoption of water-conserving technologies and other improvements in resource allocation. Consequently, impact assessment of the IWMI research project should ultimately be derived from assessing the impact of changes that these projects trigger. However, the attribution of adoption may require time-consuming reviews, surveys, case studies and testimonials.

Establishing the links between research in the CG centers and policy changes therefore requires the following issues to be taken into account:

Policy research is part of a larger societal policy debate. The basic knowledge behind some macro-level innovations that develop improved rules for international, national and regional agencies governing natural resources is derived from research in the natural and social sciences. Some NRM-related policy innovations reflect societal debates and a broad variety of scientific and civic perspectives. In policy research, the role of the CG centers is fundamentally different from the role that centers play in germplasm improvement. In the latter, centers generate products that can be reproduced or modified by national actors. In policy matters, centers mainly complement existing basic knowledge by evaluating and synthesizing available ideas and concepts. Often, centers integrate competing perspectives to obtain operational principles. The product of such research may be embodied in guidelines and other types of documented recommendations, which can help governments, national, and international organizations to reduce transaction costs, increase the success of policy change, hasten policy changes and their implementation, and reduce the probability of misguided policy interventions. Such effects were demonstrated in the IWMI project, although no quantification was carried out.

Timing of policy reforms. There may be a significant time lag between policy recommendation and actual implementation. Rausser and Zusman (1991) argue that policy reforms are frequently induced by a crisis but the reform relies on available knowledge. In California, economists and other experts have promoted trading in water resources but it took a major drought to precipitate the establishment of legislation and institutions that trade in water. In Indonesia, removal of pesticide subsidies and nationwide promotion of IPM was preceded by a major outbreak of the brown plant hopper in rice, resulting in a political crisis (Pincus et al., 1999; Kenmore, 1996).

Policies reflect political compromises and deviate from expert recommendations. Fischhendler and Zilberman (2005) argue that natural resource policies are packages that integrate complementary elements. They may be inspired by, or based on, scientific principles, but political systems must accommodate various interest groups to attain sufficient political support for reform proposals. Frequently, political systems operate on majority rule, which leads to horse-trading, which in turn can significantly modify science-based proposals. For example, in Thailand, pesticide subsidies were removed after studies had shown that they were ineffective. Because of vested interests, the so-called pest outbreak budget was not abolished, but was substituted by a policy whereby less harmful pesticides would be purchased by government (Praneetvatakul et al., forthcoming).

Transparency. Political systems are opaque; the mechanisms for transferring knowledge are not always transparent. As Timmer (2004) suggested, sometimes some policy-makers take advice only in secrecy – through personal contact and sometimes without written evidence. This is even more serious in many developing countries where the capacity for science-based policy research is often underdeveloped, and political and cultural rules inhibit public debate of certain policy issues.

Governance institutions. The works of Becker (1983), Dixit et al. (1997), Rausser (1982), and others emphasize that political systems are mechanisms for management trading and for resource allocation of among various groups. However, differences in the rules of the systems will result in different outcomes. For example, lobbying efforts and the weight given to different groups are different in a centralized democracy compared with a federal system. A system with a two-tiered parliament (e.g. the United States' House and Senate) is politically different from one with a one-parliament system (e.g. France). A non-democratic society may be less formal, more difficult and more idiosyncratic. In such societies, it is more difficult to precisely model the adoption of policy recommendations.

Multiple actors shaping the policy process. A generic approach to modeling the outcomes of politico–economic systems is introduced by Zusman (1976) and McFadden (1976). They view policy-making as the outcome of cooperative games involving a number of interest groups, each of which has a certain weight that may vary over time. Note, however, that different groups may have varying capacities to access and use policy research; therefore, policy research may benefit various groups differently. This also suggests it is important that researchers study policies in order to develop outreach programs that make their results accessible to many groups. Otherwise, researchers may tilt outcomes in favor of groups able to use their research.

Policy results are public goods, and there is spill-over of results across locations. Policy analysis findings from one location may be applied at other locations. Policy dialogue leads to export and import of ideas. Policy-makers may dismiss a proposal from their local institute but give the same idea more weight if it originates from, and is applied, elsewhere. An ideal impact assessment should have multiple uses of research results across locations and over time. Of course, the public goods nature of policy research and the possibility of policy spill-over also apply to non-NRM policy research.

Measures of benefits from policy research
The assessment of benefits from policy research requires both the estimation of benefits of each policy and the quantitative attribution of the share of benefits generated by policy research projects. Both the estimation of benefits and their attribution are challenging, and the complexity of transferring knowledge between research and its application suggests that no single measure can convey the key features of the impacts of macro-projects. Therefore, impact measures should include several elements, including attribution, overall efficiency and distribution of benefits.

Measures of attribution. These may include citations, personal testimonials and 'guesstimates' by experts and policy-makers. Both the IWMI and CIFOR projects provided several bibliographical measurements thanks to the proliferation of the internet and electronic databases. One of the big challenges is to interpret the meaning of a given number of citations within a certain context. Testimonials are not necessarily quantitative but when a few individuals control policy-making, their perspective on the contribution of research to the decision they make may be crucial.

Measures of overall efficiency. These measures may include expected net benefits or an expected IRR. The measures combine benefit assessments of effective policies, as well as research's contribution to each of these policies. Given the high degree of uncertainty both in terms of benefits and attribution, it may be useful to provide a range or distribution of discounted net benefits and IRR.

Distributional measures. One of the major benefits of welfare economics is its ability to identify the distribution of impacts among various groups. This may be crucial for policy assessment, especially given public concern that policies may have distributional objectives such as poverty alleviation. With the appropriate attribution coefficient, it is possible to aggregate the expected impact of research on different groups across policies. Thus, measures of impact on urban consumers, producers, farmers and the landless, as well as the environment, may provide extra insight. As mentioned above, another set of distributional measures may include impact on indices of poverty like headcount and poverty gap ratio, the Lorenz curve and Gini coefficients. If a research project affected several policies at different locations, breakdown of distributional impacts at different locations will be useful when making comparisons.

Concluding comments

Based on the seven case studies and an analysis of concepts and methods from the literature, it is clear that assessing NRMR impact remains challenging. Combining the conceptual thinking of this chapter with the findings of the seven NRMR impact case studies yields a number of lessons and raises new questions.

The NRMR impact studies demonstrate that, at least in cases where benefits can be quantified, CGIAR investment in NRMR has paid off. Although the IRRs do not reach the level of breeding research there are likely to be additional environmental benefits for NRMR. To quantify such effects in future impact assessments collection of baseline information needs to be incorporated in the design phase of such projects.

The tools of welfare economics can be applied to quantitatively assess the impact of NRMR projects. Assessing expected net benefits (discounted), IRRs, distribution of benefits among groups and impacts on income distribution all provide useful information which can be gathered without too much effort. Such information is especially useful for the micro-projects. The major challenge is to organize research projects in such a way that impact assessment and documenting costs and benefits are integral parts of the project. Information technology developments have reduced the costs of data collection: quality assessments are possible with modest resources.

The two areas of assessment that require extra effort, and that provide intellectual and administrative challenges, are: (i) environmental effects; and, (ii) the attribution of benefits to individual projects, especially in the case of macro-projects, where policy-making may be affected by many parties and different kinds of research. Ongoing research in environmental economics and improvements in GIS are likely to improve the assessment of environmental impacts. Further research is required to improve both attribution and quantification of the impacts of micro-projects.

Quantitative assessment of the benefits of macro-policy NRM projects is challenging because of methodological and data difficulties. While the CIFOR and IWMI policy projects successfully documented dissemination of results, they were, however, unable to quantify net social benefits. Future policy studies should facilitate data collection that will enable quantitative impact assessment. On the other hand, farm-level NRM technologies are more amenable to assessment using well-developed adoption models and economic surplus techniques.

Future research should further investigate the extent and reasons for differences in rates of return between micro NRM and crop-breeding projects. And while the present analysis cannot conclusively answer this question, it does emphasize a number of important methodological points:

- One reason for the high rate of return for crop improvement research projects is that the dissemination of results benefits from existing extension and marketing networks, such as seed companies and NARSs. NRMR projects are diverse in nature and frequently require the establishment of a new dissemination mechanism as part of the project. This challenge is exacerbated by the heterogeneity of agroecologies, the location-specificity of many micro-level NRMR innovations and the usually poor infrastructure in such at-risk environments. These either reduce the project benefits and/or increase the costs, thus lowering rates of return.
- The environmental impact of both CGI research and NRMR projects has not been adequately analyzed and documented. Both types of projects have environmental benefits[15] (and costs) but it is plausible that environmental benefits and genetic resource conservation play a more major role in NRM projects, and thus the exclusion of environmental benefits from calculations of rates of return has a stronger downside impact on NRMR projects.
- There is plausible concern that rates of return fail to adequately attribute all the contributions of NRMR activities because of the complexity of the natural resource systems they affect. While there have been some attempts to parcel out such contributions, in general, there is inadequate evidence to robustly address this claim.
- Research outcomes are always uncertain, and thus only a fraction of research projects have substantial effects. Most CGIAR impact and adoption studies have focused on CGI, and commodity-oriented centers such as CIMMYT have invested much more in impact assessment than have NRM-oriented centers such as IWMI, WorldFish and CIFOR. Thus, the smaller investment and lower levels of data collection related to NRMR projects relative to CGI projects have led to fewer success stories and more uncertainty about the impacts of the NRM projects.

The remaining major challenge is to further advance theoretical frameworks and methodologies for assessing the impact of NRM policy research. This calls for a dynamic model that includes learning and

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[15] Seed of yield-increasing varieties can reduce the area allocated to agriculture and may slow deforestation, although such causality will depend on institutional conditions.

adaptation, for fewer misguided policy interventions in a multi-agent setting. In addition, such a model should measure reductions in transaction costs, increases in productivity and gains in time.

The fact that the seven case studies took different approaches in impact assessment provides insights and useful lessons for further development of a relevant and practical set of strategic guidelines for impact assessment in the CG system. Such guidelines will have to explicitly deal with issues such as credibility, plausibility and transparency. The guidelines will also have to develop acceptable counterfactuals, means for the attribution of benefits, baseline data and explain how to accommodate the specific impact assessment requirements for different types of research. The present initiative provides pointers on these topics.

4. Conclusions and Future Directions for NRMR Impact Assessment

Conclusions

The SPIA NRMR impact assessment initiative explored several dimensions of NRMR impact assessment in the CG system. This initiative was based on seven case studies. The cases varied in their ability to clearly and credibly define and assess the impacts of CG NRMR. In two of the case studies (CIFOR and IWMI), it was only possible to identify the impact pathways and identify, but not to quantify, plausible likely impacts. For these two studies, quantitative conclusions relating to impacts in relation to investment could not be reached. On the whole, for those cases where quantification was possible, it is possible to conclude that NRMR in the CGIAR has produced economic benefits that significantly exceed costs.

NRMR poses a number of methodological difficulties for impact assessment. In some cases, NRMR projects produce findings that are intended to foster incremental improvements in policies or management. Assessing the influence of such outputs is no simple matter, as many factors drive policy outcomes, and the role of research findings cannot be empirically observed. Furthermore, indirect contributions to policy changes may have significant benefits but these are difficult to estimate, particularly when policy implementation is partial or incomplete. Accordingly, policy-oriented NRMR case studies were unable to quantify impact values. Clearly, more effort is needed to develop impact assessment methods for policy impact pathways.

Farm-level NRM technologies are more amenable to assessment using well-developed adoption models and economic surplus techniques. Consequently, for the five studies that focused on such technologies, IRRs and other economic measures were computed. The resulting IRRs were found to be acceptably high, with benefits significantly exceeding costs. They were, however, lower than those observed for the most productive investments in CGI research.

This then leads to the question: Is there a significant differential between actual IRR values for CGI and for NRMR oriented towards farm-level technologies?

The present analysis cannot conclusively answer this question, for a number of reasons.

- First, there is a reasonable concern that measures of the returns on CGI fail to adequately attribute the contributions made by complementary NRMR activities. While there have been some attempts to parcel out such contributions (see Bell et al., 1995), in general, evidence to support this claim is inadequate.
- Second, only a proportion of research projects actually lead to widespread impact. As most CGIAR adoption studies have focused on CGI, and commodity-oriented centers such as CIMMYT have invested much more in impact assessment than have NRM-oriented centers such as IWMI, WorldFish and CIFOR, there is a much broader pool of evidence from which selective impact studies of the biggest CGI ‘winners’ have been drawn.
- Third, some NRMR is oriented towards objectives that are difficult to value reliably in economic terms, such as genetic resource conservation, environmental services and other loss-avoidance objectives. This is especially true for NRM macro-oriented research projects, where the classic conceptual framework for adoption and impact, widely applied in CGI research and less complex micro NRMR projects, is inadequate.

In light of these caveats, the fact that four of the five studies that attempted to calculate IRR found substantial returns does indicate that the assessed NRMR investments were justified. However, from these case studies, it is not yet evident whether the actual returns could equal those of productive CGI investments even if the three caveats noted above were adequately addressed. Furthermore, the seven cases of NRMR impact included in this initiative are far too few to compare with hundreds of studies of CGI research.

There is greater uncertainty about the impact of NRMR than that of CGI research. Therefore, additional impact studies of NRMR are needed. This SPIA project should be the beginning, rather than the end, of more comprehensive impact assessment of NRMR.

The seven case studies used different approaches to the assessment of impacts and thus provided insights and lessons that will prove useful to SPIA and the centers as they move to develop a relevant and practical set of strategic guidelines for impact assessment. It is evident that such guidelines will have to explicitly deal with themes such as credibility, plausibility and transparency, developing acceptable counterfactuals, attributing benefits, developing baseline data and addressing the uniqueness of various types of research in terms of their impact assessment needs. This initiative throws light on all of these topics.

Future directions

There are a number of key challenges for enhanced impact assessment of NRMR, which SPIA plans to address through several planned initiatives.

First, much NRMR is macro- and policy-oriented, and research with this orientation poses particular problems for the attribution of impact and the identification of adoption, influence and responses. SPIA's ongoing policy-oriented, research impact assessment initiative should help to identify appropriate methods for such impact pathways.

Second, it is important to draw on novel methods identified through the present NRMR impact initiative, the SPIA CGI impact assessment study (Evenson and Gollin, 2003) and the SPIA policy-oriented research impact assessment in a comprehensive methodological guidance document. These strategic guidelines should draw on opportunities offered by recent methodological advances in the context of the documented perceived needs of key audiences in impact assessment findings (Raitzer and Winkel, 2005). A central document with practical guidelines should offer consistent demand-driven guidance on impact assessment for the different types of research across the CG system.

Third, more frequent interactions – both formal and informal – among the impact assessment focal points in the centers, SPIA members and external experts will help to ensure that best-practice methods for NRMR impact assessment are developed, disseminated and applied in future studies that tackle under-assessed areas of research such as NRMR. This will mean convening more frequent impact assessment focal point meetings. In addition, the impact indicators of the performance monitoring system will lead to greater focus on the impact assessment performance of a center. These indicators incorporate criteria for crediting a center with the methodological papers it has developed and the efforts it has made to measure impacts for research areas that pose methodological difficulties. The indicators should encourage centers to continue advancing NRMR impact assessment techniques.

Ultimately, NRMR impact assessment remains a challenge, and more effort is needed to resolve the lingering uncertainty on returns on investment in this area. SPIA's planned activities will continue to build upon the progress of this initiative, so that more conclusive evidence of impact can be tabled in the future.

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Annex I

Table I.1 CGIAR research agenda investments by activity: 1994–2001

CGIAR activities	1994		1995		1996		1997		1998		1999		2000		2001		2002[1]	
	US$	**%**	**US$**	**%**	**US$**	**%**	**US$**	**%**	**US$**	**%**	**US$**	**%**	**US$**	**%**	**US$**	**%**	**US$**	**%**
Increasing productivity (of which)	124.3	47.0	134.4	47.0	129.1	40.0	133.1	40.0	124.3	37.0	117.3	34.0	119.7	36.0	123.3	35.0	125.4	34.0
Germplasm enhanced breeding	61.9	23.0	64.0	22.0	58.8	18.0	63.7	19.0	60.0	18.0	61.2	18.0	61.8	18.0	64.1	18.0	n.a.	n.a.
Production systems development and management:	62.4	24.0	70.5	25.0	70.2	22.0	69.4	21.0	64.3	19.0	56.1	16.0	57.9	18.0	59.3	17.0		
Cropping systems	41.6	16.0	38.5	13.0	40.5	12.0	35.1	11.0	32.7	10.0	29.3	8.0	32.1	10.0	32.7	9.0		
Livestock systems	15.7	6.0	21.1	7.0	18.4	6.0	18.7	6.0	19.7	6.0	15.6	4.0	13.8	4.0	16.7	5.0		
Tree systems	3.9	1.0	8.9	3.0	9.2	3.0	14.2	4.0	10.4	3.0	9.3	3.0	8.3	3.0	7.9	2.0		
Fish systems	1.2	0.5	1.9	1.0	2.2	1.0	1.4	0.4	1.5	0.4	1.9	0.5	3.7	1.0	1.9	1.0		
Protecting the environment	40.1	15.0	45.3	16.0	53.7	17.0	57.4	17.0	64.5	19.0	67.9	20.0	60.4	18.0	67.2	19.0	66.5	18.0
Saving biodiversity	22.6	9.0	28.5	10.0	34.6	11.0	35.3	11.0	37.2	11.0	36.2	10.0	34.8	10.0	34.2	10.0	36.9	10.0
Improving policies	26.0	10.0	25.2	9.0	38.9	12.0	37.3	11.0	39.9	12.0	46.8	13.0	48.0	14.0	49.0	14.0	55.4	15.0
Strengthening NARS	51.7	20.0	52.6	18.0	68.7	21.0	70.2	21.0	70.9	21.0	78.6	23.0	74.6	22.0	81.1	23.0	84.9	23.0
TOTAL	**264.7**	**101.0**	**286.0**	**100.0**	**325.0**	**101.0**	**333.3**	**100.0**	**336.8**	**100.0**	**346.8**	**100.0**	**337.5**	**100.0**	**354.8**	**101.0**	**369.0**	**100.0**

[1] 2002 figures are taken from the CGIAR Annual Report for 2002.
Source: *World Bank, CGIAR financial reports 1994–2002.*

Table I.2 Financial allocations to CGIAR Centers: 1994–2005 (million US$, not deflated)

Center	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005[1]
CIAT	33.6	31.5	31.0	31.7	32.1	28.7	29.5	29.7	32.3	32.0	36.3	36.3
CIFOR	6.1	9.0	9.0	10.6	11.3	11.5	12.6	12.6	11.7	13.6	14.8	16.5
CIMMYT	31.2	31.7	28.9	28.6	30.1	33.8	39.0	40.7	41.3	36.2	41.2	30.5
CIP	22.8	23.2	24.2	23.4	22.2	20.0	20.2	19.7	19.2	18.0	22.3	23.1
ICARDA	19.0	19.3	21.1	22.3	25.2	19.5	23.4	21.3	24.3	25.4	24.8	23.2
ICRAF	17.0	16.9	17.4	21.8	20.4	20.6	20.7	22.9	21.8	26.6	29.7	30.9
ICRISAT[2]	30.8	30.0	29.7	27.7	26.5	21.2	23.3	23.9	24.7	23.2	27.7	29.8
IFPRI	13.8	13.8	16.0	18.2	20.1	20.8	21.2	22.5	22.7	26.5	32.8	32.5
IITA[3]	33.4	31.4	31.2	30.8	29.2	30.7	30.1	35.3	32.6	36.6	42.8	45.5
ILRI[4]	29.1	29.6	28.3	26.1	24.6	26.6	26.5	28.2	27.5	29.5	32.9	32.2
IPGRI	14.5	12.6	16.4	18.8	21.2	20.1	21.5	23.1	25.6	27.9	34.8	37.9
IRRI	39.8	38.1	38.3	35.4	34.8	32.5	32.6	32.6	33.4	27.3	32.4	32.6
ISNAR[5]	10.4	11.3	10.7	9.9	9.6	8.2	8.2	8.1	8.9	8.3	5.8	–
IWMI	8.9	10.2	10.0	10.0	9.4	8.8	8.9	11.4	20.7	22.1	23.3	23.6
WARDA[6]	8.1	9.7	8.7	8.6	10.0	10.8	9.4	9.7	9.8	10.7	10.4	12.1
Generation											1.1	10.0
HarvestPlus											2.4	6.8
Water and Food											1.9	4.6
WorldFish	6.6	7.8	9.6	9.0	10.6	14.2	10.4	13.1	12.3	14.5	14.3	15.1
Sub-Saharan Africa												0.4
Total	**325.1**	**326.1**	**330.5**	**332.9**	**337.3**	**328.0**	**338.5**	**355.0**	**369.0**	**396.0**	**420.0**	**475.0**

[1] estimated
[2] ICRISAT = International Crops Research Institute for the Semi-Arid Tropics
[3] IITA = International Institute of Tropical Agriculture
[4] ILRI = International Livestock Research Institute
[5] ISNAR = International Services to National Agricultural Research
[6] WARDA = The Africa Rice Center

Source: World Bank, CGIAR financial reports, 1994–2005.

Annex II

Selected key points and relevant discussion (italics) from the Fujisaka and White (2004) paper

Four overlapping sets of NRM/INRMR activities and associated sets of *ex post* impact assessment methods were identified by Fujisaka and White (2004):

1. NRM to increase crop productivity.
Starting with the efforts that led to the Green Revolution, CG research has improved crop productivity through innovations in the management of resources such as soil, soil nutrient, and water.

> ***Associated impact assessment approach.*** *Impact assessment of resource management research for enhancing crop productivity examines the effects of innovations on crop outputs at the field and farm levels under controlled conditions. Impact estimates are extrapolated from farmer adoption. Cost-benefit analysis and estimating returns to different factors of production are common tools. Large samples of adopters and non-adopters are compared to estimate the impact of Green Revolution technologies such as irrigation and fertilizer.*

2. NRM to increase farm productivity and resource-use efficiency.
Starting with what came to be known as farming systems research (FSR), equally high investments have been made to increase whole-farm productivity and resource-use efficiency through innovations such as contour hedgerows for soil erosion control, alley cropping, agroforestry, cover crop, and conservation agriculture. In many cases, these innovations have been tied to the development, testing and dissemination of adapted germplasm and of combinations and sequences of crops and cultivars (i.e. what was called cropping systems research (CSR).

> ***Associated impact assessment approach.*** *Impact assessment of more complex ways of increasing whole-farm productivity are largely economics-based (e.g. analysis of returns to different factors of production, total factor productivity and farm budgets), and can include consideration of a range of variables related to adoption. Some* ex post *impact assessments rely on numbers of adopters without direct measures of impact. Impact assessment also includes descriptive and/or qualitative evaluation of the impacts of user participation and gender analysis on the research process.*

3. NRM to protect, conserve and /or rehabilitate natural resources and systems.
NRMR on global environmental issues is growing in the CG – in large part because different agricultural systems are now known to have substantial effects on the global ecosystem and its functions. These past impacts can be measured: e.g. greenhouse gas emissions, deforestation. Modeling projects implications for the future. Case studies have been conducted to shed light on past-to-present impacts of human resource use (including with or without NRMR innovations). Significant efforts are being made to protect natural resources and to reduce and reverse damage to the natural environment (e.g. reducing greenhouse gas emissions, protecting biodiversity, rehabilitating degraded lands, reducing forest conversion and protecting wetlands). Much of this research is policy-based and is conducted at regional to global scales, reflecting concerns about global public goods.

__Associated impact assessment approach.__ A great deal of what can be considered impact assessment is current scenario characterization using GIS data and ex ante *modeling of future outcomes without mitigation. Although efforts at mitigation have yet to mature, if and when mitigation does take place,* ex post *impacts will be measured in terms of the particular resource or environmental measures of interest. Again, the desirable measures will be reductions in greenhouse gas emissions, area reforested, decreases in deforestation, mangrove areas saved, wetlands rehabilitated, preservation of biodiversity via creation of reserve, and rehabilitation of degraded lands. However, valuation and attribution to research of these mostly public goods, remains problematic.*

4. INRM research.

Centers currently conduct integrated, more process-based research to enhance the outputs of both private (farm production) and public (environmental) goods in ways that reconcile the often-conflicting desires of different stakeholders in different spatial and temporal scales. TAC states: "International integrated NRMR should be process-oriented to ensure maximum contribution to production of international public goods" (TAC, 2001b).

__Associated impact assessment approach.__ One of the reasons for the shift towards INRMR was the desire to make significant and sustainable development impacts. Impact assessment of INRMR, however, has generated lots of discussion. It is agreed that INRMR is ideally assessed through analysis of various indicators reflecting multiple scales and the differing respective goals – both public and private – of a range of stakeholders. Methods of development for ex post *impact assessment of NRM and INRM have not kept abreast of the progress in the thinking underlying the NRM-to-INRMR transition: to date the CG lacks an established set of methods for* ex post *impact assessment of NRMR (of course, methods of development for germplasm research impact assessment required many years). Moreover, the increased breadth and complexity coupled with the process orientation of INRM, have led some (many?) to conclude that* ex post *impact assessment is either inappropriate, or necessary but insufficient for assessing INRMR. Although work with complex and multi-scaled systems conceptually recognizes a need to examine multiple variables using different methods, to date the few actual assessments available are commonly limited to using a few selected key measurable variables or indicators. Such outcomes are ironic, given the degree of discussion of the multitudinous factors agreed to be of importance. NRMR processes have also been assessed in terms of impacts of stakeholder participation, on the basis of gender analysis, and in terms of adoption of selected innovations.*

SPIA comment

In the discussion of cases from the CGIAR, Fujisaka and White point out that the examples of NRM/INRM impact assessment emanate from a large body of research. This statement is somewhat at odds with the view put forward in Chapter 1, that one of the reasons for undertaking this SPIA initiative is the fact that there is a dearth of documented evidence of the impact of CGIAR NRMR. In SPIA's opinion, the contradiction appears to be due to the fact that donors and reviewers, such as the World Bank Evaluations Department team, are concerned about the lack of credible demonstration of the quantitative impacts of CGIAR NRMR. Much of the literature reviewed by Fujisaka and White deals with assessments of the impacts of NRM changes rather than impacts only of the research underlying the changes. The literature deals with adoption and quasi-measures of outcome – qualitative or proxy indicators of impact that do not rigorously document the impacts of the research in terms of CGIAR goals.

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