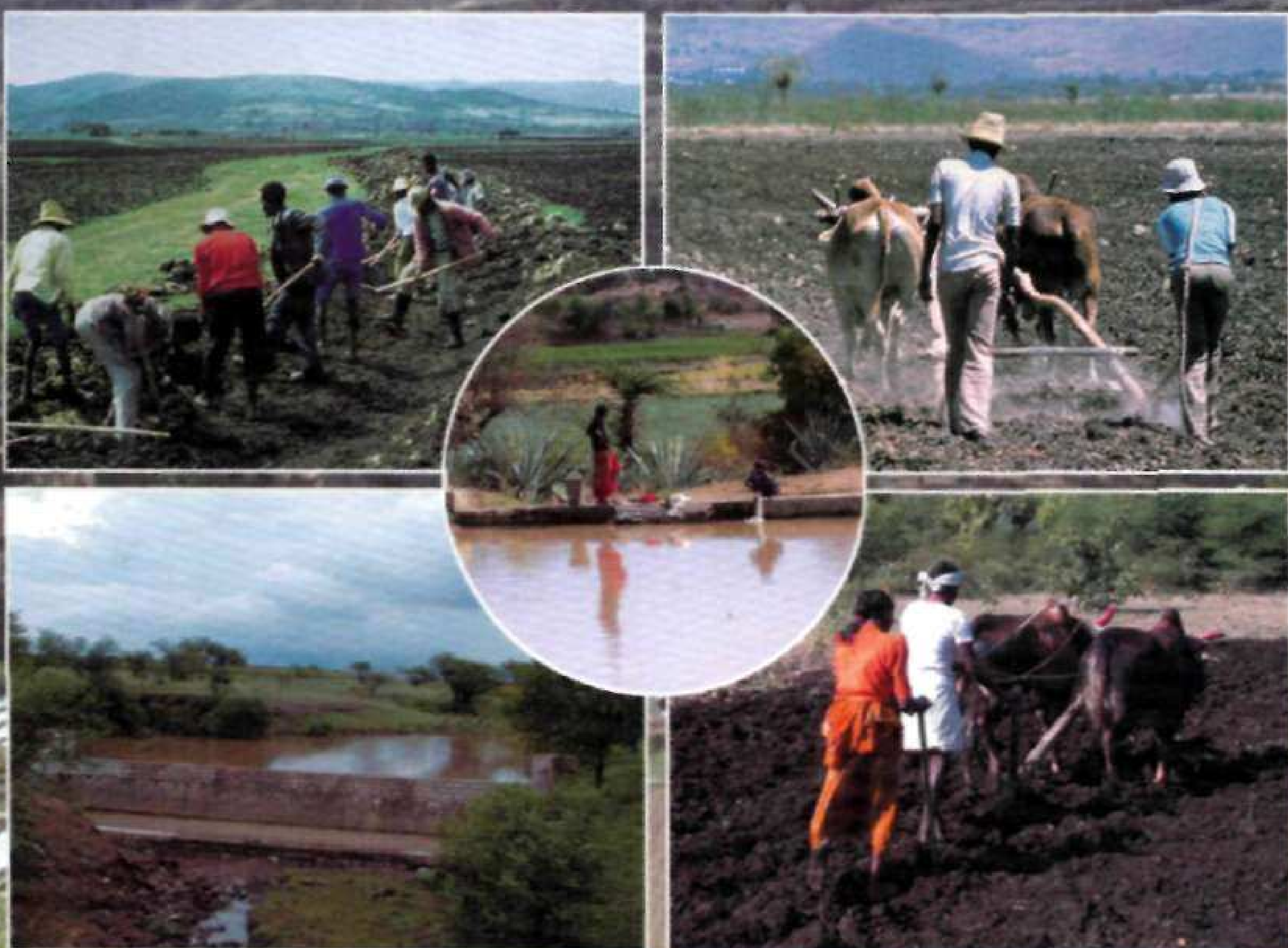
Methods for Assessing the Impacts of Natural Resource Management Research



International Crops Research Institute for the Semi-Arid Tropics

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Abstract

The perceived risks to sustainability of production systems and livelihood security of the poor in the many developing countries in recent years have prompted increased investment in natural resource management (NRM) research and development efforts. The national and international agencies, and non-governmental organizations making these investments are anxious to assess the effectiveness of these interventions on attaining the stated environmental and livelihood objectives. But measuring changes in natural resource and environmental outcome is notoriously difficult, as is assigning a monetary value to those tangible and non-tangible changes. Yet, accountability is impossible without measurement of impacts. These methodological difficulties have hindered impact assessment studies in this area.

This publication contains a summary of papers and discussions from the international workshop 'Methods for Assessing the Impacts of Natural Resource Management Research' held at ICRISAT-Patancheru, 6-7 December 2002. The workshop aimed to review recent advances in methods for assessing the economic and environmental outcomes of NRM practices in agriculture. It was attended by researchers from various national and international agencies, with specific expertise in applied methods for assessing the impacts of integrated NRM innovations.

The presentations and discussions highlighted the special features and challenges of NRM impact assessment; indicators for monitoring biophysical and environmental impacts; methods for valuation of various ecosystem services derived from NRM investments; and economic methodologies and approaches for integrated assessment of economic and environmental impacts of NRM interventions in agriculture.

Résumé

L'importance des ressources naturelles dans l'amélioration de la productivité agricole, de la durabilité des systèmes de production et des sources de revenus des pauvres de nombreux pays en voie de développement a provoqué un accroissement des investissements dans les efforts de recherche et développement de la gestion de ces ressources naturelles au cours des récentes années. Les agences nationales et internationales, et les organisations non gouvernementales qui ont pris part aux investissements sont désormais soucieuses d'estimer l'efficacité de ces interventions à atteindre les objectifs fixés. Mais mesurer les changements des ressources naturelles ou les résultats environnementaux peut s'avérer difficile, comme il peut l'être d'attribuer des valeurs monétaires à ces améliorations tangibles ou non. Et les besoins de comptabilités restent impossible sans mesures d'impact. Ces difficultés méthodologiques ont entravé les études estimatoires dans ces domaines. Cette publication contient la récapitulation des documents et discussions du colloque international sur « les méthodes d'évaluation des impacts de la recherche en gestion des ressources naturelles » qui s'est tenu à l'ICRISAT- Patancheru les 6 et 7 décembre 2002. Ce colloque a tenté de rendre compte des récentes avancées dans les méthodes d'évaluation des résultats environnementaux et économiques des pratiques de gestion des ressources naturelles en agriculture. Il a rassemblé des chercheurs et académiciens provenant de nombreuses organisations nationales et internationales de tous pays, développés ou non, et avec eux des expertises spécifiques sur les méthodes appliquées évaluant les impacts des innovations de la gestion intégrée des ressources naturelles. Les présentations et discussions ont mis en exergue les défis et caractéristiques propres de l'évaluation de ces impacts ; les indicateurs pour contrôler les impacts biophysiques et environnementaux ; les méthodes pour l'évaluation de différents travaux dérivés des investissements en gestion des ressources naturelles ; et les méthodologies et approches pour une évaluation intégrée des impacts économiques et environnementaux des interventions en gestion des ressources naturelles en agriculture.

Methods for Assessing the Impacts of Natural Resource Management Research

A Summary of the Proceedings of the ICRISAT-NCAP/ICAR International Workshop

ICRISAT, Patancheru, India
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Contents

Session 1

Welcome and Opening

Opening Address

Maximizing impacts from natural resource management research: overcoming methodological challenges

William D. Dar[1]

On behalf of ICRISAT, allow me to extend my warmest welcome to all of you, to this important international workshop on *Methods for Assessing the Impacts of Natural Resource Management Research,* organized in collaboration with the National Center for Agricultural Economics and Policy Research (NCAP) of the Indian Council of Agricultural Research (ICAR).

I am pleased to see here today, leading scholars from biophysical and social sciences in the field of impact assessment research coming together to dialogue and discuss this important methodological hurdle. Some of you may be visiting ICRISAT for the first time, and many of you have come from long distances.

I would especially like to note the presence among us, of scientists from our partner CGIAR Institutes (e.g., International Food Policy Research Institute [IFPRI], International Water Management Institute [IWMI], etc.), the Standing Panel for Impact Assessment (SPIA) of the CGIAR, and partners from Michigan State University (MSU), the Agricultural University of Norway (NLH), NCAP-ICAR, Central Research Institute for Dryland Agriculture (CRIDA)-ICAR, Centre for Economic and Social Studies (CESS), University of Hyderabad, Acharya N G Ranga Agricultural University, and others. Once again, I extend to you our warmest gratitude and welcome.

As you all know, along with increasing agricultural productivity to alleviate poverty and improve food security in poor regions of the world, natural resource management is one of the corner stones of research in the CGIAR. Protecting the production potential of natural resources and the

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ecosystem services, upon which current and future food production depends, is very crucial to improve agricultural productivity and to eradicate poverty.

Unfortunately, lack of cost-effective and economically attractive natural resource management options for the poor farmers in much of the developing world is slowing down our progress towards more sustainable and eco-friendly agriculture.

Coupled with the increasing risk of climate change and global warming, degradation of the natural resource base and desertification are threatening livelihoods in much of semi-arid tropics (SAT). Rains are not only low, but also highly unpredictable. Hence, drought is a regular phenomenon, threatening the lives of millions of poor people in Africa and South Asia.

For instance in India this year, the monsoon started early, but suddenly stopped. This was followed by a long dry spell that affected large areas spread over 17 states. Fortunately, the country has large food stocks to avert famines. Our future strategy for drought management should include innovative policies and the tools of science should be harnessed for improved natural resource management.

It goes without saying that the overlapping problems of poverty, resource degradation, and the threats of climate change and desertification, are real concerns for the future of agriculture in the SAT, which is home to over 400 million people (40% of the total rural poor). Moreover, many of the technological options developed for high-potential and irrigated regions are not suitable for agricultural systems in the SAT.

Let me emphasize that poverty alleviation and sustainable livelihood security would be difficult to attain in the SAT without systematic integration of natural resource management research with the broad efforts to improve the productivity of agriculture. ICRISAT has long recognized this, and our motto has been 'grey-to-green revolution'. This refers to sustainable productivity improvement in SAT agriculture for poverty alleviation and environmental protection through generation of demand-driven and appropriate technologies. Natural resource management research is the crucial element in this initiative.

Along with degradation of the resource base, scarcity of water in much of the dry tropics is becoming a constraint to development. In poor countries, lack of economic resources to increase water supply aggravate the problems of physical scarcity of water. There are fears that future wars could be precipitated by water use conflicts. Proper management of water is a key to avert this sort of a crisis.

A few weeks ago, we brought together scientists and various stakeholders here to discuss the recurring problems of drought and the mechanisms to mitigate drought impacts on livelihoods. The brainstorming resulted in many recommendations for drought management. Demand management - to produce more crop per drop - stands out clearly. Good agronomy and effective water management options are critical for saving water.

During the recent World Summit on Sustainable Development in Johannesburg, world leaders expressed a strong commitment to poverty eradication and protection of the environment. We, at the CGIAR, are well placed to respond to these challenges in the developing world through development of win-win options that improve the well-being of the poor, while also protecting the natural resource base and the health of the ecosystem.

We have already recognized these benefits on farmers' fields for many of the crop improvement technologies, through several impact assessment studies. Impact evaluation is a critical component of our work, mainly because it contributes to our understanding of the elements that work and do not work, to achieve our broader goals of eradicating poverty and protecting the environment. We use this information to set priorities in our research and devise strategies to relax socioeconomic constraints to maximize adoption and impacts of our research. In order to help us streamline these activities, ICRISAT has institutionalized an Impact Assessment Office (IAO) within its structure. This workshop is one of a series that we plan in order to strengthen our research to maximize impacts.

Improvements in the methods for assessing the wide-ranging impacts of new innovations in the area of crop improvement research in the last few years have enabled such analyses. However, this has not been the case for much of the natural resource management research. The complex mechanisms through which natural resource management technologies influence the environment and human well-being has made it difficult to make progress in this area.

For example, watershed management technologies that we have developed, in partnership with farmers and communities in many catchments in Asia and Africa will affect the well-being of the people as well as the quality of the environment. Adoption of these technologies contributes to improving several ecosystem services, ranging from food production to regulation of water flows, nutrient cycles and climate change.

It is interesting to note that some of these benefits from private and community investments for watershed management may even extend to the global community. Some of the benefits are tangible, while others, although crucial to the health of the ecosystem, may be non-tangible, indirect and difficult to put money-value to. Impact assessment for natural resource management technologies must deal with these complexities and multi-dimensional changes.

It is important that we deal with this methodological dearth in NRM research impact assessment, so that the broader picture of R&D intervention benefits can be assessed, and strategies developed to maximize impacts. Development of such methods for broader applications, together with our multiple partners, and through participatory approaches, is an important contribution that we at the CGIAR could make.

I understand that advances in impact assessment research, especially in resource and environmental economics in the last few years have contributed to the development of useful techniques and indicators to deal with these methodological problems. It is timely to come together and deliberate on these methodological advances, and suggest the way forward for NRM impact assessments. I am certain that you will be deliberating widely on these aspects and give us direction for our future work.

The contribution of this workshop, and your recommendations would therefore bring us a step closer to developing useful methods and approaches to bridge the gap in the area of NRM impact evaluation research.

I wish you then, a very productive, dynamic, and creative interaction during these two days of the workshop.

Once again, I wish you all a very fruitful and memorable stay at ICRISAT.

Thank you, *Namaskar.*

Introduction and objectives of the workshop

Bekele Shiferaw[1]

The challenges and motivation

Apart from conservation of the productive resource base and sustainability of past productivity gains, it is widely believed that natural resource management (NRM) does have an important role in poverty reduction. These twin objectives have motivated many national agricultural research systems (NARS) and international agricultural research centers (IARCs) of the CGIAR to expand their research and development investments in environmental protection and sustainable management of natural resources. This research effort is also accompanied by substantial investments by national development agencies, non-governmental organizations (NGOs) and donors in the development and conservation of soil, water, forest and biodiversity resources in developing countries. Researchers, development agents, policy makers and donors are keen to evaluate and quantify the social benefits derived from these investments. *Ex-post* impact assessment will help evaluate the success of R&D efforts in terms of attaining the stated objectives. Apart from helping to justify future investments in NRM in agriculture, the concurrent and ex-post impact assessments could also help inform the research process to better adapt innovations to local conditions and deal with the socio-economic and policy constraints for the uptake of economically viable technologies.

Unlike many crop improvement technologies, there are few demonstrated impacts from the adoption of NRM technologies. Several factors contribute to this lack of *ex-post* evidence of impact from NRM research investments. The lack of a comprehensive, applicable and scientifically acceptable method for assessing the wide-ranging impacts from NRM interventions is one major problem. Unlike crop improvement technologies, where the technology is embodied in the new germplasm (e.g., high-yielding variety), the impact of NRM-related technologies occurs through indirectly generated economic and ecosystem goods and

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services. These benefits are often multi-dimensional, including economic, environmental and social gains to society, typically accruing over a period of time and across different spatial scales (ranging from the plot to the wider global community). These factors make it very difficult to develop useful indicators of change, and develop unambiguous measures of impact that include spatial and inter-temporal effects.

Developing useful impact assessment methods for wider application generates international public goods, and is an area that CGIAR Centers could contribute to more effectively. In response to this demand, there have been some attempts within and outside the CGIAR, towards developing robust and cost-effective methodologies for assessing NRM impacts. Some workshops were organized to discuss the methodological difficulties, design suitable frameworks and develop action plans for NRM impact assessment. The International Centre for Research in Agroforestry (ICRAF) workshop in Nairobi, Kenya, in April 1998 is a good example, targeting mainly the methodological difficulties. Other international efforts where some aspects of the methodological issues were discussed include the integrated natural resources management (INRM) Task Force workshops in Penang, Malaysia (August 2000), Cali, Colombia (August 2001), Aleppo, Syria (September 2002), and the TAC-SPIA workshop in Rome, Italy (May 2000). Some progress has been made in understanding the complexity of issues involved, and in developing useful frameworks and concepts towards NRM impact assessment. Much remains still to be understood before routine impact assessment tools could be developed for diverse areas related to NRM. One of the major outcomes of the ICRAF workshop was an appreciation of the dimension and complexity of NRM impact pathways and the methodological difficulties involved in capturing these diverse effects. This is unlike the relatively straightforward methods now routinely in use in evaluating crop improvement technologies. Some progress has, however, been made recently in a few areas in terms of developing useful methods for assessing NRM impacts.

ICRISAT is one of the major players in NRM research in the dryland tropics where poverty, water scarcity and environmental degradation are constant threats to livelihood security. Since its establishment in 1972, ICRISAT has made substantial progress in designing and developing cost-effective technologies to improve and sustain agricultural productivity. Many of the new legume varieties (e.g., pigeonpea and chickpea) developed at ICRISAT will have positive environmental benefits in terms of enhancing sustainability of cropping systems. The same is true of the integrated pest and disease management (IPDM) methods that reduce the demand for harmful chemicals. Other high-yielding varieties may also have both positive and negative environmental outcomes. Past efforts for assessing the impacts of new technologies have not been able to account for such externalities. In addition, several innovative technologies have been developed for integrated soil, water and nutrient management, and pest and disease management. These innovations are now being implemented in the context of integrated community watershed management with the participation of farmers. The increasing emphasis on research for development and impact has motivated ICRISAT to look for better approaches and methods to evaluate the outcomes from its extended effort to develop technologies for sustainable intensification and diversification of agriculture for poverty reduction in the marginal and ecologically fragile environments of the semi-arid tropics (SAT). No doubt, these methods will be very useful to many partners within the national and international R&D system.

After consultations within and outside ICRISAT, including with other CGIAR Centers and several partners, ICRISAT decided to organize this international workshop in partnership with the National Centre for Agricultural Economics and Policy Research (NCAP) of the Indian Council of Agricultural Research (ICAR). The workshop has brought together leading scientists from within and outside the CGIAR system, including NARS and advanced research institutes and universities, with a recognized track record in the application of useful NRM impact assessment methods.

Workshop objectives

The workshop objectives are to:

- Deliberate on the special features and methodological difficulties of NRM impact assessment, with special reference to temporal, spatial and multi-dimensional effects.
- Examine the strengths and potentials of alternative approaches (econometric, economic surplus, bio-economic, etc.) for assessing the multi-dimensional (economic, environmental, and social) impacts of NRM research.

- Assess and identify data requirements for developing impact indicators and approaches for generating the required information for implementing NRM impact methodologies.
- Recommend suitable and applicable methodologies for assessing the impacts of NRM technologies with emphasis on soil and water conservation options in smallholder agriculture in the SAT.

Expected outcomes

The workshop is expected to deliver the following outcomes.

- Enhance our understanding of the methodological difficulties, special features and approaches for addressing multidimensionality of NRM impacts (economic, social, environmental), inter-temporal issues (e.g., deferred benefits and upfront costs), externalities (e.g., spatial interlinkages), and identify knowledge gaps in key areas related to integrated soil and water management.
- Identify useful quantitative (econometric, economic surplus and bio-economic modeling) and qualitative approaches and their strengths and weaknesses, as well as ways to integrate the approaches and makeup for the respective shortcomings.
- Suggest suitable biophysical impact indicators and measurement methods, and useful approaches to link these indicators to economic and environmental outcomes. The discussion is expected to highlight data requirements to ensure plausibility, and the need for developing participatory, applicable and cost-effective indicators for monitoring integrated soil and water management interventions in farmers' fields.
- Propose suitable methods for NRM impact assessment across scales and technologies, including integrated watershed management technologies, private and community level soil- and water-conservation investments, germplasm technologies with environmental impacts (e.g., biological nitrogen fixation, high-yielding varieties, etc.).

Further, the workshop is expected to identify knowledge gaps and areas for future research; foster exchange of institutional experiences; and create opportunities for networking and collaboration for developing new tools and testing suitable methods at a pilot scale within and outside the CGIAR system.

The issues to be addressed are very broad and diverse. In these two days of deliberations, I hope that the workshop will be focused on relevant issues, and address many practical questions that impact assessment practitioners face in reality. As we discuss the relevant methods, we need to carefully define the scope of the deliberations and the diverse NRM issues to be considered; the scale at which the methods would be applied (plot, household-farm, watershed, etc.); the type of performance indicators required, especially to account for externalities; and the modalities for implementation, including mechanisms for ensuring the participation of the local resource users (e.g., farmers and communities) in the monitoring/valuation of changes in relevant indicators and evaluation of outcomes.

Session 2

Special Features and Indicators for NRM Impact Assessment

Why impact assessment of NRM technologies presents methodological difficulties

H. Ade Freeman[1] and Bekele Shiferaw[2]

Introduction

It is increasingly recognized that the management of natural resources can contribute significantly to poverty reduction and human welfare (World Bank 2001). This perspective partly explains the increased investment in natural resource management (NRM) research in the Consultative Group on International Agricultural Research (CGIAR) over the past two decades.

The emergence of NRM as a major area of CGIAR research investment has made assessment of the impact of this research inevitable, both for setting research priorities and for monitoring the efficiency and effectiveness of research investments. However, methods for assessing the range of impacts of NRM research are much less developed, compared with methods for assessing impact for crop improvement research.

The scant evidence on the impact of NRM research is due, in part, to formidable methodological challenges in assessing such impacts, whether *ex-ante* or *ex-post.* This paper explores some of these methodological challenges, and provides suggestions to improve impact assessment of NRM research.

Impact assessment of NRM research

A range of methods and tools has been used to assess impact of NRM research. However, there are weaknesses in several of these studies, and most have not succeeded in generating credible measures of NRM research impact.

The methodological challenges in impact assessment for NRM research are associated with interrelationships among natural resources, spatial and temporal dimension of impact, and valuation of environmental benefits

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and costs. Natural resources are interrelated in ways that a single "shock" to the system could have substantial impacts on other components. NRM research is therefore extensive, encompassing several issues and activities over multiple dimensions. This multi-dimensionality partly explains the lack of clarity on the goals of NRM research and the way in which the outcomes of NRM research are measured. It is still not clear whether the objective of NRM research is to enhance productivity, or manage the sustainability of the environment. This lack of clarity often makes it difficult to accurately assess NRM research impact.

The concept of sustainability has been frequently used for impact assessment of NRM research. The definition and measurement of sustainable agricultural systems is debatable, and there is no consensus on suitable indicators, measures, and valuation techniques that can be utilized for ***ex-ante* or *ex-post*** impact assessment. The total social factor productivity (TSFP) has been popularized as an appropriate summary measure of sustainability. However, as Byerlee and Murgai (2001) observed, TSFP as a measure of sustainability is conceptually flawed, and several practical issues limit its application.

The spatial dimension implied in the interrelationship of natural resources makes impact assessment of NRM research very difficult. This dimension extends over plots, farming systems, watersheds, landscapes, and ecosystems. A particularly thorny methodological issue is that impact assessment should include externalities. For example, externalities may be pervasive in a watershed because land and water users are linked by upstream and downstream hydrological relationships. Factors such as collective action in negotiation, decision-making, management, and conflict resolution among different stakeholders, further complicate impact assessment of watershed projects.

Methodological difficulties arise in measuring NRM research impact across different scales in a spatial hierarchy. For example, biodiversity can be evaluated below ground (microbes), within species, and within ecosystems. A related difficulty with NRM research is that it involves a wider range of stakeholders than does crop improvement research. These stakeholders may have different needs and expectations from NRM research, complicating the assessment of costs and benefits.

The temporal dimension of NRM impact also presents methodological difficulties. Transformation in land use and resource exploitation may change projected costs and benefits. In other cases, NRM research interventions may have long-term impacts that are difficult to perceive or assess. There are also difficulties in assessing the impact of NRM research vis-a-vis the situation, had there been no research intervention (i.e., the appropriate counterfactual).

Quantifying changes in resource quality or impacts for NRM research pose difficult valuation problems. Economists use the total economic value (TEV) to measure the benefit (and costs) of an environmental benefit (or damage). The components of TEV are measured by direct procedures such as hedonic prices and contingent valuation. Hedonic price methods are frequently subject to bias arising from omitted variables, while the practical application of contingent valuation methods can be limited by several sources of bias (strategic, design, hypothetical, and operational).

Towards credible impact assessment of NRM research

To motivate the way forward for impact assessment of NRM research, we outline several issues that need to be addressed, if we are to make progress in this difficult area of the CGIAR's research portfolio. Some of these relate directly to the broad NRM impact assessment agenda but have important methodological implications, while others are specific to methodological development for impact assessment of NRM research.

NRM research has multiple goals. They may include improvement of productivity, reduction of risk and conservation of the productive resource base. A critical step towards credible impact assessment of NRM research is to clarify the goals of NRM research so that measures of impact can be less ambiguous. A clearer specification of the goals of NRM research would narrow the scope of research to realistic proportions, and assist in identifying gaps in data and methodologies.

CGIAR Centers need a clearer understanding of their comparative advantage in impact assessment of NRM research. Methodology development for impact assessment of NRM research is one area where CGIAR Centers need to pursue more active collaboration with universities and Advanced Research Institutes (ARIs) in the developed world.

Impact assessment undertaken by CGIAR Centers should do more to support development interventions (Baur *et al.* 2001). In particular, impact assessment should provide meaningful information that will help development investors, research managers, and scientists. These concerns have led to increasing interest in combining quantitative and qualitative methods for impact assessment, recognizing that both methods have limitations and that the strengths of each can compensate for the disadvantages of the other (Kerr and Chung 2001).

Conclusions

This paper has provided a brief overview of some of the complexities that present methodological difficulties for impact assessment of NRM research. This explains, in part, the dearth of evidence on the impact of NRM research. This is in contrast to crop improvement research where the tools and techniques for assessing impact are more developed. The fact that impact assessment on NRM research presents methodological difficulties does not imply that there are no impacts. Scientists and research managers in CGIAR Centers need to increase their efforts to develop and disseminate cost-effective methodologies for impact assessment of NRM research. But for these efforts to be fruitful there is a need to actively pursue collaboration building on the complementarities of CGIAR Centers, NARS, and ARIs. The goal of establishing plausible linkages between research investments and impact assessment is reasonable, both for crop improvement research and NRM research. Similarly, combined quantitative and qualitative methods for impact assessment appear to be a step in the right direction for generating credible impact assessment of NRM research.

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Biophysical indicators for assessing the impact of watershed-based technologies

P. Pathak, S.P. Wani, A. Ramakrishna and K.L. Sahrawat[1]

Introduction

Watersheds provide a focus for tackling poverty and environmental problems in dryland agriculture. Contemporary watershed management embraces a holistic approach aimed at optimizing the use of land, water and vegetation resources in a catchment area. These measures alleviate drought, moderate floods, prevent soil erosion, improve water availability and increase fuel and fodder, thus enhancing the livelihoods of rural poor and marginal farmers.

Biophysical indicators play an important role in assessing the overall impact of watershed programs, particularly on the quality of the natural resource base. The development or identification of accurate and reliable biophysical indicators for monitoring and assessing the impact of watershed technologies is a rather difficult task. Unfortunately, there is no universal set of indicators that is equally applicable in all cases. Several types of biophysical indicators are available, and the selection of relevant indicators is extremely important. In the following sections, we discuss various biophysical indicators, which may be useful for assessing the impacts of watershed technologies.

Land quality indicators (LQIs)

Land quality indicators have been used by several researchers and development agencies to monitor the land quality and its impacts on sustainable agricultural production and environment (Pieri *et al.* 1995; World Bank 1997). Land quality indicators are measures that provide estimates of the condition of land relative to human needs, changes in this condition and human action, which are linked to this condition. Land quality indicators are similar to the economic and social indicators already in use. It is only by means of indicators that changes in land quality can be

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monitored and policy or management action taken. Here, the land refers not to soil alone, but to the combined terrain - water, soil and biotic resources that provide the basis for land use. Land quality refers to the condition or health of land, especially to its capacity for sustainable land use and environmental management. The LQI program monitors the environment and the sector performance of managed ecosystems. Generally, using just one indicator of land quality has not been found satisfactory. It is more appropriate to use a combination of two or three land quality indicators, such as soil quality, land degradation, agro-biodiversity, water quality, and land contamination/pollution.

Land quality indicators can be applied at different scales: farm, watershed, district and regional. Land quality indicators have particular application, first in development projects, both sectoral and in the area of natural resource management; secondly, with respect to assessing the impact of natural resources management technologies, and thirdly, to determine policy priorities at various levels. To researchers/policy makers, land quality indicators can provide a good indication of whether environmental conditions and land quality are getting better or worse. Land quality indicators are also useful for decision makers to monitor and improve project performance as related to socio-economic and environmental impact, and to assess the trend towards or away from land-use sustainability.

Soil quality indicators

Over the years, scientists have worked on developing a set of basic soil characteristics that serve as key soil quality indicators (Scott *et al.* 1999). These indicators are sensitive to changes in both management and climate. Scientists suggest that the best soil quality indicators are those characteristics that show significant changes between 1 and 3 years, with 5 years being an upper limit to usefulness. Soil quality indicators are usually classified as physical, chemical or biological. Physical indicators include soil texture, depths of soil, bulk density, penetration resistance, porosity, infiltration rate, and water-retention characteristics. Chemical indicators are total organic C and N, pH, electrical conductivity, extractable N, P, and K, and micronutrients. The basic biological indicators are microbial biomass C and N content, potentially mineralizable N, and soil respiration.

Soil attributes that are most sensitive to management are most desirable as indicators. In a given agroclimatic region, the measurable soil attributes that are primarily influenced are given in Table 1. These are a minimum number of indicators (minimum data set) that need to be measured, to evaluate changes in soil quality resulting from various management systems.

However, depending upon the local conditions, one may have to add or delete the soil indicators as given in Table 1. From a long-term watershed experiment at ICRISAT Center, several soil physical, chemical, and biological properties were measured to assess the long-term impact of

Table 1. Key soil indicators for soil quality assessment.

Selected indicator	Rationale for selection
Organic matter	Defines soil fertility and soil structure, pesticide and water retention, and use in process models.
Topsoil-depth	Estimate rooting volume for crop production and erosion.
Aggregation	Soil structure, erosion resistance, crop emergence and early indicator of soil management effect.
Texture	Retention and transport of water and chemicals, modeling use.
Bulk density	Plant root penetration, porosity, adjust analyses to volumetric basis.
Infiltration	Runoff, leaching and erosion potential.
PH	Nutrient availability, pesticide absorption and mobility, process models.
Electrical conductivity	Defines crop growth, soil structure, water infiltration; presently lacking in most process models.
Suspected pollutants	Plant quality, and human and animal health.
Soil respiration	Biological activity, process modeling; estimate of biomass activity; early warning of management effect on organic matter.
Forms of N	Availability to crops, leaching potential, mineralization/ immobilization rates, process modeling.
Extractable N, P and K	Capacity to support plant growth, environmental quality indicator.

Source: Arshad and Martin (2002)

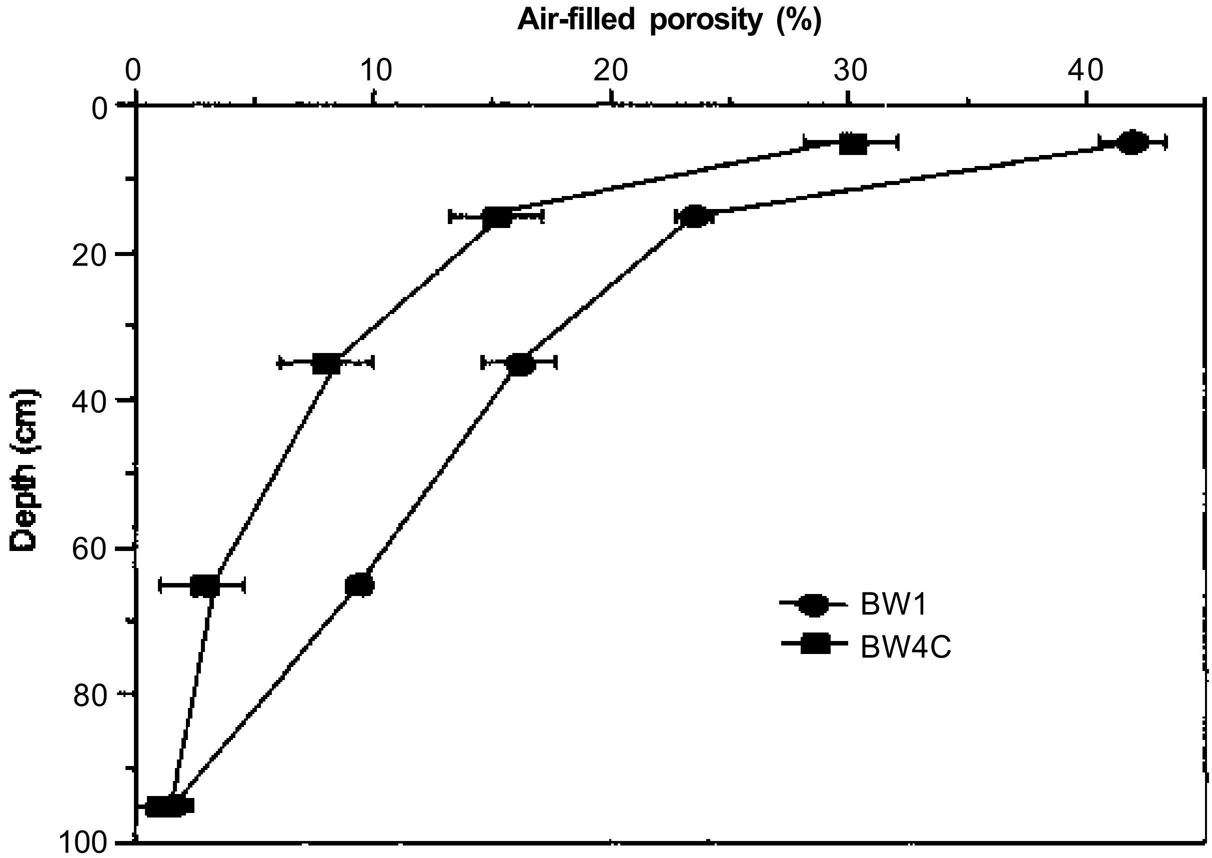

Figure 1. Air-filled porosity at the ICRISAT watershed, under Improved (BW1) and traditional (BW4C) technology for Vertlsol management (1976-1998).

watershed technologies. Among the various soil physical properties, air-filled porosity was found to be important to improve and sustain the productivity (Figure 1). The improved watershed technology significantly increased the air-filled porosity, thereby reducing the water-logging problem that crops commonly face on these soils. Significant differences in other key soil physical properties vis-a-vis soil texture, bulk density, total porosity, infiltration, and penetration resistances were recorded between improved and traditional technologies.

Microbial indicators of soil quality

The dynamic nature of soil biological communities, microbial and macro-faunal, makes them a sensitive indicator for assessing alterations in soil quality due to changing management practices (Kennedy and Papendick 1995). Soil populations could provide advance evidence of subtle changes in the soil before changes in soil physical and chemical properties become apparent. Management practices on the land result in changes in soil physical and chemical properties, altering the soil environment that supports the growth of the microbial population.

For microbial indicators, the basic set includes total organic C and N, microbial biomass C and N, potentially mineralizable N, and soil respiration. Two useful ratios include biomass C to total organic C and the soil respiration rate compared with the total biomass. Imbalances in these two ratios could be an early indicator that the soil biology is responding to changes in the soil condition, and these changes may soon be reflected in the physical and chemical properties of the soil. To understand the various nutrient cycles and levels of microbial activity, investigators have looked at various enzymatic activities in the soil, including dehydrogenase and fluorescein diacetate hydrolysis, both indicators of general microbial activity; phosphatase, involved in the P cycle; arginase, involved in protein hydrolysis; arylsulfatase, part of the S cycle; and β-glucosidase, involved in the C cycle. Microbial community fingerprinting is also developing as a possible indicator of soil quality (Kennedy and Smith 1995). The soil biological indicator measured (Wani et *ah* 2003) from the on-station watersheds experiment clearly shows that these biological indicators are useful for assessing the short- and long-term impact of watershed technologies on soil quality (Table 2).

Table 2. Biological and chemical properties in watersheds under improved and traditional technology, 1976-1998.

	Soil depth (0-60 cm)	
Properties	Improved system	Traditional system
Soil respiration (Kg C ha^{1})	723	260
Microbial biomass (Kg C ha^{-1})	2,676	1,462
Organic Carbon (t C ha^{1})	27.4	21.4
Net N mineralization	-3.3	32.6
Microbial biomass N (Kg N ha^{1})	86.4	42.1
Non-microbial organic N (Kg N ha^{1})	2,569	2,218
Total N (Kg N ha^{-1})	2,684	2,276

Source: Wani *et al.* (2003)

Soil quality indices

Soil quality index was proposed at the International Conference on the Assessment and Monitoring of Soil Quality, held at the Rodale Institute, Emmaus, PA, USA. (Rodale Institute 1991). At this conference, Parr *et al.* (1992), proposed a soil quality index (SQ) as follows:

$$SQ = f\,(SP, P, E, H, ER, BD, FQ, MI) \quad (1)$$

where SP refers to soil properties, P the potential productivity, E the environmental factors, H the health (human/animal), ER the erodibility, BD the biological diversity, FQ the food quality/safety and MI refers to management inputs.

Doran and Parkin (1994) described a performance-based index of soil quality that could be used to provide an evaluation of the soil function with regard to the major issues of (i) sustainable production, (ii) environmental quality, and (iii) human and animal health. They proposed a soil quality index consisting of six elements:

$$SQ = f\,(SQEI, SQE2, SQE3, SQE4, SQE5, SQE6) \quad (2)$$

where SQEI is food and fiber production, SQE2 the erosivity, SQE3 the ground water quality, SQE4 the surface water quality, SQE5 the air quality, and SQE6 is the food quality.

Integrated indicators

He-ChanSheng et *al.* (2000) developed integrated ecological indicators to assess the overall changes in hydrological and biological conditions in watersheds. Several other integrated and multidisciplinary indicators (Riley 2001, Nambiar *et al.* 2001, Allen *et al.* 1999, Mecracken 1990) have been developed to assess the overall impact of watershed technologies.

Hydrological indicators

Several hydrological indicators are being used to assess the impact of watershed technologies. Some of the most commonly used indicators are:

Soil loss

This indicator is used to measure the extent of soil loss by sheet, rill, and gully erosion, which reduces the short- and long-term productive capacity of soils, and the extent and amount of sediments moving into streams and downstream reservoirs including chemical fertilizers, micronutrients, and pesticides. It is also very useful in determining off-site sediment damages, and the conservation effectiveness of various watershed technologies. It could also be indicative of the general quality of watershed management. It can be directly measured using suitable hydrological equipment (Pathak *et al.* 2002). It can be also estimated using soil loss equation, that is, Universal Soil Loss Equation or using Water Erosion Prediction Project (WEPP) model, which requires data such as soil type, slope, erosion control practices in use, vegetative cover, rainfall amount and its intensity.

Water supply

The following indicators are most commonly used to assess the overall impact of watershed technologies on water availability and utilization.

Indicator for surface water. This indicator measures the overall status of surface water in the watershed. It includes surface water availability (from tanks, check dams and streams), its utilization and the overall trend.

Indicator for groundwater. This is one of the important indicators that measures the overall status of groundwater. It includes the overall availability of groundwater, its utilization and trend. In most of the current watershed programs, excessive withdrawal of groundwater is posing a serious problem.

Indicator for water use efficiency. This indicator measures the overall water use efficiency in the watershed, in rainfed and irrigated systems. Inefficient rainfed and irrigated systems cause irrecoverable loss of water, local overuse of ground and surface water, excessive energy use, lost opportunities for higher crop yields, and possible degradation of water quality. In a water-deficit situation, it is a very important indicator for assessing the efficiencies of watershed technologies in improving water use efficiency.

Water quality

Currently, several indicators are used to assess the overall conditions of water quality in the watershed. Water quality standards differ according to the purpose for which water is used. For example, different water quality standards will be required for agricultural purposes, human consumption, and recreational purposes. Separate indicators are used to assess the water quality in surface water bodies - sediment loads and sources, nutrient loads and their sources, pesticides and other toxic chemicals loads - and groundwater (Mecracken 1990).

Agronomic indicators

One of the most important indicators for assessing impact of watershed technologies is time series data on crop productivity. Cropping diversity, intensity, pest infestation and diseases, and deleterious weeds are the main attributes whose indicators are often used by farmers and implementing agencies (Allen et *al.* 1999). Plant communities can be used as indicators for soil quality/soil health. Weed communities are found to be better indicators than single species. Also, perennial weeds often make better indicators than annual ones.

Conclusions

Biophysical indicators are commonly used to diagnose natural resource degradation processes, and to assess the overall impact of watershed interventions. This paper discusses the various types of biophysical indicators that are available for assessing the overall impact of watershed technologies. Among the currently available biophysical indicators, land quality indicators, soil quality indicators, hydrological indicators (soil loss, water supply, water quality and runoff), and agronomic indicators are most commonly used in watershed projects. Other types of indicators such as soil quality indices, and integrated indicators (ecological indicators, and multidisciplinary indicators) have not been used widely. Some of the key points on the biophysical indicators are:

- There is no universal set of biophysical indicators that is equally applicable in all cases. Therefore, selection of relevant indicators is extremely important based on a good understanding of various processes at the local level.

- Most of the currently available biophysical indicators may need modification or refinement before they can be used for assessing impacts of watershed technologies.
- Researchers, government departments and other major implementing agencies use most of the biophysical indicators discussed in this paper. The perceptions of other stakeholders such as farmers need to be taken into consideration to make them more useful. This is important because their perception of the processes that are taking place in the natural resources base may be different from that of the researchers.

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Valuation methods and methodological approaches for evaluating the impacts of natural resource management technologies

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Introduction

As a response to increasing degradation of natural resources (soil, water and biodiversity) and concerns about sustainability of the agricultural production potentials in many poor regions of the world, national and international organizations have initiated research programs targeted at developing methods and technologies to conserve or enhance the natural resource base. These technologies are expected to have impacts resulting in poverty reduction and improving the quality of the resource base. Methodological difficulties for impact assessment are rooted in several unique features of natural resource management (NRM) technologies. Unlike germplasm technologies where the required trait is embodied directly within the improved seeds, the impact of the NRM technology occurs only indirectly, through the economic and environmental goods and services that generate direct and indirect benefits to humans and other living organisms. These benefits are often multi-dimensional in the sense that they include economic, environmental and social gains to society across different scales. External benefits often accrue to agents who may not be willing to pay for the goods and services consumed.

On the other hand, benefits from NRM investments may often be lagged and accrue over a relatively longer period of time. The relatively long gestation (maturity) and payback periods necessitate an inter-temporal approach to assessing NRM impacts. This is true of tree planting, investment in gully control methods, and terracing on sloping lands. Even if the investment matures relatively quickly, the time required to fully recover the investment could be relatively long. Figure 1 illustrates how NRM technologies generate various ecosystem functions that provide

1. ICRISAT, Patancheru, India.
2. ICRISAT, Nairobi, Kenya.

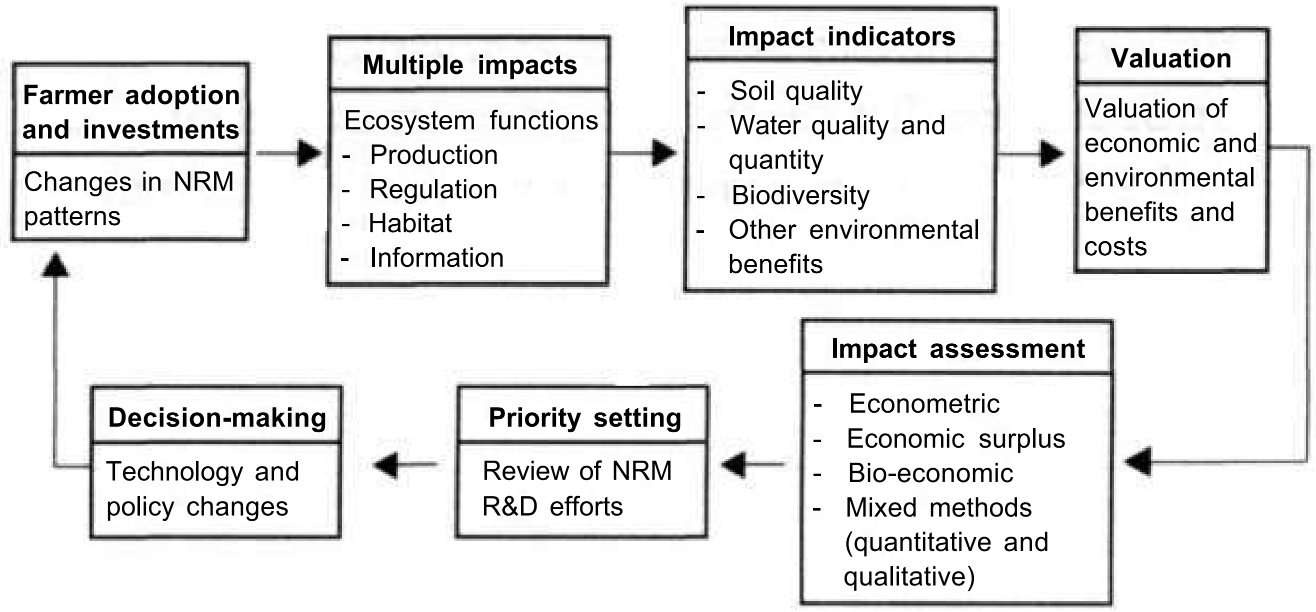

Figure 1. The process of translating changes in ecosystem functions into economic and environmental impacts.

direct and indirect economic and environmental benefits, valuation of such benefits, eventually leading to application of comprehensive impact assessment methods to evaluate societal impacts. These would, in turn, contribute to changes in NRM priorities and policies.

This paper provides a summary of the methodological approaches and valuation methods that may be used to value economic and environmental benefits of NRM technologies, and for evaluating the associated societal impacts. This includes a brief discussion on the multiple ecosystem services, and biophysical and economic indicators of such changes. This is followed by a brief discussion on the techniques used to value the various ecosystem services and create links between economic and biophysical indicators. Some of the most relevant impact assessment (evaluation) methods are discussed in the final section.

The process of translating changes in ecosystem functions into economic and environmental impacts.

Agro-ecosystem functions

Agro-ecosystems (e.g., watersheds) offer a number of ecosystem goods and services of value to society. In many cases, such services are public goods, and self-interested private individuals may lack the economic incentive to provide such services in socially optimal quantities. Depending on the type of NRM technology introduced, the effect on the agro-ecosystem could be transmitted through any of the following ecosystem functions (de Groot *et al*. 2002):

- *Production function:* through conversion of solar energy into edible plants by autotrophs.
- *Regulation function:* through maintenance of essential ecological process and life support system.
- *Habitat function:* through provision of habitat and reproductive space (nursery function) for cultivated and uncultivated plant and animal species.
- *Information function:* through provision of aesthetic information (e.g., attractive landscape), recreational services (e.g., ecotourism), and scientific and cultural values.

Each of these ecosystem functions generates a diverse set of direct and indirect economic and environmental goods and services.

Biophysical and economic indicators

If NRM interventions in agro-ecosystems generate multiple benefits, a major difficulty in impact assessment would be the identification of measurable impact or performance indicators along the multi-faceted avenues through which change is expected. The primary candidates for indicators of change that could be regularly monitored include indicators for quality and quantity of soil, water, forests, and biodiversity. These indicators should reflect the changes in quantity and quality of these resources that may be linked with the intervention. Pathak *et al.* discuss these issues in detail in this volume.

As NRM investments may not generate goods and services directly 'consumed' by human beings and are often used as inputs in agricultural production, it is important to link how such investments translate into welfare gains to the people[3].

The changes in biophysical, ecological and environmental indicators of the resource base provide economic and productivity benefits, which may also be associated with changes in the human and social capital (including

3. Exceptions include orchards, agro-forestry and water-harvesting investments that generate products (like fruits, fodder, fuelwood, and water) with direct economic benefits to human beings.

organizational changes). The types of indicators to be used may differ by the type and scale of NRM interventions and anticipated impacts. Table 1 presents a stylized example of indicators at different scales across the multi-dimensional outcomes resulting from soil and water conservation investments.

Cambell et *al.* (2000) proposed linking indicators to changes in the quantity and quality of five livelihood assets (natural, physical, financial, social and human capital). They also suggested an aggregate measure for each of the assets that could be used to develop an aggregate index for all the assets. However, several performance indicators are needed to capture relevant changes. Such multi-dimensional indicators for each asset will be very difficult to implement.

Table 1. Multi-faceted indicators of impact at different spatial scales—the case of soil-conserving technologies.

	Level		
Indicator	Farm	Household	Watershed
Biophysical	• Rate of erosion • Soil fertility status • Vegetation cover • Crop yields • Areas abandoned due to high erosion	• Food produced • Access to water and fuel • Quality of drinking water • Quantity of drinking water	• Slopes stabilized • Rate of siltation • Quantity of water in reservoir • Area under tree cover
Social		• Awareness of environmental degradation	• Rate of immigration • Conflict for access to land and water • Income redistribution • Access to natural resources
Economic	• Fertilizer use • Rate of profits • Level of risk • Level of diversification	• Income level • Level of food security • Level of assets	• Infrastructure network • Biodiversity level • Dam siltation cost

Source: Izac (1998).

Valuation techniques

Valuation of the economic and environmental goods and services generated through NRM investment requires a careful inventory prepared by a multi-disciplinary group of scholars and local stakeholders. Empirical monetary valuation of these goods and services often depends on the existence of markets and the spatial diffusion of the goods and services (Table 2). As can be seen from Table 2, the benefits from goods and services in Quadrant I are both tradable within the local economy and are captured on-site. These goods and services could be valued using market prices, with important adjustments for any market distortions (e.g., taxes, subsidies) that may exist. For goods and services in Quadrant II, market prices may exist but the local producers do not capture benefits. The lion's share of such benefits is externalized. For those in Quadrant III, benefits accrue within the local economy (of the household or village) but many of the goods and services are non-tradable.

The total use value of a natural resource resulting from a given investment is the sum of direct and indirect use benefits (marketed and non-marketed) that accrue to all the beneficiaries on-site and off-site.

Table 2. Valuation of environmental goods and services from tree planting: the role of markets and externalities.

		Location of goods and services	
		On-site	Off-site
Tradability	Marketed	I Benefits accrue on-site (e.g., fuelwood, fodder, timber, etc.) and are tradable. Usually included in Environmental Impact Assessment (EIA).	II Off-site tradable benefits (e.g., higher crop yields or more hydropower resulting from reduced siltation in dams). Sometimes included in EIA.
	Non-marketed	III Benefits accrue on-site but are highly non-tradable (e.g., soil and water conservation, recreational values, regulation of micro-climate, etc.). Seldom included in EIA.	IV Off-site non-tradable benefits (e.g., carbon sequestration, reduced flooding, biodiversity conservation). Usually ignored in EIA.

Hence, the total use value of a given resource is the sum of non-overlapping component parts of goods and services that accrue to different agents. The total economic value of a given resource, however, includes non-use values. The non-use values include what are called option value, bequest value, and existence value.

Total economic value = Current use value + Non use value
= {Direct use value + Indirect use value} + {Option value + Bequest value + Existence value}.

Recent advances in resource and environmental economics provide many useful methods that can be employed for valuation of use and non-use values of ecosystem goods and services, both marketed and non-marketed. An overview of such methods is given in Table 3. The methods can be distinguished by the type of market used as well as the implied behavior of the economic agent in the valuation of goods and services. Some of these methods are briefly described below.

Change in productivity: Technologies developed through NRM research are expected to reduce resource degradation and increase sustainable utilization of scarce natural resources such as soil, water, forests and biodiversity. For wider adoption and impact, such technologies are also expected to be economically attractive to small farmers, in terms of increased yields, reduced costs and/or reduced vulnerability to climatic

Table 3. Valuation methods for ecosystem goods and services.

Implied behavior	Conventional market	Surrogate market	Constructed market
Actual or revealed behavior	Defensive (preventive) expenditure	Property values (hedonic pricing)	Experimental markets
	Provision costs	Wage differentials	
	Relocation costs	Travel costs	
Based on potential or expressed behavior	Change in productivity (factor income)		Contingent valuation method (CVM)
	Replacement costs		
	Avoided costs		
	Opportunity costs		

risk (e.g., drought). This means that physical changes in production or overall farm profits derived from adoption of such technologies could be technically established and valued using market prices. This requires establishing statistical relationships between the change in the quantity and/or quality of the affected resource (e.g., soil depth, soil fertility, fodder, water availability, etc.) and agricultural productivity by crop or livestock type. The change in productivity approach is used to value such benefits.

Defensive expenditure: Farmers, communities and governments often incur actual expenditures in an attempt to mitigate or prevent resource degradation. When the extent and potential effect of resource degradation or improvement is difficult to assess, preventive or defensive expenditures may be used to have a rough value of the resource in question. This approach has limitations. First, the defensive expenditure, like all willingness to pay, is limited by income and the value so obtained may not reflect the social scarcity value of the resource. Second, it tends to be quite arbitrary and very generic, as actual expenditures may be targeted to attain several outcomes including poverty alleviation, and conservation of several resources at the same time.

Provision costs: This refers to the actual expenditures that farmers or communities may incur to provide vital environmental goods and services. These expenses are directly targeted in the provision and production of the required goods and services. The strength of the method is in trying to value the resource in question, using the actual cost outlays in producing the required environmental good or service.

Replacement costs: Under this approach, potential expenses that may be needed to replace the damaged natural resource asset are estimated using prices of marketable products. For example, mineral fertilizers could be used to replace lost nutrients due to erosion or nutrient depletion. However, the resulting estimate is not a measure of benefits of avoiding the damage in the first place, since the damage cost may be higher or lower than the replacement cost.

Hedonic pricing: When environmental goods and services cannot be directly valued using conventional markets, revealed behavior through surrogate markets may be used for valuation. To the extent that surrogate markets are competitive, the property value approach can be used for valuing NRM impacts. For example, land values in competitive markets (with transferable rights) may be used to value differences in land quality resulting from NRM investments. The hedonic function for a given parcel with a vector of biophysical characteristics L = (l_1, l_2,..., l_n) and socio-economic characteristics of the location and the buyer Y = (y_1, y_2,..., y_n) can be estimated as P = P (L, Y), where P is the revealed market price.

Contingent valuation method (CVM): In the extreme cases where preferences are not revealed directly or indirectly through conventional markets, the CVM tries to assess people's potential willingness to pay (WTP) for environmental goods and services by posing hypothetical questions. It basically asks people what they are willing to pay for a benefit or what they are willing to accept (WTA) by way of compensation to tolerate a cost or forgo a benefit. WTP is constrained by income whereas WTA is not. As a result, estimates of WTA tend to be higher than WTP. The suggestion made therefore, is to use the WTP approach for situations where individuals are expected to gain from an improvement, and the WTA approach in situations where people are forced to give up or suffer some damage to their welfare. There is a good potential for application of this method in NRM impact assessment in developing countries, where missing or imperfect markets prevent proper assessment of resource values.

Impact evaluation

An impact evaluation intends to assess changes in the well-being of individuals, households and institutions, which can be attributed to a particular project, program or policy (Baker 2000). This definition, used for traditional impact evaluation of development projects, excludes potential effects of such projects on the natural resource base or the environment. Along with potential effects on human well-being, NRM impact evaluation should also encompass changes in the condition of the biophysical environment. The information generated through *ex-post* or *ex-ante* impact evaluation will inform decisions on whether or not to expand, modify, or eliminate particular elements of the technology, policy or program, and can be used to prioritize public actions. Three approaches used for impact assessment of NRM technologies are highlighted below.

Economic surplus: This is the most commonly used method for evaluating the impacts of agricultural research investments, particularly those related to crop improvement. The approach relies on the measurement of research benefits in terms of changes in consumer surplus (CS) and producer surplus (PS), resulting from a shift in the supply curve. Thus, the economic surplus (sum of the producer and consumer surplus) is taken as a measure of the gross benefit from research investments in a given year. This method is useful for aggregate analysis of technology-induced supply shifts in a given industry. The usual calculation of producer and consumer surplus, however, does not account for external effects associated with adoption of new technologies. For example, improved NRM technologies reduce social costs associated with agricultural production activities. Hence, the effect of NRM research on such externalities may be handled through the changes in the social marginal cost of production. When these externalities could be measured and the effect of the new technology on the marginal social cost of production (supply curve) is estimable, it may be possible to account for external effects using the conventional economic surplus method.

Econometric approach: Another approach for estimating benefits from research investments is related to the use of econometric (and non-parametric) methods to link measures of output, costs and profits directly to past research investments. The econometric approach uses primal and dual functions wherein lagged research and extension investments appear as explanatory variables in the statistical model of production. The primal approach relies on empirical estimation of production functions, while the dual approach uses profit or cost functions along with associated systems of supply and factor demand functions. The production function approaches assume that the major benefits from NRM research investments can be reflected in changes in output. Eventually, the parameter estimates obtained from production, profit and costs functions should be translated into measures of economic benefits of research. The econometric method can also be used for testing causality and the relationship between measurable indicators of outcome and research investments at any scale of analysis.

Bio-economic models: Alternatively, bio-economic models link economic behavioral models with biophysical data to evaluate potential effects of new technologies, policies and market incentives on human welfare and the environment. The main challenge in developing the models is to establish the functional relationship between economic activities and biophysical indicators and processes. Econometric models are often used to estimate production or cost functions that include biophysical indicators as input factors. The strength of this approach is in the close integration of important biophysical information and ecological processes with economic decision behavior. Bio-economic models have been applied at the level of the household (e.g., Holden and Shiferaw in press), at village and watershed levels (e.g., Okumu et *al.* 2000) and for the agricultural sector (e.g., Schipper 1996).

Conclusions

This paper provided some insights about the vital ecosystem functions that natural resource investments offer, the type of indicators needed, problems of valuation of tangible and non-tangible benefits from natural resource management investments. It also provided a brief review of the impact evaluation methods with potential relevance to natural resource management. Each of the valuation and impact evaluation methods reviewed has its own strong and weak sides. The valuation methods can be used to measure the importance of changes in ecosystem goods and services resulting from adoption of resource-conserving or productivity-enhancing options. Linking the changes on the biophysical side with economic (behavioral) models is the key for evaluating impacts. There are very few applications of some of the methods in NRM impact assessment. For micro-level impact studies, bio-economic methods that explicitly link biophysical and economic parameters have recently become more popular in impact-related studies.

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Session 3

Methodological Advances for NRM Impact Assessment

An econometric approach to NRM impact assessment: an example from Uganda

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Introduction

In Uganda, land degradation and low agricultural productivity are serious problems. Other than these, soil nutrient depletion, erosion, and other manifestations of land degradation appear to be increasing. The rate of soil nutrient depletion is among the highest in sub-Saharan Africa (Stoorvogel and Smaling 1990), and soil erosion is a serious concern, especially in highland areas (Bagoora 1988). Existing evidence indicates that farmers' yields are typically less than one-third of the potential yields found on research stations, and yields of most major crops have been stagnant or have been declining since the early 1990s.

Addressing the problems of resource degradation and agricultural productivity decline in Uganda (and indeed in many developing regions) is a formidable challenge, owing to the diverse agro-ecological and socio-economic conditions, and the complex set of factors and interactions that influence farmers' land management decisions. This paper attempts to address this challenge by developing and estimating a structural econometric model of household decisions regarding livelihood strategies, crop choices, land management, and labor use, and their implications for agricultural productivity and land degradation.

The objectives of this paper are to:

- Investigate the determinants of land management practices in Uganda, and their impacts of these determinants on agricultural production and land degradation.
- Identify effective strategies to increase agricultural productivity and reduce land degradation.

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Conceptual framework and methods

A system of seven equations was specified to estimate the structural system. This includes value of crop production (Y), erosion (E), pre-harvest labor use (L), land management practices (LM), proportion of plot area planted to different crops (C), the livelihood strategy pursued by the household (LS), and participation of the household in various organizations or technical assistance programs (P).

$$Y_{hp} = f(LS_h, P_h, C_{hp}, LM_{hp}, L_{hp}, X_v, X_h, Xp) + q_{hp} \quad (1)$$

$$E_{hp} = g(LS_h, P_h, C_{hp}, LM_{hp}, L_{hp}, X_V, X_h, X_p) + r_{hp} \quad (2)$$

$$L_{hp} = h(LS_h, P_h, C_{hp}, X_v, X_h, X_p, Z_{lh}) + s_{hp} \quad (3)$$

$$LM_{hP} = i(LS_h, P_h, C_{hp}, X_v, X_h, X_p, Z_{1h}) + t_{hp} \quad (4)$$

$$C_{hp} = j(LS_h, P_h, X_v, X_h, X_p, Z_{lh}) + u_{hp} \quad (5)$$

$$LS_h = k(X_v, .X_h, Z_{zh}) + v_h \quad (6)$$

$$P_h = 1(X_v, X_h, Z_{2h}) + w_h \quad (7)$$

Due to the nature of the dependent variables, this structural system cannot be estimated using a standard linear systems approach such as three-stage least squares. As measured by the survey and used in the analysis, the endogenous variables in this system are of different types; most are limited dependent variables (categorical or censored). Y and L are continuous uncensored variables (logarithms of the value of crop production and amount of pre-harvest labor); thus least squares regression can be used for equations (1) and (3). E is measured as an ordinal variable (three levels for no erosion problem perceived, mild, or severe); thus we use ordered probit to estimate equation (2). LM are dichotomous choice variables; we use probit models to estimate equation (4). C are censored continuous variables (censored below at 0 and above at 1); we use a maximum likelihood Tobit type estimator for equation (5). LS is a polychotomous choice variable; we use multinomial logit to estimate equation (6). Three approaches, direct estimation, instrumental variable (IV) or two-stage estimation, and reduced form (RF) estimation are used to investigate robustness of the regression results. Due to space limitations, only results from the total value of production and erosion equations are reported in this paper.

Inclusion of endogenous explanatory variables in this system may result in biased estimates, due to correlation of the error term with the endogenous explanatory variables. In limited dependent variable models, IV estimation cannot be used, but consistent estimates can be produced by a two-stage approach substituting predicted values of the endogenous explanatory variables. However, in IV or two-stage models, identification of the effects of the endogenous variables is often difficult, unless one has valid instruments that strongly predict endogenous variables. With weak instruments, results of IV or two-stage estimation can be more biased than that of OLS.

Theoretical considerations and hypothesis testing are used to exclude some household level variables from production and erosion regressions such as effect of household size. Ethnicity and village-level access to various infrastructure, services, and organizations are used to predict participation.

Data

The data for this analysis were obtained from a survey of 451 households conducted in 107 villages in southern, central and parts of northern Uganda in 1999-2000. The villages were selected based on a stratified random sample within the study region, stratified to represent variations in agroclimatic conditions, market access and population density (Pender *et al.* 2001). Four-to-five households were randomly selected from each sample village and surveys were conducted at the village, household and plot level (all plots owned or operated by the sample households).

Selected regressors include several variables at the village, household and plot levels. Village-level factors (X_v) include the agro-ecological zone the village is in, the market access of the village, and the population density of the village. Household factors (X_h) include physical capital, human capital, social capital and access to technical assistance. Plot-level factors (X_p) include the size, tenure and land rights status of the plot, the distance of the plot from the farmer's residence, roads and markets; the investments that have been made on the plot (irrigation, trenches, grass strips, live barriers and planted trees are most common), and various plot quality characteristics (slope, position on slope, soil depth, texture, color and perceived fertility).

Results

The value of crop production is substantially higher on plots where bananas are grown than where cereals and many types of crops are grown (Table 1). Though crop rotation reduces the value of production significantly in the short run, it may contribute to production by helping to restore soil fertility in the long run. Not surprisingly, the value of crop production on a plot increases both with plot and labor use. In the IV regression, the elasticities of supply response with respect to plot size and labor, 0.650, 0.322, respectively, indicate that production is approximately constant returns to scale (where the sum of elasticities = 0.972). Among the NRM investments, irrigation substantially increases the value.of crop production. The IV regression implies that irrigation increases the value of production by a factor of 4.6, controlling for labor inputs and land management practices (Table 1). Output value on a given plot is also significantly affected by agro-ecological zone and the livelihood strategy of the household. Age of the household head and amount of land owned affect output value negatively, while value of livestock owned is found to have a positive effect.

Erosion is perceived as less severe on plots where slash and burn is practised. Some land investments have significant and robust impacts on erosion. Irrigation and trees on the plot are negatively correlated with perceived erosion. Perceived erosion is more severe on plots with trenches or grass strips. The slope and topographic position of a plot has a substantial impact on perceived erosion where plots on steep slopes have the most severe erosion problems, while plots with moderate slopes also have more erosion than flat plots. Market access and production of cereals or export crops as the livelihood strategy are found to reduce perceived erosion, while access of the plot to the farmer's residence and higher population density are found to increase it. The positive effect of population density on erosion supports neo-Malthusian concerns about population-induced land degradation, consistent with findings of other studies in Ethiopia (Pender et *al.* 2001; Grepperud 1996). Other things being equal, household heads with secondary education perceive less erosion while households headed by women perceive more erosion. This may be due to differences in the perception rather than the reality of erosion. Consistent with a prior expectation, land tenure security reduces perceived erosion.

Table 1. Summary of selected results[*]

Variable	Ln (output value) (USh) OLS	IV	RF[b]	Rill and gully erosion (Ordered probit) Direct	Two stage	RP
Crop choice (cf.cereals)						
- Legumes	-0.068	0.808		-0.040	-0.721	
- Root crop	-0.468*	1.008		0.416	0.538	
- Vegetable	0.525	1.321		-0.039	-1.303	
- Coffee	0.098	-0.189		0.242	0.954	
- Banana	0.988***	1.515***		0.163	0.836	
Land management practice						
- Slash and burn	-0.048	0.394		-0.443**	-1.416**	
- Crop rotation	-0.201 *	-0.613**		0.222	3.214***	
Ln (Pre-harvest labor use)	0.385***	0.322*		0.140*	-0.536	
Livelihood strategy (primary income source)						
- Cereals	0.484***	0.549"*	0.337*	-0.982***	-1.286***	-1.080***
-Export crops	0.483***	0.361**	.573***	-0.381*	-0.278	-0.446*
Agro-ecological zone						
-BL	0.295	0.240	0.599**	0.104		0.422
-BH	0.291	0.278	0.518**	-0.132		0.237
High market access	0.013		-0.003	-0.474**		-0.556***
Distance (miles) to:						
- Residence	-0.093*	-0.070	-0.076	-0.294***		
Ln (Population density)	0.014		0.042	0.118		0.225**
Assets						
- Own land	0.305	0.375	0.579*	0.230		
- In (Area owned)	-0.097*	-0.112*	-0.132**	-0.044		
- In (Value of livestock)	0.068*	0.056	0.107***	-0.028		
Education of household head (cf. not completed primary)						
-Secondary	0.129	-0.005	0.245	-0.606*		-0.935**
Ln (Age of head)	-0.359**	-0.185	-0.386**	-0.102		-0.172
Woman-headed households	-0.152		-0.256	0.534**		0.781***
Slope of plot (cf. flat)						
- Moderate	-0.074	0.000	-0.023	0.959***	0.791***	0.992***
- Steep	-0.001	0.012	-0.090	1.721***	1.547***	1.716***
Investment on plot						
- Irrigation	0.790	1.533**	1.259***	-8.170***	-11.510***	-7.742***
- Trenches	-0.009	0.169	0.195	0.434**	-0.287	0.344**
- Grass strips	0.046	0.169	0.217	0.377*	0.670*	0.378**
-Trees	0.030	0.030	-0.013	-0.230*	-0.689***	-0.205*
No. of observations	930	920	937	1163	1290	1306
R^2	0.56	0.48	0.48			

*, **, *** mean reported coefficient is statistically significant at 10%, 5%, 1% level, respectively.

a. Complete regression results available from the authors.

b. Reduced Form model.

Impact of selected policy interventions

Controlling for livelihood strategies, land management options and other factors, road improvement is predicted to lead to somewhat lower agricultural productivity. For example, if all households were 10 miles farther away from an all-weather road, the value of crop production is predicted to be 11.5% higher (direct effect in Table 2). This may be because road access increases farmers' efforts in other activities at the expense of crop production. Considering adjustments that farmers make in livelihoods and land management (total effect), there is still a predicted decline in crop production, though relatively small. Road improvement is also predicted to reduce the probability of erosion (both direct and total effects) possibly due to a lessening of the intensity of crop production. This

Table 2. Simulated impacts of policy changes (% change compared to mean value).

Scenario	Mean of selected variable (actual values)		Value of crop production (Ush)		Severe gully/ Rill erosion (probability)	
	Before change	After change	Direct effects	All effects	Direct effects	All effects
Distance to all-weather road	1.57	11.57	+11.5%	+4.1%	+11.0%	+7.4%
Universal primary education	0.502	1.000	-7.7%R	-8.6%	-19.0%	-20.8%
Higher ed. for people with secondary ed.	0.095	0.183	+1.0%	+0.1%	+4.2%*	+2.4%
Agricultural training for all households	0.485	1.000	+17.0%***R	+16.4%	-8.0%	-8.9%
Extension for all households	0.297	1.000	+23.9%*"	+18.4%	-18.5%R	-22.0%
Convert customary to freehold tenure	0.484	0.000	-4.5%R	-5.3%	+30.4%**R	+26.8%

*, **, *** mean the direct effect is based on a statistically significant coefficient at 10%, 5%, 1% level.

R means the coefficient upon which the direct effect is based Is also significant in IV or two-stage regression.

situation appears to cause tradeoffs between production and sustainability objectives.

Investment in universal primary education (UPE) for household heads lacking any education is predicted to reduce both agricultural productivity and land degradation, while investment in agricultural training and extension programs offers more potential for 'win-win' outcomes. A change in land policy to promote conversion of land under customary tenure to freehold tenure appears to offer 'lose-lose' outcomes, leading to both lower productivity and more erosion.

Conclusions

This study has shown that improvements in land management in Uganda are possible, leading to higher productivity as well as lower land degradation. We find the participation in technical assistance programs, pursuit of certain livelihood strategies, investment in irrigation, and promotion of more specialized production of cereals or export crops, can achieve 'win-win' outcomes, increasing agricultural productivity while reducing land degradation. Banana production is found to be more profitable than other crops. Although 'win-win' or 'win-no lose' outcomes are possible, many interventions would likely lead to tradeoffs between production and sustainability objectives.

The results of this study do not support the optimistic 'more people-less erosion' hypothesis, though the results are consistent with population-induced agricultural intensification, as hypothesized by Boserup. We do not find evidence of a poverty-land degradation trap, given that erosion is not found to depend on asset ownership. However, there may be a vicious cycle of land degradation occurring because households are less apt to invest in conserving lands that are already degraded. This is supported by the positive relationship between indicators of soil infertility (and several other indicators of low land quality) and erosion.

Further research is needed to identify profitable as well as sustainable land management options, as no land management practices except irrigation were found to be very profitable in the short run. Limited and sometimes puzzling impacts of land management practices deserve further study, and econometric approaches should be supplemented by other approaches (experiments, participatory evaluations, etc.). Research using qualitative indicators of perceived land degradation can yield useful insights, but should be validated by more objective measures.

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Integrating sustainabiiity indicators into the economic surplus approach for NRM impact assessment

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Introduction

Over the past three decades, major advances have been made in the economic assessment of agricultural research impacts, especially assessment of technologies that enhance productivity. However, despite the recent proliferation of sustainability-oriented research projects, little progress has been made in measuring the impacts of research on natural resource management (NRM) (Pingali 2001). In particular, there have been scarcely any attempts to assess the economic impacts of new NRM practices using the economic surplus approach (Alston *et al.* 1998).

The economic surplus framework for impact assessment aims to capture both consumer and producer net benefits from new technologies. It is based on supply and demand curves. The cumulative value of these unsought gains across all consumers is called 'consumer surplus' (Figure 1). By analogy, some producers can sell for more than their costs of production, and their aggregate gains are called 'producer surplus.' Together, the sum of consumer surplus and producer surplus is referred to as economic surplus.

New technologies change the total amount of economic surplus as well as its distribution between consumers and producers. In applying the economic surplus approach to NRM impact assessment, estimating the supply shifts due to new NRM technologies and how consumers will value those changes requires confronting the triple challenges of attribution, measurement and valuation.

This paper, therefore, outlines elements of methods for incorporating NRM indicators into the economic surplus approach to impact assessment.

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Economic surplus approach to impact assessment

The economic surplus approach to impact assessment is rooted in the microeconomics of supply and demand. Consumer demand can be described by a downward sloping demand curve. Across all consumers, the area beneath the demand curve, D, and above the equilibrium price, p*, measures the total value of *consumer surplus* (Figure 1).

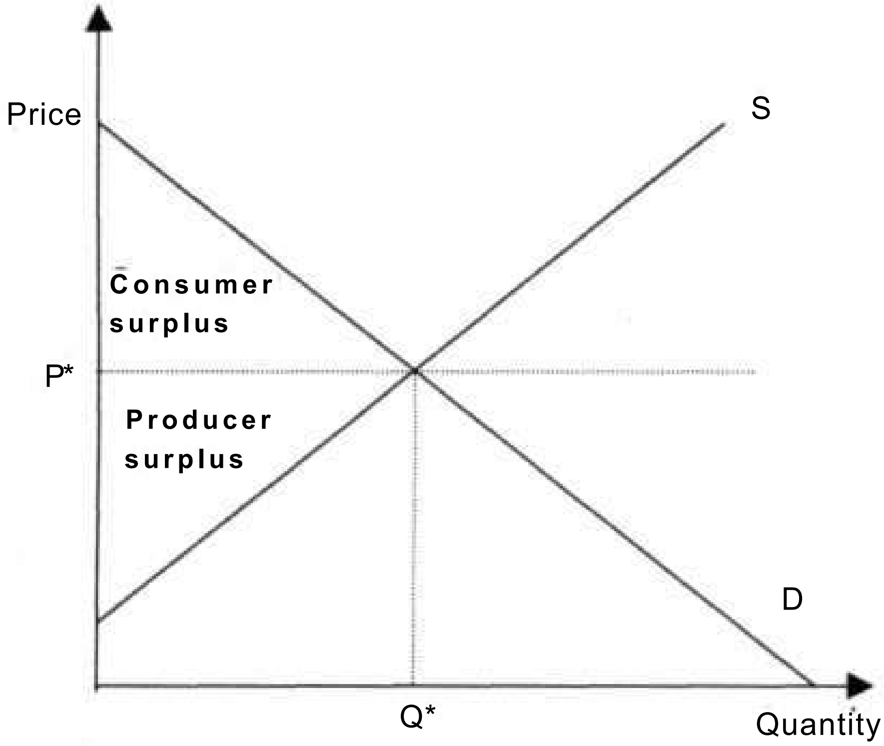

Figure 1. Economic surplus divided between consumer and producer surplus.

Producer supply can be described by an upward sloping curve. The aggregate benefits described by the area above the supply curve, S, and below the equilibrium price, p*, measure the total *producer surplus.* Together, consumer surplus and producer surplus sum up to *economic surplus.*

The economic impact of a new production technology can be estimated as the change in economic surplus that results from a shift in the supply curve. New production technologies typically reduce the cost of producing a unit of output. The comparative static effects on product supply and economic surplus are illustrated in Figure 2. Both yield-enhancing and cost-reducing technologies have the net effect of reducing the average cost of production. How the effects of a new technology are divided between

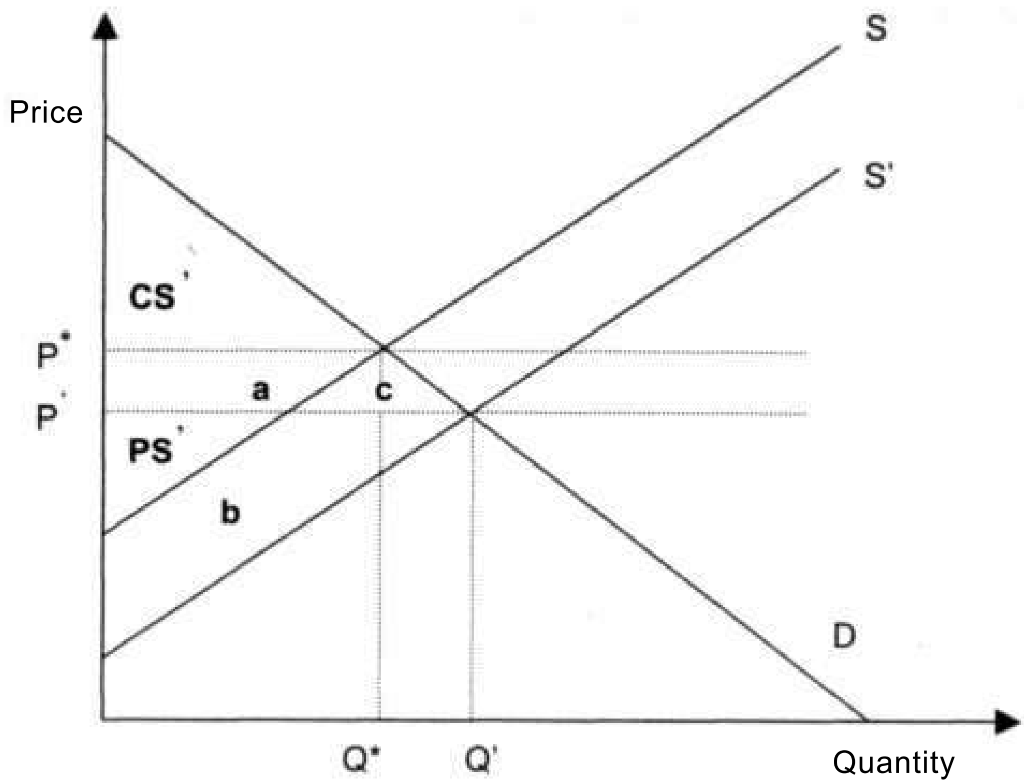

Figure 2. Change in economic surplus due to an outward shift in supply.

producers and consumers depends upon the slopes of the supply and demand curves[2]. Most NRM technologies present several special characteristics that require a different approach to conceptualizing and measuring economic surplus.

Attribution and measurement of NRM research impacts

The key challenges to assessing NRM impacts are attribution, measurement, and valuation. All are complicated by the dynamics of how natural resource stocks evolve over time. Attribution of identified effects can be accomplished with controlled experiments or simulation models over time. For example, both can be used to identify and measure changes in crop productivity from soil conservation practices.

2. In the extreme case where demand is perfectly elastic, increase in production resulting from a new technology does not affect prices. In this case, all the gains accrue to producers. When demand is perfectly inelastic, a supply shift will affect prices but will not result in changes in quantity demanded.

What to measure and how to do it are related challenges. For on-site productivity effects, controlled experiments and simulation models are very suitable. The consequences of such effects are felt chiefly on site by the farm household. However, NRM technologies have two other kinds of effects. Some on-site effects are delayed, and may not be recognized at first by the manager. Other effects are not experienced by the farm household, but rather are experienced off site as 'externalities' to the farmer's privately optimal management choices. By the same token, NRM and yield-enhancing agricultural research may create positive externalities in the form of land-saving effects that protect amenities associated with forests and natural uses (Nelson and Maredia 1999).

NRM technologies may potentially affect a wide variety of environmental and natural resource (ENR) services, so what to measure depends upon the NRM technology in question, and the environmental setting where it is used. What to measure is also linked to those NRM impacts likely to have the greatest social value. Because the issue of valuation is a large one, it deserves a section of its own.

Valuation of private versus public NRM benefits

The benefits of NRM practices can broadly be divided between those captured privately (by the NRM practitioner) and those captured publicly, external to the NRM practitioner. Privately captured benefits are the easiest to measure, especially when they are tied to marketed products. Within the realm of private benefits, the next level of benefit covers effects that are still privately experienced but hidden, due to lags or lack of obvious market valuation. Reduction in pesticide-related human health effects is a case in point (Crissman et *ah* 1998; Maumbe and Swinton 2003; Rola and Pingaii 1993).

Some NRM practices have public effects felt beyond the NRM practitioner. Such economic externalities are common among ENR services. In particular, production processes for marketed commodities sometimes generate byproducts that are bad for the environment. Yet harmful byproducts that have no market (e.g., nitrate or pesticide leaching) are likely to be ignored in the producer's benefit-cost calculus. Hence, the value of an NRM innovation that reduces the externality problem may need to be calculated indirectly.

The major measurement challenge here lies in estimating the value of the externality. The thorniest NRM impact valuation challenge occurs when the impacts are publicly borne and associated with private use of a public good.

Economic valuation of ENR services

While markets serve to place values on privately marketed products of NRM research, other methods are required for the economic valuation of human health and ENR services. Three classes of valuation methods dominate: direct market measures, revealed preferences inferred from market behavior, and stated preferences for ENR services that are contingent on hypothetical market settings.

A key limitation of most health and ENR valuation methods is that their implementation is expensive. A small, but growing area of research into 'benefits transfer' examines the conditions under which environmental values reported in one study may be applied to a different setting. The simplest method of benefit transfer is to take a mean value from a reported study site and apply it to a new site. An alternative is to transfer a *benefit function.* The benefit function approach is generally believed to be more accurate (VandenBerg et *al.* 2001). For economic surplus estimation purposes, the benefit function approach has the added advantage in that it can be applied to simulate the variability in benefit valuation across a sample population at a new site, thereby capturing not just the average value of the benefit, but also a range of values emulating a demand curve.

Implementing NRM impact assessment in the economic surplus framework

How should the idiosyncrasies of NRM technology impacts be accommodated in an economic surplus analysis? Although private and social costs are sometimes combined in theory, for empirical work it is more practical to separate privately captured changes in economic surplus due to marketable goods and services from publicly captured externality effects due to non-marketed health and ENR services. Keeping private and public costs separate implies a parallel measurement and valuation process.

In principle, all these same elements could enter into integrating sustainability indicators for ENR services into the economic surplus approach to NRM impact assessment. Obviously, data on price elasticities of supply and demand are especially scarce for non-marketed goods and services. The elasticities that do exist come from revealed and stated preference, survey-based estimates of demand for ENR services. Although demand elasticities have been estimated for agriculturally related ENR services (Owens 1997), none have been incorporated into an economic surplus analysis of NRM impacts. Those few studies that have estimated the cumulative value of NRM impacts on non-marketed ENR services over time have used the benefit-cost approach.

Translation from consumer WTP units to producer NRM impact units

The biggest challenge in incorporating NRM impacts into economic surplus analysis is to obtain a monetary valuation of ENR benefits. An important secondary hurdle in applying this benefit transfer to NRM impacts is to associate consumer willingness to pay (WTP) for ENR amenities consumed with producer measures of ENR amenities produced by adopting NRM practices. For example, consumer WTP for cleaner water is typically measured per unit of water consumed (e.g., household water consumption per year), whereas producer ENR services are typically measured per unit of land (e.g., soil erosion deterred per acre per year). Consumer WTP measures must be translated into producer units in order to measure the impact of improved ENR services due to NRM adoption.

A useful extension of the nascent efforts to incorporate NRM innovations into the economic surplus approach would be to apply empirical estimates of supply and demand elasticities for ENR amenities that arise from NRM practices. Supply elasticities would have to be estimated from survey data or multilocational experimental trials that reflect geographic and other differences in producer costs.

Scoring methods as an alternative to economic surplus analysis

Although few studies have attempted to incorporate NRM technology impacts into the economic surplus approach to impact assessment, several have used indexes for a multiple criteria approach to impact assessment (Crissman *et al.* 1998). This trade-off approach does not generate a single-valued economic-environmental measure of economic surplus. However, it can inform decisions by policymakers or individual NRM practitioners about links between the profitability and ENR consequences of alternative courses of action.

In general, scoring or indexing methods offer a simpler approach than monetary valuation to aggregating and weighting the effects of distinct ENR. The chief limitations of scoring approaches are that their weighting criteria may be viewed as arbitrary, and there is typically no direct conversion from the index units to value units that could be used in economic surplus analyses.

Conclusions

The nascent state of attempts to integrate sustainability indicators linked to NRM technologies into economic surplus analysis leaves ample room for innovation. One area ripe for a contribution is the incorporation of supply and demand elasticities for ENR services so that their valuation becomes more than a benefit-cost analysis exercise. Additional research into benefits transfer will also be key to clarifying criteria and methods for adapting ENR amenity valuation estimates from one setting to another.

There are two areas that are worth exploring. More comprehensive efforts should be made to place value on how the ENR amenities preserved could supplement impact assessments of ENR services due to direct NRM interventions. Estimates are also needed to see how ENR amenity valuation is affected by rising incomes in developing countries.

Although NRM technologies can play an important role in reducing health and ENR risks linked to agricultural production processes, policy plays a crucial role in internalizing the externalities that make these technologies worth adopting. Producer adoption is the *sine qua non* for impacts to occur. So another important role for *ex ante* assessments of NRM impacts is to reveal the value of ENR services that could be had if policy incentives for adoption of sustainable technologies were put in place.

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Applied bio-economic modeling for NRM impact assessment: static and dynamic models

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Introduction

Bio-economic models link human behavior and biophysical resource use and stock changes. They are typically applied programming models that may have a basis in simpler theoretical dynamic or static models. Due to the complexity of socio-economic and biophysical conditions, a dynamic or evolutionary perspective is required in order to handle inter-temporal issues.

In this paper, the focus will be to better understand the evolution patterns of land use and human welfare (pathways of development) where changes take place due to population growth, land degradation, technological and institutional changes and exogenous shocks. Further, bio-economic models could be used to predict future changes in land use under different land use scenarios or other alternative assumptions about changes in exogenous conditions. This implies that such models could be used to assess impacts on the natural resource base as well as on human behavior and welfare.

This paper gives a brief theoretical basis for the formulation of bio-economic models, and discusses some advantages and disadvantages of the different approaches and model types for use in NRM impact assessment. The objective is to illustrate how bio-economic models could be used to assess the impacts of new technologies and projects or policies that affect NRM in rural economies in developing countries.

Theoretical basis

In developing countries, the dominant decision-making units in rural economies are farm households that are partly integrated into markets.

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Farm households maximize their own utility subject to a set of socio-economic and biophysical constraints. Due to high transaction costs and asymmetric information, farm households typically face a situation with imperfect markets. The pattern of imperfections in markets is systematically affected by basic material conditions in rural economies and by basic behavioral conditions. The pervasiveness of credit market imperfections coupled with poverty cause farm households to have high discount rates (Holden et a/. 1998a), and this may affect their ability and willingness to invest in conservation of natural resources. In the context of rural economies of the developing countries, bio-economic models that use farm household economics as a foundation will have a valid theoretical basis.

Bio-economic optimization models

Optimization models have an explicit objective function that is maximized or minimized. For rational agents, this objective could be to maximize utility, maximize profit, minimize drudgery, or minimize risk, subject to socio-economic and environmental/biophysical constraints. Basic needs requirements of agents could also be handled through a set of constraints that should be satisfied. Some examples of bio-economic optimization models are described below.

Static optimization models

Static separable and non-separable farm household models

Farm households are both production and consumption units, and there is optimization behavior related to both the production and the consumption sides. When markets function well, several studies have shown the separability between production and consumption decisions. Under such conditions, it does not matter for land use as to who owns or operates the land. In this case, poverty does not matter for investment decisions since well-functioning markets ensure optimal use of resources. Based on the assumption of well-functioning markets and the separability of production and consumption decisions, one may model a village economy, a watershed or another unit as a single decision-maker on the production side.

However, the implications of high transaction costs and imperfect information greatly undermine the assumption of well-functioning markets. Imperfect land, labor, and inter-temporal markets jointly affect land use, input and investment decisions related to land use. Treatment of a village or a watershed as a single decision-maker in bio-economic models may not be a good solution in such cases.

It is therefore useful to assess carefully how wealth or poverty affects land use on different types of land, and how imperfections in different markets affect land use decisions. Careful modelling of the interactions between the location-specific biophysical as well as socio-economic conditions is required to predict with more certainty, the outcome of changes in policies, technologies, prices and institutional constraints. Non-separable linear and non-linear programming models are particularly useful for this kind of analysis.

There is a long tradition of using linear programming (LP) to model farm household resource use in agricultural economics (Hazell and Norton 1986). Some of the advantages of static LP models are that they:

- Are simpler to construct and solve.
- Can handle a large number of constraints related to biophysical, institutional or behavioral conditions.
- Can capture multiple goals either in hierarchy or as weighted goals.
- Can approximate non-linear relationships through piece-wise linearization.

Such programming models are therefore very suitable for dealing with complex farming systems that, for example, encompass crop-livestock interactions, many types of land, land degradation, and market imperfections.

However, many remain skeptical toward LP models due to the linear relationships, as the real world is highly non-linear.

Multi-agent models

Bio-economic multi-agent models typically consist of linear programming models, which are solved for a large number of individual farms. This allows for a careful treatment of the variation in key resource constraints across farms. The approach has the advantage of reducing the aggregation bias that may stem from pooling of data across households or due to the use of average data for household groups. However, the approach does not capture the general equilibrium effects that may be important at the aggregate level.

Woelcke et *al.* (2002) have developed a bio-economic multi-agent model for a rural economy in Uganda. The model has been used to assess whether adoption of ecologically sustainable farming practices is financially and technically feasible, and further, to assess whether technological innovations in combination with changing socio-economic conditions (market access) have the potential to improve the negative nutrient balances.

Non-linear programming models

Non-linear programming (NLP) models can be non-linear in objectives as well as in constraints. Hence, they represent an improvement over linear models in simulating bio-economic and biophysical relationships. However, large NLP models may demand more computer power or take a longer time to solve. Therefore, it is crucial to set good starting values to solve such models and avoid being locked into unrealistic local optima.

Dynamic optimization models

Dynamic programming refers to a situation where the final (end period) state is known, and it is therefore possible, through backward induction, to arrive at an optimal pathway. Dynamic programming models may be derived from optimal control theory. Here we discuss other types of dynamic optimization models.

Non-stochastic dynamic farm household models

Non-stochastic dynamic farm household models may be formulated without knowing the exact end point levels of stocks (free terminal value problems) but have a limited time horizon. The models may or may not incorporate risk. Such models will typically have multiple constraints in each period. At the same time, final period depletion of resource stocks cannot be accepted unless it is realistic.

Holden and Shiferaw (in press) have developed a non-linear, non-stochastic dynamic non-separable farm household model with risk. Market imperfections (missing markets, price bands, rationing, share tenancy); weather risk (drought, frost, hailstorms); price risk (covariate risk) and land degradation (soil and nutrient loss, loss of land productivity) and conservation investments are included in the model. Newer versions of the model, (e.g., Holden et a/. 2003) simulate the impact of improved access to credit markets, off-farm employment, and promotion of tree planting (eucalyptus).

The models are used to assess the impact of changes in market access and policies on natural resource management, the impact on soil erosion and nutrient depletion, and its impact again on land productivity and household welfare.

Stochastic dynamic bio-economic models

Discrete stochastic programming (DSP) may be used to construct a dynamic bio-economic model. This is a type of time-recursive model where some of the decisions are made based on expected probabilities about future events, while other decisions can be delayed till the outcome of the random event is known. This implies that the models have a decision-tree structure with the nodes of the tree as decision points, and the branches as different states of nature.

Barbier and Hazell (2000) have developed a discrete stochastic programming model with recourse bio-economic model for an agro-pastoral area in semi-arid Niger. The model is used to simulate the longer-term consequences of changes in population growth and reduced access rights to transhumance grazing areas with special emphasis on the role of drought risk in conditioning the model's results.

Bio-economic economy-wide (multi-market) models

Social and Environmental Accounting Matrices (SEAMs) Models

Social accounting matrices (SAMs) are used to give a complete map of resource, commodity and service flows in an economy. It requires that all sources and sinks for the transactions and the related prices are identified.

Traditional SAMs were not used for environmental accounting. But, it is possible to link environmental accounting with social accounting. Dasgupta and Maler (1995) define the real national product in an inter-temporal economy as the real net national product (NNP). In an intertemporal village economy, the net village product (NVP) can be defined as follows:

NVP = Consumption
+ net investment in physical capital
+ value of net change in human capital
+ value of the net change in the stock of natural capital
- value of current environmental damages

The purposes of green national accounting have been to measure welfare equivalent income, sustainable income, and the desirability of policy changes. It can be used to quantify and value environmental externalities.

Static Computable General Equilibrium (CGE) models

Consumers and producers in CGE models have usually been treated as separate agents, and the agricultural sector has usually been represented as a pure profit-maximizing sector. The assumptions of the past CGE models that markets function well and agricultural production decisions can be represented by profit-maximizing behavior of pure producers, can be challenged, as the underlying assumptions are far from reality in typical rural economies in developing countries. The knowledge of market imperfections, transaction costs and their implication on farm household behavior should be incorporated with that of general equilibrium effects within the rural sector to construct consistent micro-economy wide CGE models.

Village CGE models

Village CGE models, on the other hand, are only needed when there are significant local general equilibrium effects causing the existence of endogenous prices in the village while these prices are exogenous to households (Holden et *al.* 1998b). This implies that there is no trade with the external world for these commodities or factors. Internal transaction costs within the village may lead to internal, possibly household-specific price bands between purchase and selling prices for household tradables.

When such local markets exist, it is important to study carefully how they function.

Holden *et al.* (2002) have developed a village CGE model with market imperfections for a village economy with high agricultural potential and good market access in the Ethiopian highlands. The model incorporates complex crop livestock interactions and varying factor substitution elasticities in crop production. The environmental externality in the form of land degradation (primarily soil erosion) is included through its short - and long-term productivity effect. The model is used to assess the impact of adjustment policies (removal of fertilizer subsidies and price controls) on household welfare for different household groups and on the land degradation externality. In particular, the question whether a Pigouvian subsidy on fertilizer can be defended on an environmental ground, is thoroughly assessed through a sensitivity analysis with different subsidy levels and different input substitution elasticities.

Conclusions

Bio-economic models can be useful tools for NRM impact assessment as they are capable of integrating complex biophysical and socio-economic information in a consistent way. There is considerable flexibility in terms of types of bio-economic models to use, but the best choice in each case depends on several factors. What may be achieved is more likely to be constrained by data limitations rather than by model limitations. This paper briefly discusses alternative bio-economic models for analysis of NRM impact assessment in rural areas in developing countries. There are different ways of incorporating dynamic elements in such models. For some purposes and types of changes, static models may handle such issues in an adequate way. Such models may be simpler and easier to make. They can illustrate the incentive structure and the direction in which processes go, while dynamic models are better at illustrating and predicting the development pathway itself under alternative conditions.

Aggregation biases may occur due to the distribution of heterogeneous resources, imperfections in markets and complex interaction effects. Aggregation through identification of homogenous household groups is one way of reducing the aggregation bias and link poverty/welfare more systematically to land use when markets do not work well. Market imperfections and exogenous shocks make it relevant to use stochastic recursive bio-economic household group models. Stochastic weather also creates price fluctuations. Economy-wide models may be used to predict such price impacts, while bio-economic household models better capture the land use and household welfare effects of such exogenous shocks that affect both land productivity and prices.

The choice of model will depend on the time and other resources available, and the purpose for which the modelling is done, as well as the basic characteristics of the bio-economy to be modelled. The severity and pervasiveness of market imperfections in rural economies points in the direction of incorporating non-separable household models in village economy-wide models to tackle some of the most important aggregation problems.

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Session 4

Selected Case Studies of NRM Impact Assessment

Evaluating watershed project performance in India: integration of econometric and qualitative approaches

John M. Kerr[1]

Introduction

Watershed management is seen as a way to increase rainfed agricultural production, conserve natural resources, and reduce poverty in the world's semi-arid tropical regions. In these regions, watershed management projects aim to capture water during rainy periods for subsequent use in dry periods (Farrington et *al.* 1999).

Watershed projects are often complicated by the fact that multiple people use the upper and lower reaches for multiple purposes. This poses a particular challenge when alternative resource use patterns become mutually incompatible, and any intervention will impair at least one potential user.

Given the uneven distribution of benefits, successful watershed development requires either (a) developing institutional mechanisms to ensure that all parties benefit, or (b) forcing users of upstream areas to restrict resource use, and provide environmental service without compensation.

This paper examines the experience of watershed projects in India, in managing potential trade-offs between improved natural resource management and the distribution of net benefits between land holders in the lower reaches and landless people, particularly landless women, who rely on common lands in the upper reaches. The study, therefore, addresses three related questions.

- Which projects performed the best?
- What approaches enabled them to succeed?
- What additional characteristics of particular villages contributed to achieving the objectives of improved natural resource management, higher agricultural productivity, and reduced poverty?

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Watershed projects and research issues

Watershed projects in India spread widely during the late 1980s and 1990s, in an effort to develop the semi-arid areas that the green revolution had bypassed (Government of India 1990; Government of India 1994; World Bank 1990). By the late 1990s, watershed development became a focal point for rural development in the country, with an annual budget of over $450 million from all resources (Farrington *et al.* 1999). A wide variety of donors and development agencies promote watershed development, including the central government, several state governments, the World Bank, several bilateral assistance programs, and assorted non-government organizations (NGOs).

Two main hypotheses guided this research. First, watershed projects cannot succeed without the full participation of project beneficiaries and careful attention to social organization. This is because the costs and benefits of watershed interventions are location-specific and unevenly distributed among the people affected. Second, economic conditions and access to infrastructure may have as great an impact as a watershed project in determining the outcomes that projects seek to achieve, as such factors determine the incentives for people to manage and protect natural resources and invest in increased agricultural productivity.

Methods

This study mainly uses quantitative analysis, but it also draws on qualitative information to better understand the relevant research questions, and to identify the projects' unintended consequences and the mechanisms through which they operate. The subsequent qualitative investigation thus helps to interpret the findings of the statistical analysis, and to rule out competing explanations for observed differences across projects. This is particularly important given the limitations in the data.

Econometric approach

The critical problem in quantitative evaluation is endogeneity, which arises if some factors affect the project placement and the outcome simultaneously. In such a case, it would be difficult to determine whether outcomes were driven by project activities or by pre-existing conditions.

This problem can be controlled through a statistical technique known as instrumental variables. The two-stage model is used for estimating treatment effects or sample selection bias (Greene and Caracelli 1997). The advantage of this approach is that impact evaluations may be conducted *ex post,* as long as appropriate data exist for the non-participating sites. Its disadvantages are (a) the estimated effect is highly dependent on the validity of the chosen instruments, and (b) appropriate instruments are often difficult to find. The following instrumental variables model represents the analytical framework:

$$W = a + bV + cZ + e_1, \tag{1}$$

$$Y = f + gC + hV + e_2, \tag{2}$$

Where W is a categorical variable indicating one of five project categories; C is the predicted probability that the village falls in each project category; Y represents a set of performance indicators (project outcomes); V is a set of village-level explanatory variables affecting both Y and W; Z is a set of variables that affect W but not Y; and e_1 and e_2 are error terms. The parameters to be estimated are represented by *a, b, c, f, g* and *h.* The instrumental variables approach corrects for endogeneity of *W,* which results from biases in the way that each project selects villages in which to work.

Equation (1) is a multinomial logit model, since W is a categorical variable. Equation (2) takes different forms depending on the nature of the performance indicator in question. These variables may be continuous, binary, or ordinal. In most of the models, equation (2) is an ordinal logit model, in some it is a binary probit, and in others it is a tobit or an ordinary least squares regression. In all of these cases, the models are adjusted for the use of complex survey data with stratification, sampling weights, and clustering (Stata Corporation 1999).

The study also made use of 'with/without' design, which is one of the 'quasi-experimental' approaches that have been modeled after the scientific tradition of experimental design. This approach is useful when no baseline data are available. This is often the case when an evaluation is commissioned after a project has been implemented - a typical situation in the real world.

Qualitative approaches

Qualitative approaches, conversely, took the form of detailed, open-ended discussions, mostly at the group-level, with people from different interest groups. The findings from this work helped identify some of the questions posed in the quantitative analysis, and they also helped interpret the findings. This study was primarily quantitative, hence the qualitative data aimed to augment the quantitative investigation in two ways. First, it focused on learning people's key concerns and understanding how projects affected them. Second, it sought to identify alternative indicators of some of the performance measures collected in the quantitative data.

Focus of the analysis

The analysis focuses on several indicators of watershed development performances, covering productivity, conservation and poverty alleviation considerations:

- Imposition of restrictions on access to common lands in the upper catchment, and changes in availability of products such as fodder from them.
- The extent of soil erosion on uncultivated land in the upper catchment, including the main drainage line.
- Changes in irrigation resulting from water harvesting.
- Villagers' perceptions of project benefits.
- Distribution of project benefits and costs, particularly to landless people and women.

In a few cases, data limitations prevented the *quantitative* analysis from yielding any useful information, so *qualitative* analysis became the sole source of insight from the fieldwork. However, time constraints limited the scope of the qualitative investigation to less than ideal.

Data

A total of 86 villages - 70 villages in Maharashtra and 16 villages in Andhra Pradesh - were sampled from a frame of over a thousand villages in the two states. Maharashtra projects tend to focus mainly on water harvesting, whereas the Andhra Pradesh projects often focus more on increasing the productivity of rainfed agriculture.

The quantitative component was conducted as a 'with and without' design, covering five project categories that included all the major project agencies, Ministry of Agriculture, Ministry of Rural Development, NGOs, NGO-government collaboration, and a control group of non-project villages at the time the data were collected, in 1997-98. Data were collected using a combination of structured household and village-level surveys, as well as loosely structured group interviews of people from specific-interest groups, such as farmers with and without access to irrigation and landless people. The quantitative analysis covered all the sampled villages, while the qualitative analysis focused on a randomly selected sub-sample of 29 of those villages.[2]

Findings

Econometric analysis of the determinants of project placement

A multinomial logit model is used to examine, in more detail, the determinants of which project category a particular village falls into. The dependent variable is the categorical project variable covering the five categories found in Maharashtra: National Watershed Development Program for Rainfed Areas (NWDPRA, referred to in Table 1 as Ministry of Agriculture), Jal Sandharan (referred to as the Ministry of Rural Development), NGOs, and Adarsh Gaon Yojana (AGY)/Indo-German Watershed Development Program (IGWDP) (combined into one category and referred to as NGO/government collaboration), and non-project villages.

The results show that all projects have a greater range in altitude between the highest and lowest point in the village, compared with non-project villages, and this difference is significant for all except the NGO/government collaborative projects. The AGY and IGWDP villages were significantly more likely to practice *shramdan* (voluntary community work) in 1987, while NWDPRA villages were significantly less likely to practice *shramdan* compared with the non-project villages. NWDPRA, Jal Sandharan, and NGO villages had more communal diversity, and scheduled

2. Watersheds fall within village boundaries in all project categories except the Ministry of Agriculture, in which a watershed covers multiple villages.

Table 1. Determinants of project category in Maharashtra. Multinomial logit regressions (standard errors in parentheses)[1].

Variable	Ministry of Agriculture	Ministry of Rural Development	NGO	NGO/government collaboration
	Project category			
Distance to nearest bus stop in 1987 (km)	0.83 (0.34)**	-0.16 (0.27)	0.16 (0.32)	-0.34 (0.29)
Paved road in 1987 (dummy)	0.29 (1.27)	-1.58 (1.63)	0.41 (1.11)	-2.49 (1.53)
Whether the village contained government revenue land, 1987	-0.32 (1.16)	-2.10 (1.22)*	-4.96 (1.17)***	-1.16 (0.88)
Number of communal groups in the village	1.18 (0.25)***	0.76 (0.29)**	0.85 (0.30)***	0.13 (0.35)
Altitude range ('00 meters)	3.34 (1.02)***	1.93 (1.00)*	2.44 (1.06)**	2.16 (1.34)
Distance to taluka headquarters (km)	0.21 (0.05)***	0.01 (0.05)	0.35 (0.43)	-0.03 (0.04)
Population density in 1990 ('00 persons/sq km)	3.71 (0.82)***	0.88 (1.76)	-1.81 (-1.43)	-0.59 (0.88)
Percentage area irrigated in 1987	2.90 (3.28)	-2.39 (5.76)	8.29 (3.55)**	1.94 (4.52)
Whether the village had sufficient drinking water in 1987 (dummy)	3.31 (1.38)**	-1.35 (1.27)	0.26 (1.54)	0.93 (1.49)
Distance to nearest public health center, 1987 (km)	-0.38 (0.15)**	0.17 (0.15)	0.18 (0.15)	0.33 (0.14)**
Distance to market for agricultural inputs in 1987 (km)	-0.15 (0.11)	0.23 (0.15)	0.34 (0.16)**	0.10 (0.13)
Village practised community voluntary labor in 1987 (dummy)	-2.01 (1.10)*	-1.31 (1.51)	1.57 (1.57)	8.42 (2.35)***
Area of the village ('00 ha)	0.17 (0.13)	1.29 (1.34)	0.09 (0.13)	0.30 (0.13)**
Approximate % of households with at least one seasonal migrant, 1987	-0.10 (0.03)***	-0.06 (0.04)	-0.10 (0.06)	0.09 (0.03)***
Percentage of inhabitants of SC, ST, BC	0.047 (0.025)*	0.08 (0.03)***	0.12 (0.03)***	-0.03 (0.06)

1. Reference category is no project; variables reflect values in the pre-project period. 70 observations. Model is not corrected for choice-based sampling, i.e., that the sample is stratified on the dependent variable. Coefficients and standard errors are adjusted to account for sampling weights, stratification and finite population size.

*, **, and *** indicate statistical significance at the 10%, 5% and 1% level, respectively. $F(46,15) = 41.3$.

castes and tribes. NGO and Jal Sandharan villages were significantly less likely to contain government revenue land, possibly suggesting that these projects sought to reduce the potential for tradeoffs between poverty alleviation and other objectives.

NWDPRA villages were likely to have significantly fewer seasonal migrant workers, while AGY and IGWDP villages were likely to have significantly more. A higher number of migrant workers can be an indication of poor economic conditions locally. AGY and IGWDP villages are also significantly larger in area than the NWDPRA villages.

NWDPRA villages were significantly likely to be more densely populated. NGO villages, on the other hand, were significantly likely to be located further from markets and *tuluka* headquarters, while AGY and IGWDP villages were significantly further from the nearest public health office.

These findings are consistent with the NWDPRA's efforts to operate in more visible, better-connected areas and the NGOs' efforts to work in more remote areas and where people had demonstrated the ability to work collectively.

Conservation and productivity outcomes

Table 2 shows the explanatory variables used in the econometric analysis of conservation and productivity outcomes.

Table 2. Explanatory variables in the regressions.

Variable	Description/Explanation
Altitude range (m)[1]	Determines susceptibility to erosion; more hilly indicates greater risk of erosion. Positively correlated to rainfall; potentially more grass growth.
Number of communal groups in village	Makes collective action more difficult because of distrust between communities.
Percentage of shepherds in village	Shepherds are expected to oppose restricting access to upper catchments.
Whether village contains common land	Common land is difficult to manage, so drainage line is expected to be eroded in villages with common land.

Continued

Table 2. *Continued.*

Variable	Description/Explanation
Whether land is operated privately	Private land is expected to be better managed and less eroded.
Distance to nearest bus stop	Another indicator of accessibility to markets and services.
Distance to market town	Another indicator of accessibility to markets and services.
Population density	Higher density can increase pressure on resources but also raise incentive to manage resources productively.
Percentage of people who earn income off-farm	Affects dependence on natural resources. May provide cash to support investment in resource management, or may cause reduced incentive to care about natural resource conditions.
Project category interacted with expenditure/ha	Captures different project approaches as well as extent of project effort.
Availability of grass fodder from common lands in 1987	Affects the likely direction of change in availability of grass fodder between 1987 and 1997.

1. Altitude range is highly correlated to rainfall (r >0.6), so rainfall, which also affects the risk of erosion, is omitted from the model.

Restriction on access to common lands

Examination of where projects operate suggests that some projects aimed to avoid the problem of managing common lands completely, by working in villages that had none. The most common institutions for restricting access are bans on grazing and cutting trees. Only five out of 40 villages with common lands (12.5%) had banned grazing before the projects, rising to 35% afterwards.

Two findings are particularly interesting. First, even some of the non-project villages imposed grazing bans, showing that this action does not necessarily require a watershed project. Second, while none of the NGO-Government villages had imposed bans or penalties in 1987, 50% of them had done so by 1997 compared with no more than 25% for other project categories. Only in the NGO-Government category did a significantly higher percentage of villages impose access restrictions under the non-project categories.

Erosion of uncultivated lands in the upper watershed

Erosion was analyzed as a function of various hypothesized determinants such as agroclimatic conditions, population and market pressure, and project interventions. Analysis of both conditions of the main drainage line and of uncultivated lands in the upper catchment, shown in Table 3, suggests that all the projects contributed to improved condition of the drainage line relative to the case of no project expenditure. In both cases, the NGO-Government collaborative projects appeared to have the greatest impact on reducing erosion, followed closely by the NGO projects.

Changes in irrigated area

Owing to the lack of reliable quantitative data, the analysis relied on farmers' perceptions of whether water-harvesting measures raised the water table. Qualitative discussions revealed that respondents were keenly aware that water-harvesting structures in the drainage line could raise the ground water level, thus promoting irrigation development. In Maharashtra, among farmers with access to irrigation, reported benefits from water harvesting were highest in the NGO-GO projects, and only NWDPRA had low reported benefits among irrigating farmers. In Andhra Pradesh, on the other hand, perceived irrigation benefits were very low for all projects. This is consistent with project objectives in the two States.

Poverty alleviation outcomes

Population growth and privatization caused an overall decrease in availability of products from the commons over the years. Multivariate econometric analysis of the 40 villages containing common land suggests that, controlling for other factors such as population density and reduced area, projects have led to reduced access to grass fodder from common lands compared with non-project villages (Table 3). This is because short-term access restrictions reduce access to the products of the commons. Qualitative investigations provide additional insight into the finding of reduced availability of fodder from the common lands.

Table 3. Regression results for various performance indicators (standard errors in parentheses).[1]

Variable	Coefficients		
Dependent variable	Drainage line condition[2]	Erosion on uncultivated lands[3]	Availability of grass fodder[4]
Availability of grass fodder in 1987	n.a.	n.a.	2.09(0.61)***
Whether the village contains common land (dummy)	0.42(0.11)***	n.a	n.a.
Altitude range ('000 m)	-5.85(7.88)	0.33(1.40)	3.71 (0.96)***
Distance to nearest bus stop in 1987 (km)	0.04(0.04)	-0.02(0.05)	0.53(0.19)***
Paved road in 1987 (dummy)	0.17(0.12)	0.31 (0.33)	0.92(0.66)
Population density in 1990 ('00 persons/sq km)	0.07(0.14)	-0.66(0.21)***	-1.06(0.51)**
Distance to taluka headquarters ('0 km)	-0.06(0.06)	0.04(0.09)	0.33(0.33)
Percentage of inhabitants working primarily in non-agricultural sector	-0.01(0.01)	0.008(0.017)	0.10(0.04)**
Percentage of inhabitants working primarily as shepherds	-0.06(0.04)*	0.04(0.05)	0.62(0.17)***
Whether land is operated privately (dummy)	n.a.	-0.57(0.36)*	n.a.
Mean expenditure per ha in MOA village ('000 Rs)	0.10(0.05)**	-0.20(0.14)	0.06(0.60)
Mean expenditure per ha in JS village ('000 Rs)	0.07(0.04)	-0.20(0.07)***	-0.89(0.31)***
Mean expenditure per ha in NGO village ('000 Rs)	0.17(0.06)***	-0.35(0.17)**	1.35(2.29)
Mean expenditure per ha in NGO-GO village ('000 Rs)	0.27(0.05)***	-0.45(0.13)***	-2.04(0.38)***

1. Coefficients and standard errors are adjusted to account for sampling weights, stratification and finite population size. ***, **, and * indicate statistical significance at the 10%, 5% and 1% level, respectively. Predicted values based on the multinomial logit regression in Kerr *et al.* 2002, Table 13, are used for the project category variables. Standard errors are not adjusted for use of predicted values in complex, two-stage regressions.
2. Tobit regression; possible transect scores range from 1 to 3. 64 observations (6 villages have no main drainage line). $F(12,43) = 6.20$ ($p>.0000$); $R^2 = 0.38$.
3. Ordered probit regression; possible transect scores range from 1 to 3. 174 observations from 64 villages (6 villages have no uncultivated land.) $F(13,42) = 3.45$, $p>0.002$.
4. Ordered probit regression; possible scores range from 1 to 3, where 1 = less, 2 = same, 3 = more. 40 observations (30 villages have no common land). $F(13,19) = 6.88$, $p > 0.01$.

Project impact on herders

A survey of 120 respondents in 10 study villages found that respondents' perception that they had benefited from projects rose with land holding size; this pattern was statistically significant. In addition, landless people were much more likely to indicate that projects had harmed their interests; among landless people, the unanimous complaint was lost access to common lands. NGO-Government projects had the best overall performance in terms of the conservation and productivity indicators examined in the study, but in these projects, perception of benefits rises significantly with land holding size, and perception of harm falls with land holding size.

Project impacts on women

Unstructured interviews with women in the study villages suggested that restricting access to common lands had reduced their access to fuelwood, consequently they were more likely than earlier to use alternative fuel sources, purchasing them from the market, or even stealing them from land belonging to other villagers. They also indicated that closing the commons had caused them to lose access to a variety of sources of income that they had themselves controlled, independent of men.

None of the projects made any special efforts to replace women's lost sources of income from reduced access to commons, although some of them tried to train women in other activities, such as the use of improved stoves for cooking, tailoring, or growing plants and trees that could be used in the watershed program. Watershed development can also have a negative impact on women from wealthy households owning irrigated lands, because increased crop production from expanded irrigation may require women to contribute more agricultural labor.

Conclusions

The analysis used in this study compares conditions in the study villages before and after the projects were implemented. Quantitative analysis at the village level examines performance indicators such as change in access to irrigation water, soil erosion and conservation on uncultivated lands. The analysis is mainly econometric, augmented by qualitative discussions aimed at understanding villagers' perceptions of project activities and impacts. An instrumental variables econometric approach is used to correct for endogenous program placement. This analysis is supplemented by qualitative information about the effects of the projects on different interest groups in the villages such as farmers with and without irrigation, landless people, shepherds, and women.

In both Maharashtra and Andhra Pradesh, the participatory projects performed better than their technocratic, top-down counterparts. However, participation combined with sound technical input performed best of all. For example, while all projects reduce soil erosion on uncultivated lands reasonably well, the NGO and NGO/government collaborative projects had particularly good records in this regard, probably because they effectively introduced social institutions to limit exploitation of uncultivated lands.

The evidence presented also suggests that the projects do face potential poverty alleviation trade-offs in the effort to increase agricultural productivity and conserve natural resources through watershed development. In particular, the projects most successful in achieving conservation and productivity benefits also had the strongest evidence of skewed distribution of benefits toward larger landholders. Indirect benefits for the poor, through increased agricultural employment or peripheral activities such as micro-finance, need to be assessed more thoroughly. In any case, short-term costs imposed on 'losers' may be substantial, and projects would gain from a greater focus on mechanisms to share project benefits.

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Assessing the impact of participatory watershed development: a sustainable rural livelihoods approach

V. Ratna Reddy[1] and John Soussan[2]

Introduction

Watershed development is a suitable approach for technological change in the dry and drought-prone regions, while the sustainable livelihoods approach is more comprehensive in the context of poverty alleviation/ eradication. The new watershed guidelines in India provide a comprehensive framework for a people-centered approach, bringing the watershed development concept closer to the sustainable rural livelihoods (SRL) approach, and hence making integration of both the approaches possible (Turton 2000; Baumann 2000). Several watershed-based programs have been promoted following the new guidelines developed and adopted by the Ministry of Rural Development, Government of India.

Watersheds have been studied from various perspectives (Dixon 1992) such as economic impact of investments in runoff control, soil conservation, and groundwater recharge. However, watershed development/management is more than just the cost-benefit analysis of investments. The main distinction between watershed development and other traditional developmental programs is that the former is essentially a community-based one. Given the nature of the technology, watershed development and its success critically hinges upon inter- and intra-village cooperation. In other words, collective participation and action is a critical ingredient for watershed management. This throws up a wide range of issues such as social organization, institutional development, benefit distribution, stability and sustenance of benefits, etc., that need a careful scrutiny in order to assess the impact of the program.

This paper is, therefore, an attempt to assess the impact of watershed development programs under the new guidelines, in the context of a wider

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SRL framework. This framework allows us to examine and assess the impact from many angles, compared with the earlier approaches of assessing costs (such as expenditure per unit) and benefits (income to landed and employment to landless households) in a narrow sense. The idea here is to assess the impact of watershed development on the livelihoods of the poor and less-poor communities through different types of capital assets.

Livelihood framework

The SRL model looks at the basic dynamics of livelihoods, which are complex, given the array of factors that influence livelihood choices. Within this complexity, however, there is a simple core set of contentions and relationships. People draw on a set of capital assets as a basis for their livelihoods. Carney et *al.* (1999) identified five types of livelihood capital assets:

- Human capital (skills, knowledge, health).
- Natural capital (land, water, common property resources).
- Financial capital (income, savings, credit).
- Physical capital (infrastructure, physical assets).
- Social capital (networks, group membership, migration).

The capital asset entitlements available to individual households reflect their ability to gain access to production systems (resource base, financial system, society) through which these capitals are produced.

A set of decisions on what assets to utilize when, constitutes the ***livelihood strategy,*** while the choices made within the strategy will, in turn, define the ***livelihood activities*** of the household, such as which activities are undertaken by whom and when. Allocation of income to savings/investments, inputs, repaying loans or social payments (such as taxes) and consumption constitute the ***income strategy.***

This model allows one to 'map' the consequences of specific changes, including changes brought about through external interventions intended to improve people's lives. Initiatives such as watershed development or joint forest management in India typify this approach. The points of intervention and impact of such programs can be 'mapped' on the livelihoods model that is at the core of this paper.

Data and methodology

For the purpose of assessing the impact of watershed development programs implemented under the new Government of India guidelines on rural livelihoods, four watersheds in three districts of Anantapur, Kurnool and Mahbubnagar in Andhra Pradesh were selected. The selected villages are Mallapuram (Anantapur), S Rangapuram (Kurnool), Tipraspalle and Mamidimada from Mahbubnagar (Table 1).

Both qualitative and quantitative information were elicited. Participatory Rural Appraisal (PRA) exercises such as group discussions, social mapping, resource mapping, wealth ranking, transect walks, and discussions with Watershed Association leaders were carried out. On the whole, detailed information was collected from 160 households, of which a total of 120 beneficiary households comprised 30 households from each watershed, and a total of 40 non-beneficiary households comprised another sample of 10 households from each watershed. All the sample watersheds belonged to the first batch watershed development programs after the new guidelines have been issued. Watershed works were initiated during 1995—96 and completed by May-June 1999-2000. Fieldwork was initiated during February 2001 and completed by July 2001.

Table 1. Location of the sample watersheds in Andhra Pradesh.

Name of the watershed village	District	Rainfall (mm/yr)	Major soils	Major crops	Year of starting	Year of completion
Mallapuram	Anantapur	513	Red	Groundnut, sorghum, and paddy	1995-96	2000
Sothram Rangapuram	Kurnool	665	Red and loamy	Groundnut and sorghum	1995-96	2000
Tipraspalle	Mahbubnagar	754	Black and mixed	Sorghum, groundnut, paddy and castor	1995-96	1999
Mamidimada	Mahbubnagar	749	Mixed (*chalka/ dubha*)	Sorghum, paddy, groundnut and castor	1995-96	1999

Methods

The five livelihood capital assets framework of SRL has been adopted to assess the impact of watershed development interventions on rural livelihoods. Rural livelihoods are closely linked to the enhancement of these livelihood capital assets. Improvement in all these capitals could be termed as **'strong SRL'** and is a function of changes in financial, physical, natural, social and human capitals. Improvement in some of the capitals without any decline in other capitals could be termed as **'weak SRL'.** In this case, improvements in each of these capitals are in turn dependent on various indicators. Financial capital is dependent on income, employment and savings; physical capital is dependent on assets, watershed structures and infrastructures; natural capital is dependent on water, land and common pool resources (CPRs); social capital is dependent on migration, collective action, institutional strength, equity and gender; human capital is dependent on health, education and skills. Hence, in the present context, financial capital is measured in terms of income from various livelihood activities. Physical capital is measured in terms of a household's possession of durable assets such as house, machinery, livestock, etc. Natural capital is measured in terms of improvements in land, water and other CPRs. Human capital is measured through changes in education and medical expenditure.

Measurement of variables and limitations

The major problem in measuring the selected SRL indicators is that some of them are measured at the household level, and some at the village or community group level. Synthesizing these levels in a coherent manner is difficult, though SRL framework is capable of integrating local and global aspects. Similarly, integrating quantitative and qualitative aspect is also difficult, as quantification is not possible in all the cases. Measurement of change in some of the variables such as collective actions and gender is difficult as is attributing the changes to a particular program like the watershed development program. For the purpose of assessing the impact of this program on rural livelihoods, we have adopted the 'double difference' method to analyze the information before and after the program was adopted for both beneficiary and non-beneficiary groups of households.

Results

Some of the important indicators are converted into monetary terms and the improvements are presented in Radar Diagrams (Figures 1 and 2). These indicators include benefits from improvements in the availability of fodder, fuelwood and groundwater (natural capital), improvements in household assets (physical capital), total household income (financial capital), changes in the expenditure on health and education (human capital) and changes in income from migratory labor (social capital). Indicators are measured as after and before values of monetized impacts. It may be noted that social impact, which is measured in terms of changes in migration income, indicates a negative effect when migration income increases. The watershed projects are expected to slow down or reduce migration to towns and other areas. An increase in village income from this source indicates that the watershed project did not attain this social objective. The results are presented for two villages in order to capture the contrasting situations. The impact is pronounced in the case of financial and physical capital, while it is moderate in the case of human and natural capitals. Social impact, measured in terms of increase in migration income, is negative in all the villages, and more so in Mamidimada village, where the overall impact of watershed development programs has been quite poor. The increased out-migration is attributed mainly to the poor rainfall during the previous years. This study followed three less-than-average rainfall years, suggesting that the increased out-migration from some of the communities cannot be attributed directly to watershed projects.

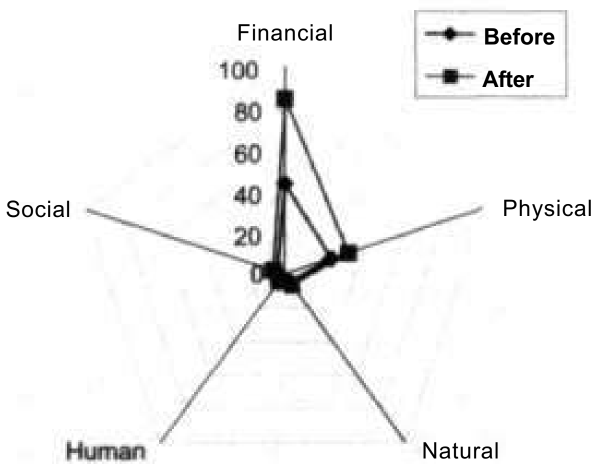

Figure 1. Impact of WSD in Mallapuram.

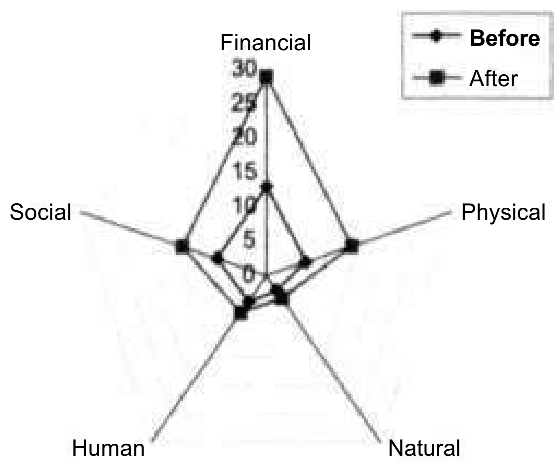

Figure 2. Impact of WSD in Mamidimada.

Impact assessment

Impact on livelihoods is measured in terms of changes in various indicators brought about by watershed development programs in the four villages studied. Enhanced livelihood security is assessed on the basis of the resilience contributions of various livelihood assets and the improvement thereof. For instance, improvements in land assets (even in value terms) provide high livelihood resilience to the household, as it enhances land productivity as well as the credit worthiness of the household. On the contrary, increases in migratory labor have low resilience, as they are dependent on external factors such as climate and crop situation in far off places. Often investments in assets like water-harvesting equipment are highly sensitive to geological factors, and could turn out to be risky (well failures are cited as one of the main reasons for farmer suicides in recent years). Improvements in such ecological indicators as groundwater, fodder and fuelwood contribute to better resilience than direct livelihood indicators such as water-harvesting assets, employment, income, etc. But increase in the number of wells could be unsustainable in the absence of replenishing mechanisms, and hence increase in the number of wells is termed as a low-resilience indicator. On the other hand, 'improvement in the depth of the water table' is a high-resilience indicator. Similarly, human and social capital indicators such as education, health, gender equity and economic equity contribute to better livelihood resilience.

Resilience levels are ranked as high, medium and low, and indicated against the impact indicators (Table 2). Here resilience is ranked in the context of the impact (positive). Scores are assigned to the indicators based on the changes associated with watershed development. Therefore, no change is represented as (0), positive change (1=low, 2=medium, and 3=high), and negative change (-1= low, -2=medium, and -3= high). Improvements in land assets (even in value terms) provide high livelihood resilience to the household, as it enhances the productivity as well as the credit worthiness of the household. On the contrary, increases in migratory labor have low resilience, as it is dependent on external factors.

Mallapuram watershed is relatively successful with respect to resilience rankings as it receives high score in a number of high-resilience indicators (Table 2). Moreover, it also receives a low score for the low-resilience indicators (i.e., number of wells and migration). It has better ranking in the case of ecological indicators (natural capital) compared with other

Table 2. Impact of watershed on livelihood security.

Impact	Measure	Resilience ranking of the indicator	Sample villages: Malla-puram	S. Ranga-puram	Tipras-palle	Mamidi-mada
Financial capital (livelihoods impact)	Assets					
	- Land	3	2	3	2	3
	- Others	2	2	3	2	2
	Employment	2	3	3	2	2
	Income					
	- Agricultural	2	3	-1 *	2	2
	- Total	2	3	2	2	2
	Consumption	2	2	3	3	2
	Stability	3	3	3	1	1
Natural capital (Ecological impact)	Drinking water	3	2	2	2	2
	Irrigation water					
	- No. of wells	1	1	2	3	2
	- Depth of water table	3	2	2	2	2
	- Area irrigated	2	1	3	3	3
	Fodder	3	3	1	1	2
	Fuelwood	3	2	1	1	2
Social capital	Migration	1	1	2	3	2
	Gender	3	3	1	2	2
	Equity	3	3	3	3	3
Human capital	Education	3	1	3	1	2
	Health	3	2	2	2	3

Note: No change = 0; Increase: 1 = low, 2 = medium, 3 = high; Decrease: -1 = low, -2 = medium, -3 - high

* Incremental net household income from agriculture is negative in S. Rangapuram.

watersheds. Overall, the performance of Tipraspalle and Mamidimada is not impressive from the standpoint of sustainable livelihood security, while S. Rangapuram performs better after Mallapuram. From the standpoint of economic viability and resource use sustainability, Mallapuram seems to perform better than the other watersheds.

Statistical significance

Paired 't' tests were carried out on all the important indicators. Most of the variables representing the five capitals were tested. These included crop yields, income, availability of fodder, fuelwood, irrigation level, education and medical expenditure, migration, livestock holdings, etc. Comparison was 'before' and 'after' within the project villages. As per the tests, improvements in area under irrigation were significant in S. Rangapuram, Tipraspalle and Mamidimada, while improvements in total household income and employment were statistically significant in all the villages. One of the natural capital indicators, availability of fodder, improved significantly only in Mallapuram. The human capital indicator (education) improved significantly for all watersheds, while the other indicator (health) improved significantly for S. Rangapuram and Mamidimada.

Further, Ordinary Least Squares (OLS) regression analysis was carried out to test whether changes in income could be explained by the watershed projects. Gross returns per acre and total income per household were regressed against independent variables such as inputs (land, irrigation, labor, fertilizer, etc.), along with indicators for beneficiary and non-beneficiary and poor and less-poor household groups. The analytical results from OLS regressions indicate that the gross returns per acre for the beneficiary farmers is not significantly different from that of non-beneficiary farmers. The impact of watershed development seems to be more in the case of poor households, which could be mainly due to employment benefits. Similarly, in the case of total income per household, the estimates indicate no significant impact of watershed development in the sample villages.

Conclusions

Assessing the impact of participatory watershed development using the sustainable rural livelihoods framework is a methodological challenge. It requires monitoring of changes in five different capital assets. Some of the important indicators of these capitals are not easily quantifiable and require a long time to be observed. Therefore, the assessment needs to be balanced between the qualitative and quantitative aspects, as well as long- and short-run aspects. Another complication is that some of the indicators are measured at the household level and some at the village or community or group level. Synthesizing these levels in a coherent manner is difficult, though SRL framework is capable of integrating local and global aspects. Measurement of change in some of the variables such as collective action and gender is difficult. Moreover, attributing the changes to a particular program like watershed development is difficult, as there could be other variables (programs) influencing these changes. For instance, changes in educational and health status could be due to programs other than watershed development. Similarly, improvements in water bodies, surface and ground, could be due to rainfall fluctuations rather than due to watershed. Collective action and gender aspects are more qualitative than quantitative.

However, these limitations can be taken care of to some extent through adoption of appropriate techniques of data generation and estimation procedure. In the absence of a baseline data, these problems can be minimized by using the 'double difference' method where 'before' and 'after' situations are examined for both control and participating groups. Further, instrumental variables methods can also be used to reduce the statistical bias (Ravallion 2001) This method was adopted with fairly satisfactory outcomes. This method can be more effectively used with appropriate sample size covering 'before' and 'after' as well as 'with' and 'without' scenarios. The small sample is the main limitation of the present study, which was mainly due to financial and time constraints.

The assessment of the four watersheds using the SRL framework indicates that the impact is not uniform even among the best (implementation-wise) watersheds. In most of the cases, watershed impact satisfies the criteria of only weak SRL, as the impact is negative in the case of social capital (migration). Though it is difficult to identify a single key factor, natural capital (ecological variables), in general, seems to be the driving force behind the performance. Improvements in ecological factors such as water, fodder, fuel, etc., not only provide such diversified livelihoods but also provide sustainability and stability of incomes.

In general, our analysis indicates improvements in some local conditions, e.g., ecological conditions such as water availability, fodder, fuelwood, etc., and economic conditions such as more employment opportunities in all the sample villages. The real issue in watershed development, however, is whether there has been any medium-to-long term (sustainable) benefit once the soil and water conservation measures are in place. The medium-term benefits - the actual target of the policy - are far less clear, as the sustainability and stability of the impact is not established in the majority of the sample watersheds. Technically, the key to success is ensuring the appropriateness of the technical interventions to the hydrological regime. Socially, the key to success is ensuring proactive community participation and collective action.

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Assessing IWMI's research impacts: a framework for action

Meredith A. Giordano[1]

Introduction

Through its research on land and water management, the International Water Management Institute (IWMI), strives to have a 'positive impact on the activities and perspectives of policy makers, water managers and poor rural communities in developing countries' (IWMI 2001). While IWMI prides itself on the quality of its research and the influence this research has had on resource use policies and practices, the Institute lacks a formal system to track and measure its impacts.

Establishing an effective impact assessment program requires clear procedures for identifying, monitoring, evaluating and communicating impacts of individual projects and programs. It is equally important for an institution to have at its core, a clear conceptual structure that describes how the desired impact will be achieved. This conceptual base is especially important for an organization such as IWMI, where impacts are designed to occur over wide geographic and temporal scales, and are therefore inherently difficult to quantify.

This paper lays out a framework for establishing an impact assessment program at IWMI. The framework addresses both the conceptual and practical considerations for measuring and tracking impacts of NRM research, and can serve as a road map for IWMI to better assess its contributions towards improved water and land management in developing countries. The paper begins with a brief discussion of impact assessment at IWMI, and highlights some of the important issues shared both by IWMI and other organizations in measuring and evaluating the impacts of resource-related research. The second section describes a logical thought process for considering the nature and scale of desired IWMI impacts and pathways for impact achievement, and outlines a methodology for practical impact assessment. The final section provides some directions for firmly establishing a systematic impact assessment program at IWMI.

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Impact assessment at IWMI

Despite the increasing interest to further enhance the quality of research and the role that research plays in improving water and land management in the developing world, IWMI lacks a formal, organization-wide system for assessing the actual impact of its research. Both the 2000 External Programme and Management Review and IWMI's 2000-2005 Strategic Plan highlighted a need for such a system, not only to improve IWMI's internal management and priority-setting processes, but also to ensure that research activities meet the needs of IWMI's stakeholders and partners. Further, it is clear that without the means to measure the significance of research results, the true value of some of the research projects could go unrecognized, and the mistakes of other projects might be repeated.

IWMI has placed strong emphasis on transforming output into impact. Through standardized logical frameworks and project proposal templates, project leaders are now required to specifically identify, at the outset of a project, anticipated impacts, beneficiaries and knowledge dissemination pathways. Similarly, at the end of a project, there is now greater focus on drawing linkages between project outputs and project impacts as well as on documenting these impacts. While these steps have helped encourage project leaders to consciously consider the ultimate effects of their work, there remains considerable concern over the ability to practically link resource-related research to broad societal outcomes. Further, project leaders have raised questions about the selection of appropriate indicators and methods of measuring and attributing impact as well as the resource requirements and internal incentives for monitoring and evaluating project impacts. To address these concerns, a conceptual framework has been established for developing and implementing an impact assessment program at IWMI.

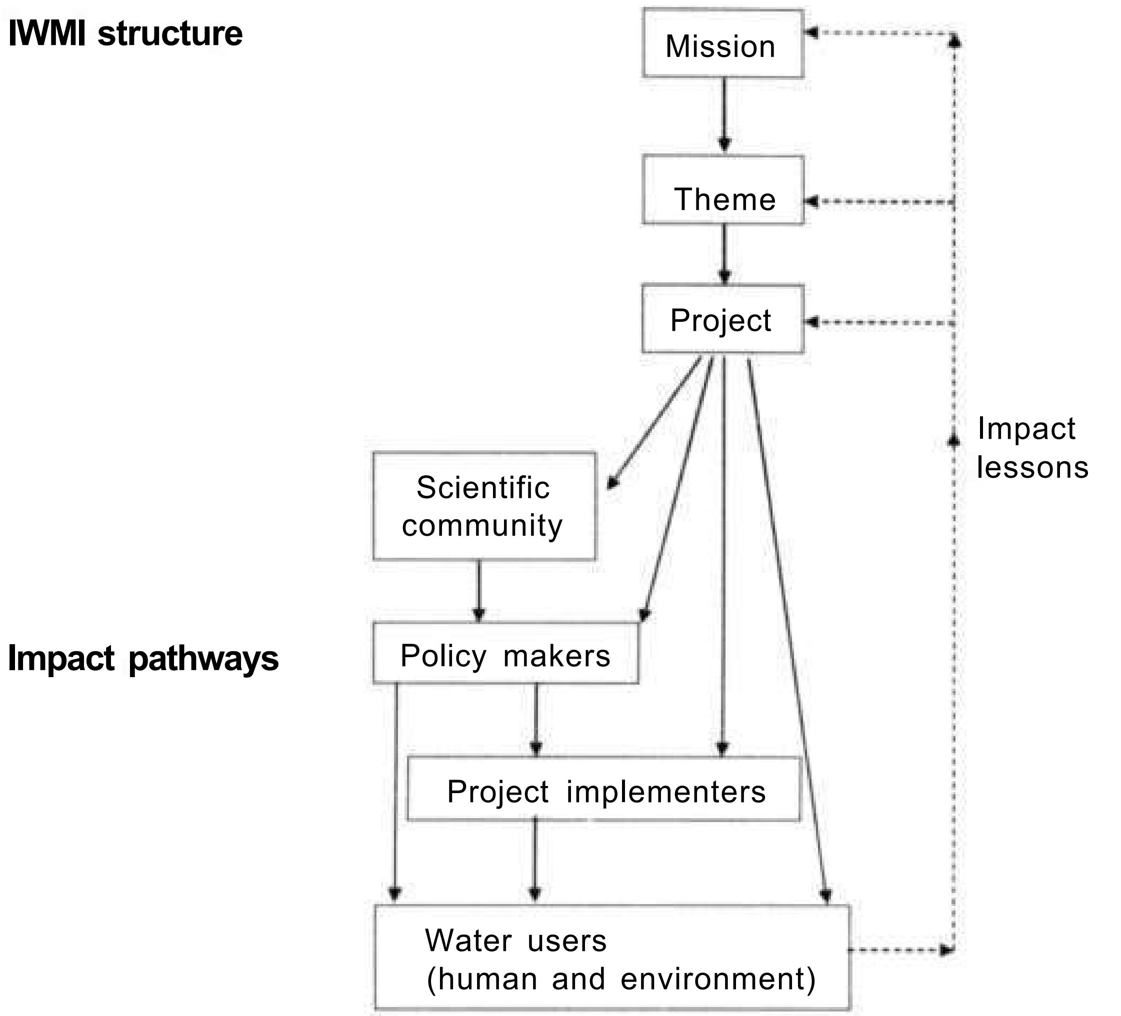
A framework for institutionalizing impact assessments

The first step in establishing an effective impact assessment program is the clarification of research goals and the means through which the institution hopes to achieve those goals. To better understand the IWMI mission, how individual projects are expected to contribute to that mission, and therefore how the contributions of those projects might be measured, we could begin by asking ourselves some fundamental questions.

On which pathways will we travel to generate impact? Impact assessment at IWMI requires a clear understanding of organizational goals. IWMI's mission, simply stated, is 'to improve the management of water and land resources for food, livelihoods and nature.' To accomplish this goal, IWMI has created interrelated themes around which to organize research. Individual projects are implemented within these themes. Given the broad nature of IWMI's overall mission and the range of external factors involved, it is relatively difficult to measure the overall impact of IWMI on the global water and land resource environment. However, the goals and objectives of individual projects can be clearly defined in terms of their linkages to broader research themes and the measurable contributions they can be expected to generate.

To accomplish its mission, IWMI works through its projects and partnerships to increase knowledge and to influence the behavior of a variety of agents including the scientific community, government policy makers, project implementers, and individual farmers (Figure 1). These agents are then expected to further change knowledge levels and behavior of actors at other levels. In order to properly assess the impact of IWMI's work, projects should be designed from the outset, with a clear understanding of the direct and indirect pathways through which intended results will reach outside agents and eventually impact the resource environment. With this understanding, practical and conceptual indicators for assessing impact can be built into the project design.

At what scales are direct and indirect project impacts expected? In the broadest sense, IWMI hopes all of its projects will have a lasting, global impact on water and land management. However, it is unrealistic to expect that such impacts can be easily measured or attributed. Nonetheless, individual projects can and should be designed with their expected, measurable impacts at relatively narrow scales clearly articulated. The projects should also consider how the impact at one scale (e.g., basin level) will impact other scales (e.g., local and global) and enhance IWMI's overall mission (Figure 2). Some of the scales that should be considered include geographic (global, basin, farm), temporal (seasonal, annual, decadal), social (individual, household, community, nation), and sectoral (agriculture, health, energy, industry, environment). While 'scaling up' is now a popular concept, projects at broader scales should also consider their potential impact in 'scaling down' (e.g., understanding the potential for



To fulfill its mission, IWMI is organized along research themes, each of which implements specific projects. Projects are designed to impact water and land use decisions either directly or through a series of impact pathways. The impact of a project at the point it enters the pathway will tend to be relatively easy to measure. The impact of the project as the results move through the pathway chain will tend to be more difficult to measure but are nonetheless critical in project design considerations.

Figure 1. Conceptual pathways to IWMI impact.

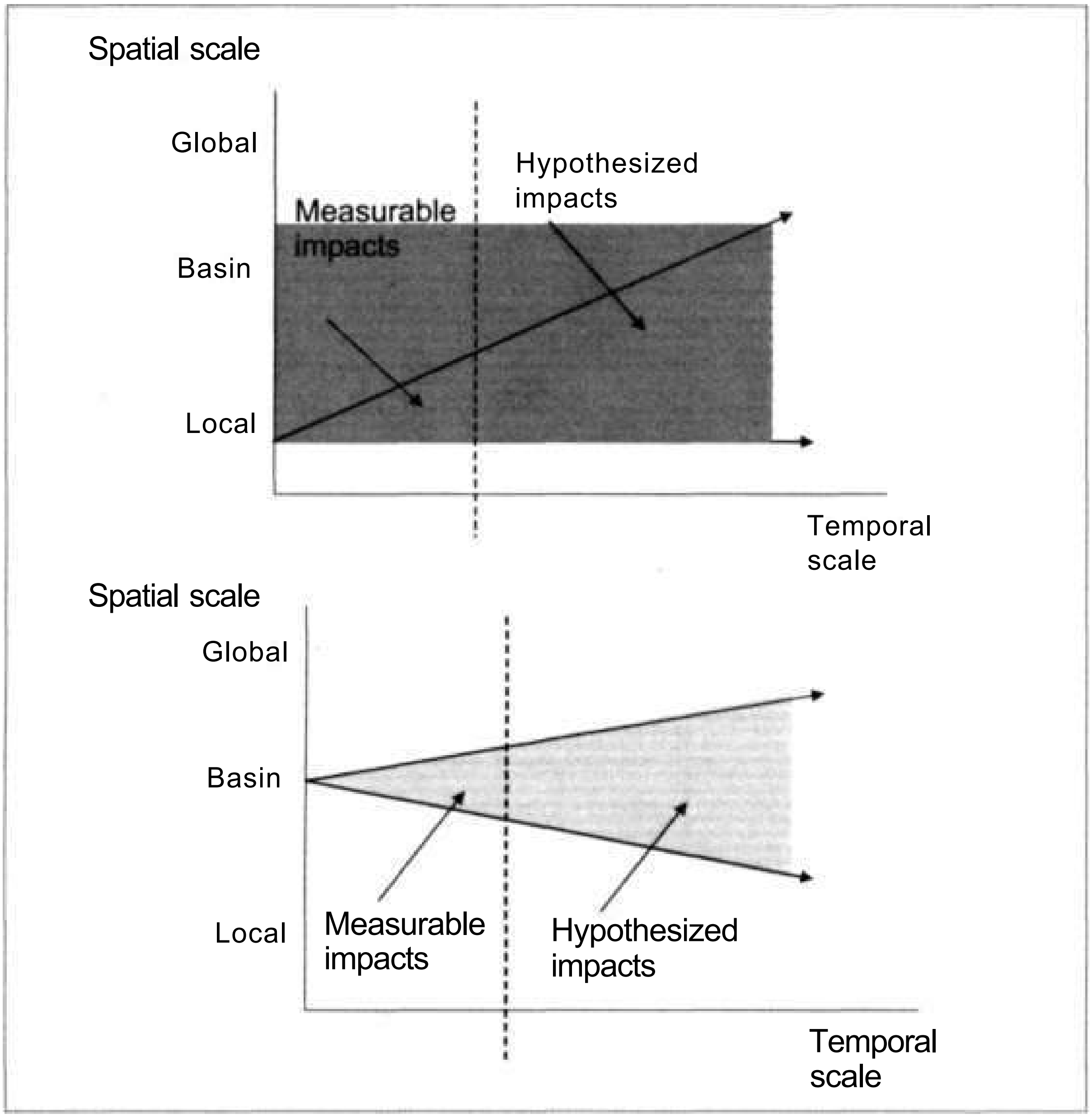


Figure 2. Impact assessment: two examples of the space/time relationship.

translating policy suggestions at the global or basin scale to local communities). Various partnerships within the impact pathways, again, may serve as important conduits in this process.

Methodological considerations

Assessment of project impact must be considered at two levels. The first level consists of the direct impacts that completion of any project is expected to have. The second level consists of the broader, secondary and tertiary impacts a given project may have. In general, it is at the first level that project impact is most easily measured, but it is at the second level that mission goals are more likely to be met. Only after the exact pathways to impact are articulated can we consider the specific indicators that might best be employed to measure whether or not the project met its immediate impact objectives.

It should be stressed that the indicators to be employed will vary from one project to another, depending on the nature and objectives of the project. In general, the creation of practical impact assessment indicators should follow the SMART approach. That is, they should be simple, measurable, achievable, realistic, and time-bound. Kilpatrick (1998) outlined other tools such as case studies, peer reviews, user evaluation and statistical methods that might prove useful to IWMI if SMART style indicators are developed. However, it is important to remember that all measurable indicators, perhaps in particular, SMART indicators, are only proxies for true impact. There is always a danger of losing sight of this fact and focusing only on the measurable proxy rather than the true goal.

In developing impact measurement tools for various project types, it is also important to remember that most, if not all, projects will have multiple impacts through multiple impact pathways. It is also important to consider the timeframe for analysis. Ideally, impact assessment involves *ex-ante,* intermediate, and *ex-post* evaluations. *Ex-ante* analysis helps identify the existing situation and the opportunities for impact generation. Intermediate assessments are used to see if projects are on track and progress is being made toward the intended impact. *Ex-post* evaluation follows the completion of a project to determine if the intended impact was indeed achieved as expected, or if other outcomes occurred. To conduct an in-depth impact assessment at all three stages can involve considerable human and financial resource requirements, and may often require the assistance of partner organizations. Thus, depending on the type of project and resources available, IWMI will need to develop guidelines for determining the timing, scope and responsibility of impact assessment.

Finally, there is no point in conducting impact assessment if the lessons learned are not used. While the intent of the institution as a whole as well as of individual project leaders is to have a positive impact on the land and water resource environment, in reality not all projects will achieve their goals, while others may have no, or perhaps even negative, impact. The point, however, is to learn from past experiences, whether positive or negative. A mechanism must be constructed so that the lessons learned from each impact assessment can be used to guide and inform future work.

Future directions

Implementing an impact assessment program is a multi-staged and time-consuming process that involves both qualitative as well as quantitative analyses. It is, however, possible to take concrete steps towards better monitoring and evaluating the direct impact of research projects and from that assess, at least conceptually, progress toward the institution's overall mission.

At the project level, we propose the development of an impact typology. This typology would divide research projects by type (e.g., primary research, field techniques, policy dialogues, outreach activities, etc.). For each project type, specific measures can then be developed to assess project impact. Developing this typology and the associated impact measures should benefit from the experiences of others and requires IWMI's active participation in the impact assessment networks, the use of literature reviews, and perhaps involvement of external resource persons. Simultaneously, specific procedures for implementing an impact assessment program should be incorporated in IWMI's Quality Management System (QMS) as part of the project management cycle.

In addition to project level initiatives, actions are also needed at the institutional level to support the development of an impact assessment program. The primary purpose of the assessment is to determine the extent to which institutional goals and objectives have been achieved to date, and to evaluate research priorities for the future. IWMI as an institution must also continue to nurture an impact culture. This will in part evolve naturally from the establishment of a practical and systematic impact assessment program.

To summarize, the framework developed in this paper addresses both conceptual and practical considerations for measuring and tracking impacts of NRM research. To begin implementing the impact assessment program, a set of tasks have been identified, to be carried out in the coming years in close coordination with the development of the 2004-2008 Strategic Plan. The tasks involve creating an impact typology, developing standard impact assessment procedures, assessing IWMI's internal organizational structure and external partnerships, and fostering an 'impact culture' throughout the organization. With the conceptual framework described here together with the proposed tasks for the coming years, there can be significant progress towards the establishment of a meaningful and effective impact assessment program at IWMI.

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Session 5

Future Directions

NRM impact assessment in the CGIAR: meeting the challenge and implications for ICRISAT

Tim Kelley and Hans Gregersen[1]

Introduction

Natural resources management (NRM) research is a growing as well as changing part of the CGIAR portfolio of research. Yet, so far, there is little convincing evidence that such research has been having a significant impact in terms of the goals of the CGIAR, related to sustainable poverty alleviation and food security. At the same time, there is a growing emphasis on showing impacts from agricultural research since the early 1990s. Donors would like to see clear linkages between research and improvements in the livelihoods of the poor.

This paper is organized as follows: First, the investment trends in the CGIAR are presented, showing that Policy and NRM-related research is a growing part of the portfolio. Second, some of the definitional issues are explored, which are related specifically to NRM and the move within the CGIAR towards integrated natural resources management (INRM) that involves a much broader and to some vague conceptual base - what some call a 'new research paradigm'. Third, an assessment of the challenges ahead, in terms of assessing the impacts of NRM research at both the center and the system level within the CGIAR.

The context: CGIAR investment trends favor NRM-related research

Table 1 shows CGIAR investment shares by Undertakings/Activities from 1994 to 2001. CGIAR investments in 'Increasing Productivity' have fallen from 47% of the total in 1994 to 35% in 2001. Within this main activity, sub-activity 'Germplasm enhancement and breeding' investments have

1. The authors are respectively, the Secretary and Chair for the Standing Panel on Impact Assessment (SPIA) of the CGIAR's interim Science Council. The views presented here are the authors' and do not necessarily represent those of SPIA or the interim Science Council.

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

	1994		1995		1996		1997		1998		1999		2000		2001	
CGIAR Activities	$	%[1]	$	%	$	%	$	%	$	%	$	%	$	%	$	%
Increasing productivity (of which)	124.3	47	134.4	47	129.1	40	133.1	40	124.3	37	117.3	34	119.7	36	123.3	35
Germplasm enhancement and breeding	61.9	23	64.0	22	58.8	18	63.7	19	60.0	18	61.2	18	61.8	18	64.1	18
Production systems development and management:	62.4	24	70.5	25	70.2	22	69.4	21	64.3	19	56.1	16	57.9	18	59.3	17
- Cropping systems	41.6	16	38.5	13	40.5	12	35.1	11	32.7	10	29.3	8	32.1	10	32.7	9
- Livestock systems	15.7	6	21.1	7	18.4	6	18.7	6	19.7	6	15.6	4	13.8	4	16.7	5
- Tree systems	3.9	1	8.9	3	9.2	3	14.2	4	10.4	3	9.3	3	8.3	3	7.9	2
- Fish systems	1.2	0.5	1.9	1	2.2	1	1.4	0.4	1.5	0.4	1.9	0.5	3.7	1	1.9	1
Protecting the environment	40.1	15	45.3	16	53.7	17	57.4	17	64.5	19	67.9	20	60.4	18	67.2	19
Saving biodiversity	22.6	9	28.5	10	34.6	11	35.3	11	37.2	11	36.2	10	34.8	10	34.2	10
Improving policies	26.0	10	25.2	9	38.9	12	37.3	11	39.9	12	46.8	13	48.0	14	49.0	14
Strengthening NARS	51.7	20	52.6	18	68.7	21	70.2	21	70.9	21	78.6	23	74.6	22	81.1	23
Total	**264.7**		**286.0**		**325.0**		**333.0**		**336.8**		**346.8**		**337.5**		**354.8**	

1. The percentages across the major categories add to 100.

Source: CGIAR Financial Reports 1994–2002.

fallen from 23% (1994) to 18% (2001), while sub-activity 'Production systems development and management' investments have fallen from 24% to 17%. CGIAR investments in 'Protecting the Environment' and 'Improving Policies' have risen from 15% to 19%, and from 10% to 14%, respectively. Although the CGIAR Activity 'Protecting the Environment' is one of the fastest-growing areas of research activity within the CGIAR, it is also an area for which there is only limited documented impact to date. As noted in the recent Operations Evaluation Department (OED) Overview of the CGIAR Report (World Bank 2003), NRM research in the CGIAR is 'under-evaluated' and requires more accountability. The OED assessment raises questions not only about the shift in priorities and investments by the System over time, from crop germplasm improvements (CGI) to NRM research, but is critically important as the CGIAR contemplates whether to adopt four new Challenge Programs, all of which have strong NRM and INRM dimensions (AGM '02 Business Meeting Summary Record).

One of the major recommendations from the OED Report is the need for the CGIAR to give more prominence to basic plant breeding and germplasm improvement, and reshaping NRM research to focus tightly on productivity enhancement and sustainable use of natural resources for the benefit of developing countries. The latter part of this recommendation - the need to focus more on the productivity dimensions of NRM - reflects a growing awareness among CGIAR stakeholders, of an increasing trend towards environmental protection, for which little impact has been demonstrated, at the expense of productivity enhancement, for which a considerable amount of documented impact exists.

It is difficult to be precise about the cumulative level of investments in NRM-type research activities for the System since its inception, principally because the CGIAR Activity definitions have changed over time. Nevertheless, the share of CGIAR investment allocated to 'protecting the environment' averaged 16.5% between 1992 and 2001, amounting to almost $500 million (in full cost terms). Over the same period, investments in 'production systems development and management' averaged 21%, accounting for roughly $630 million. Certainly not all of this can be defined strictly under NRM research, but these figures offer some indication of the significant level of investment in NRM since 1992.

In the face of data that shows CGIAR investment trends moving away from the activities and Centers where the most documented success has occurred - CGI research - it is essential that the CGIAR gear up rapidly and with significant effort, document the impacts of the past investments in NRM-related research.

From NRM to INRM

Traditional NRM research in the CGIAR tended to be narrowly defined to include land-management related themes (soil and nutrient management, irrigation and land cover management, etc.), with a strong emphasis on resource productivity. There is now growing interest in INRM, a broader research paradigm that emphasizes the integration of productivity enhancement, environmental protection, and human development as a multiple research objective across different scales, from field to landscape levels (Sayer and Campbell 2002; Turkelboom et *al.* 2003).

In recognizing the complexity of these systems, INRM research is oriented towards enhancing adaptive capacity, by incorporating more participatory approaches, by embracing key principles such as multi-scale analysis and intervention, and by the use of a variety of tools (e.g., systems analysis, GIS, etc.). Integration provides the key: across scales, components, stakeholders and disciplines. Invariably, INRM must concern itself with socio-political, economic and ecological variables (Campbell *et al.* 2001). Clearly, this represents a significant departure from traditional NRM research that simply aimed to maintain or increase productivity of resource use in a sustainable manner, that is, over the long term.

Because INRM is fundamentally different, i.e., is more development-oriented, attempts to catalyze change, focuses on the (nonlinear) 'process' of change, and is not top-down, impact assessment cannot use the static linear models of commodity crops, e.g., the traditional economic surplus or econometric approaches (CGIAR 2000). In addressing INRM impact assessment, the participants at the INRM Workshop in Penang, Malaysia, noted that INRM-based methods are more like continuous assessment, with regular feedback to improve performance. Therefore INRM impact analysis methodologies would employ a highly adaptive research approach.

There are many welcome features to the new INRM paradigm that address a range of highly important topics and dimensions of NRM research in the CGIAR that have been neglected thus far. But there are concerns as well, particularly related to the highly conceptual nature of the definition of INRM and thus, the problems introduced in attempting to do specific, quantitative *ex-post* impact analysis. While INRM research is more comprehensive and process-oriented than the conventional and more limited NRM research - a desirable characteristic by-and-large, it does raise questions about the ability to measure *ex-post* impacts in the traditional sense of the term.

In addressing these challenges, first priority for *ex-post* impact analysis should be given to the older, already-completed NRM research for three reasons:

- The impacts tend to be more tractable in measurement - by nature of the single-focused goal espoused (productivity enhancement).
- They provide the retrospective view necessary to measure *ex-post* impacts, i.e., allowing for significant research and adoption lag periods to have elapsed.
- The lessons learned from such assessment - both methodological and outcome-based lessons - will be a valuable input in developing acceptable means for measuring impacts of INRM research.

Ex-post impact assessment of CGIAR NRM research: the challenges

With the growing trend towards greater investment in NRM-related activities and Centers, there is also a growing need for demonstration of impact. Otherwise, there is a risk of significant future reductions in investment. So far, the CGIAR has shown very little evidence of significant impacts from its NRM-related research.

Insufficient evidence of NRM research impact

Pingali (2001) provides an overview of some of the important impact assessment work done in the CGIAR since its inception. Research related to CGI effects clearly dominates the literature - with relatively few 'crop management and improved input use' and other NRM-related CGIAR impact studies to date. The SPIA-commissioned CGI impact assessment, involving all CGIAR commodity centers, documents the significant contribution made by the CGIAR to improving agricultural productivity through germplasm improvement (Evenson and Gollen 2003). The Alston *et ai* (2000) meta-analysis of the rates of returns for all types of agricultural research, which include smaller-scale studies, found very few NRM-related studies in their survey (less than 4% of the total studies reviewed). Hence, unlike the situation in CGI, for which large-scale adoption of yield-enhancing CGIAR-derived varieties has been documented for a range of CGIAR crops, there are not many examples to-date, of successful (widely adopted) CGIAR-generated improved NRM technologies, for which demonstrable impact has been measured and assessed. Further, the NRM impact assessments included in the Alston et *al.* study showed lower rates of return than did the CGI-related impact assessments. External Programme and Management Reviews (EPMRs) of the CGIAR Centers have evaluated NRM research components in the Centers and the evidence they provide is not always positive in terms of the effectiveness of such research. To the contrary, with the exception of the Centro Internacional de la Papa (CIP) EPMR in 2002, recent EPMR reports have been critical of the quality of science, achievements and on-the-ground impacts from the NRM research programs.

Each of the above points to a similar conclusion: there is little documented evidence of impact - economic or otherwise - of CGIAR research on NRM and related topics. Further, some of the recent studies that do attempt to document impact, for e.g., International Livestock Research Institute (ILRI)'s *ex-post* impact assessment series, show limited impact or even negative rates of return on investments (Elabasha et *al.* 1999; Rutherford et *al.* 2001). Other NRM 'impact' reports are anecdotal or more like early adoption studies. Some are quite general and/or conjectural (claims difficult to substantiate one way or other), or else tend to focus on descriptions of potential or probable impact, e.g., the IBSRAM impact report (Maglinao 1998). Most NRM impact type studies give much stronger emphasis to evaluation, focusing on adoption and constraint issues, i.e., they have a strong learning component, rather than focusing on documenting the impact per se.

Why the lack of documented evidence of impact?

Lack of sustained critical mass investment

The lack of evidence partly reflects a lack of sustained emphasis on NRM research over the last few decades. But this can be only a partial explanation. While CGIAR investments for CGI research have been much larger than for NRM research, the absolute levels of investments in NRM research and its earlier precedents are still considerable, and certainly qualify it for assessment. Research on soil and water management, and farming systems in general, represented a significant part of many CGIAR Centers' research agenda during the first two decades, and these were typically focused on productivity-enhancing aspects of NRM. Major investments were made in areas such as BBF management, the tropicultivator, water harvesting, tank management and other soil- and water-management-related research. To date, little of this has been assessed in terms of impact - whether in terms of improvements in resource productivity or in enhancing the environment.

Inappropriate methods

NRM impact assessment has lagged behind assessment of the impacts of germplasm improvement and certain technology developments. Part of the problem with the apparent low returns to NRM research arises from the fact that methodologies have been used that are poorly adapted to the subject, and are too much a direct transpose of methodologies used for CGI research. Approaches are needed that capture environmental services and other (non-yield) outputs from NRM/INRM research such as maintenance, risk reduction, quality improvement, reduction of negative environmental externalities and compatibility with off-farm labor schedules. Certainly, the lack of appropriate methodologies has constrained efforts to document impact from NRM. Economic surplus methods for measuring impact for CGI research are often not appropriate in the case of NRM research. While this may apply to some of the current efforts in process-oriented INRM, it does not explain the lack of NRM impact assessments for research focused mainly on productivity improvements - the lion's share of NRM efforts before the mid-1990s and a significant portion of it afterwards.

The difficulty in measuring and attributing impact of NRM/INRM research is of a significantly higher order than that of CGI research (Izac 1998). These relate especially to complexity issues (in scale, in time), nonlinearity (causality), the economic and non-economic dimensions, operation indicator issues, more disciplines involved, longer time lags, attribution problems and difficulty in extrapolation. Hidden in this is the recognition that some of the major gains and impacts from CGI investments have been supported by improved crop and soil management, derived through NRM research. This is a measurement/allocation problem, but without some evidence, it remains conjectural or anecdotal at best.

Lack of impact per se

In many cases, NRM research has failed to generate the appropriate technology or institutional arrangements that adequately address the needs of farmers and communities. In cases where it is evident that adoption is lacking, there is little reason to assess impact. Thus, lack of impact per se can be another reason behind the low level of evidence of impact. This in no way is an indictment of the quality of research conducted - not all research can be expected to result in a proven, adopted technology - nor does it overlook the fact that some technologies have indeed been adopted on a limited scale. Also, in some cases, lack of an effective delivery mechanism could explain low adoption.

With respect to NRM research focused on group or community-based decision making, the emphasis on key issues such as property rights and the need for community action has resulted in several promising success stories, as brought out in, e.g., the CAPRi external review (iSC 2002). Here, the major constraint is scaling up, or out. Without that ability, the investment is usually not cost-effective. This was one of the major conclusions reached at the Agroforestry Dissemination Workshop in 1999: *The developing world has no shortage of successful 'pilot' schemes and projects that have sought to address the problems of poverty, food security and environmental degradation. There are too few cases where these successful pilots have led to widespread impact on a sustainable basis* (Cooper and Denning 2000).

Meeting the challenge: NRM impact assessment at the system level

Although the need for documenting NRM ex-post impact assessments was highlighted at the SPIA sponsored IA Workshop at FAO in 2000 (TAC 2001a), sufficient resources have not been available to embark on any system-level assessment of NRM impacts. In the expectation that additional funding is now forthcoming, SPIA/iSC is proposing three main activities in 2003-04 to better understand the impacts of the CGIAR's work in NRM: development of improved methods for assessing NRM impacts; empirical evidence of impacts from Center activities; and empirical evidence of impacts from System-wide activities.

In addition, there is a clear need for an inventory of NRM and related research activities in the CGIAR, with some measure of levels of investments therein. This, of course, will require that Centers come to grips with the definitional issues raised above, and develop a set of uniform definitions and boundaries on such issues.

Implications for NRM impact assessment activities at ICRISAT

Like other Centers, ICRISAT has focused mainly on documenting *ex-post* impacts of its germplasm improvement work - with success. Clear recognition of this is evident from the three King Baudouin Awards within the last 10 years, for millet, pigeonpea and chickpea. Also, like other Centers, ICRISAT has not been able to document rigorously and on a large-enough scale, the impact from its research in NRM and related areas. Yet, few other CGIAR Centers have had more activity in NRM research than ICRISAT. This provides a strong incentive for ICRISAT to play a leadership role among the CGIAR Centers in convincingly demonstrating the poverty impacts from ICRISAT's investments in NRM research.

The challenge here is great: first, in developing a framework for understanding, identifying, and measuring poverty alleviation impacts from NRM research; and secondly, in actually measuring and documenting impact from a few selected NRM research-related projects/areas of work. With respect to identifying an overall framework and methods, the SPIA/IFPRI poverty impacts study provides an excellent platform on which to build. Using a sustainable livelihoods framework, this project combines quantitative and qualitative analyses, and economics and social indicators to trace the effects of research on different groups of people (Adato and Meinzen-Dick 2002). It represents a good model for NRM research impact assessment, although scaling up aspects will need to be considered carefully.

With respect to the selection of specific NRM research topics and case studies, one approach (and one used by SPIA at the System level in the Meta B-C analysis) would be to compare the total cost of all NRM investments to date at ICRISAT against the aggregated benefits from one or two large-scale ICRISAT NRM success stories. Some areas where ICRISAT has had significant activity in the past, and for which there appear to be plausible (though admittedly difficult-to-measure) impacts to document are the Vertisol technology work, watershed management and IPM in chickpea and pigeonpea.

Apart from the accountability motivation, a close examination of the benefits to date from NRM research activities would provide highly useful reflection as to what has and what has not worked, and an insight as to why this has happened. In the first instance, this could be an economic assessment based on productivity improvements, but not only this. Qualitative assessments of the nature and scope of environmental improvements would be useful, as long as they are well documented.

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Where do we go from here? Issues raised during the final panel discussion session[1]

Prabhakar Pathak[2]

The discussants in the panel discussion of the session were Steve Twomlow (ICRISAT), Suhas P. Wani (ICRISAT), Bekele Shiferaw (ICRISAT), John Pender (IFPRI), and Christopher Scott (IWMI). The Chairperson of the session was H. Ade Freeman. Dyno Keatinge, Deputy Director General for Research, ICRISAT, kindly agreed to moderate the session.

The moderator opened the session with three questions:

- Are the goals of NRM research clear?
- What methodologies are preferred for a particular problem?
- How can we collaborate better in the future?

The discussants were given about 20 minutes to cover each question during the debate.

Twomlow emphasized the need for developing proper methodologies for assessing the impacts of NRM research. He pointed out that the research cannot continue in isolation, and highlighted the need for participation and interaction with all stakeholders at different levels. He suggested that the goals and objectives should be simple and specific. He also questioned the need for in depth measurement, and asked whether this issue is part of the agenda for impact assessment. He said that the tools to measure biophysical properties and plant diversity are already available, and are required in the process of impact assessment. He felt that the *CG* Centers should look at these aspects with a more global perspective, and the issue of NRM impact assessment should not be solely the responsibility of NARS and other stakeholders.

Wani emphasized that the NRM approach should be holistic and simple. He also distinguished between short-term 'objectives' and long-term 'goals'; while 'objectives' can be achieved in 3-5 years, 'goals' imply a

1.. This is an edited version of the Rapporteur's report. An effort has been made to capture the essence of the views expressed by the discussants. This is, however, not a verbatim reproduction and some inadvertent omissions may have occurred.

2.. ICRISAT, Patancheru, India.

relatively long term for the desired outcomes to be attained. He stressed that objectives and milestones of NRM research should be clearly defined to facilitate impact assessments. To bridge this gap in INRM, simple indicators and specific measurements need to be considered. He gave an example of how the objective of watershed development projects in India shifted over time from soil conservation to soil and water conservation and then to participatory approaches, and now to strengthening livelihood options.

Shiferaw pointed out that there has been a paradigm shift in the NRM goals and objectives over time. Earlier, the goals were focused on conservation of resources and sustainability without a clear focus on linking conservation with productivity and income opportunities for the poor. But today, there is a paradigm shift in our NRM research goal, which focuses more on reducing vulnerability and strengthening livelihood options of the poor resource users. He underlined the relevance of clear objectives and goals in developing NRM technologies, which often have multiple influences vis-a-vis production and ecosystem conservation and the implications for impact assessment.

Pender stressed the need to focus on NRM research by establishing the possible links between INRM research and its impacts. He strongly felt that we should try to understand how NRM research has affected NRM, and assess how NRM practices affect poverty and other outcomes. He raised several questions relative to this:

- What is the impact of NRM research on NRM? Before we can say what impact NRM research has had on productivity, poverty, environment and other outcomes, we should establish what impact the research has had on NRM practices of farmers.
- Should we focus on impacts of specific technology development or on more general principles that have been learned? Given the site-specific nature of NRM technologies, he argued that focusing more on principles might be more useful.
- How widely are NRM technologies developed by researchers adopted by farmers?
- Has NRM research helped promote farmers' own innovations?
- What principles have been learned from NRM research, and how widely have they been disseminated and taken up?
- Where has the generated information been used?

He added that the methods to address some of these questions are simple surveys; e.g., surveys that tell us how many farmers have adopted specific technologies. But he argued that different methods would be needed to assess dissemination and uptake of more general principles learned from NRM research, and impacts of such research on farmer innovation. He also stressed the importance of considering how different stakeholders such as NARS, NGOs and farmers use the new knowledge generated.

One of the general comments made by the discussants was that sometimes scientists are very harsh on themselves to say that NRM research has not made any impact. There is a need to clarify the objectives and references for impact assessment. There was a general consensus indicating that there are problems that should be addressed in terms of clearly defining the research goals and objectives, especially in situations where there are multiple actors, multiple interventions, and the processes involved and ecosystem functions affected are very complex (e.g., INRM approach).

Keatinge mentioned that we should produce international public goods, as well as achieve local development and impact. We also need to be realistic and should do the research in different ways. He indicated that the INRM community has broadly defined the goals and objectives of NRM research, and this could help in defining the objectives of new projects and impact assessment efforts. The challenge is to incorporate these broad goals and objectives in the impact assessment process in ways that would be plausible and scientifically acceptable.

Ramakrishna pointed out that the importance of 'impact by whom' should not be neglected while addressing the relevance of 'impact for whom'. He also raised the following questions:

- Regarding collection of data on biophysical indicators for impact assessment, are the national programs capable of doing this?
- What kind of infrastructure is available with them?
- What capacity building activities are required in the future to enable the national programs to practice NRM impact assessment? There are a certain minimum data sets (biophysical and economic) required to undertake NRM impact assessment. For many of our NARS partners, these may not really be 'minimum' data sets.

Freeman replied that the human and institutional capacity development program for NGOs, NARS, and other partners, particularly in African situations, is very relevant and must be given high priority.

Shiferaw also replied to the question raised by Ramakrishna, by pointing out that the 'impact assessment by whom' is relevant. The necessary capacity for NRM research and impact assessment within the NARS should be developed. It is also very important to know what methods are appropriate for a particular problem. We need to know which method should be used for various resources (soil, water, biodiversity, watersheds, etc.) at different scales. In many cases, a combination of methods and quantitative/qualitative approaches is needed. Training programs should be conducted for capacity building in methods for NRM impact evaluation.

Wani emphasized that it should not be economists alone who do impact assessment; biophysical scientists should also provide their expertise when needed. Impact assessment should be a continuous process involving the local community in the regular monitoring of biophysical and socioeconomic changes resulting from changes in patterns of resource management. Advanced scientific tools such as geographical information systems (GIS), remote sensing, etc., should be used to collect and analyze useful information. The biophysical modeling group and the impact assessment team should keep minimum data sets, and information on changes in ecosystem services and environmental quality should also be included in impact assessment of NRM interventions.

There were additional brief comments and suggestions by non-panelists on the choice of methods and data requirements. Some emphasized that specialized economic models are generally very complex and difficult to develop, suggesting that we should mainly think of simple surveys and cost-effective approaches for collecting and analyzing data for NRM impact assessments. The major difficulty with 'quick-and-dirty' methods, however, is lack of scientific validity, which will in turn affect the plausibility of the reported impacts. The future approach in developing methods should be to strike a balance between scientific validity, simplicity and cost-effectiveness. It was also mentioned that the right partnership with the local communities and consortium partners is extremely important for proper impact assessment. There was a general feeling that a lot needs to be done in identifying or developing appropriate methodologies for assessing the impact of NRM research. Collection of baseline data and continuous monitoring should be given high importance.

Shiferaw agreed with Pender that adoption is a prerequisite to attaining livelihood and environmental impacts. Small farmers may not adopt technologies unless they expect better returns compared with their existing practices. When the private benefits are low, farmers may not adopt NRM technologies even if the social benefits may be high. In such cases, governments should provide support to small farmers to enhance technology uptake. In other cases, farmers may lack the necessary credit or secure rights to land and water to carry out beneficial investments. This also requires government intervention to create proper institutional structures. These are some factors that could limit societal benefits from NRM R&D investments and contribute to paucity of evidence of impact. NRM research would affect NRM only when available technological options are adopted and adapted by the resource users. However, there have been several adoption studies that show the extent of adoption, and analyze the economic, institutional and biophysical determinants of technology uptake. In situations where adoption is significant, it would be useful to evaluate the social benefits from the R&D effort. Where adoption is limited, we should continue to explore the limiting factors that may be related to the inherent failure of the technology, or the economic and institutional constraints. This should, in turn, inform NRM research and development efforts.

Freeman mentioned that we are moving towards a combination of quantitative and qualitative methods. More work needs to be done in identifying mechanisms for integrating these approaches in the process of data collection and analysis for impact assessment. Clarity of the objectives of NRM research will facilitate this process.

Twomlow emphasized that the key variable in terms of the objectives of NRM research is careful preparation of concept notes with clearly defined outputs and verifiable indicators.

Pender made a remark regarding collaboration, that the strengths of different disciplines and institutions should be identified and the potential that different partners could contribute should be explored. This kind of a strategic partnership with complementary skills will be very useful for developing and testing relevant impact assessment methods.

Participants from IWMI stressed the need to collaborate with others, and that it would be very important to learn from the experiences of others on how to develop indicators and evaluate societal impacts.

Shiferaw mentioned that different Centers within the CGIAR system are at different stages of developing methods for impact assessment. In addition, the relevant NRM issues differ across Centers, depending on their 'commodity' focus. There is much to be gained from collaboration among the CG Centers in developing more comprehensive impact assessment methods that will include innovations for crop, soil, water, vegetation and biodiversity management. It is also important that we identify the relative strengths within and outside the CGIAR system, and establish strategic partnerships to test and develop useful and simple impact assessment methods.

There was also some discussion regarding potential donors for the development of new tools and pilot-testing some methods identified for specific purposes. Scott Swinton was requested to explore the possibility of support from the United States Agency for International Development (USAID), Stein Holden about Norwegian support, and Meredith Giordano about support and possible links with the Challenge Program on Water and Food. Each of the respondents agreed to collaborate in the area of developing and testing useful methods, and to jointly explore any emerging opportunities for funding.

Workshop Agenda

ICRISAT-NCAP/ICAR International Workshop on
Methods for Assessing the Impacts of Natural Resource Management Research
6-7 December 2002, ICRISAT, Patancheru, India

6 December 2002

Session 1. Welcome and opening

0830	Welcome and introduction	H.A. Freeman
0840	Inaugural address	William D. Dar, Director General
0850	Objectives of the workshop	B. Shiferaw

Session 2. Special features of NRM impacts

Chairperson: Steve Twomlow **Rapporteur:** A. Ramakrishna

0900	Why impact assessment of NRM technologies presents methodological difficulties	H.A. Freeman and B. Shiferaw
0930	Measurable biophysical indicators for impact assessment: The case of watershed management technologies	P. Pathak, S.P Wani, A. Ramakrishna, K.L. Sahrawat and T.J. Rego
1000	Overview of valuation methods and methodologies applied for assessing NRM technology impacts	B. Shiferaw and H.A. Freeman
1030	Coffee/Tea break	
1100	Panel discussion	Discussants: P.K. Joshi (NCAP), T.J. Rego and P. Singh
1200	Lunch	

Session 3. Methodological advances for NRM impact assessment

Chairperson: B. Shapiro | **Rapporteur:** B. Shiferaw

1300	Econometric approaches for NRM impact assessment	J. Pender (IFPRI) and J. Kerr (MSU)
1345	Integrating sustainability indicators into the economic surplus approach for NRM impact assessment	Scott Swinton (MSU)
1430	Bio-economic modeling approaches for NRM impact assessment: static and dynamic models	Stein Holden (NLH)
1515	Coffee/Tea break	
1530	Panel discussion:	Discussants: K.N. Murthy (University of Hyderabad), Suresh Pal (NCAP), K.P.C. Rao (ICRISAT)

Session 4. Selected case studies of NRM impact assessment

Chairperson: M.C.S Bantilan | **Rapporteur:** T.J. Rego

1630	Empirical approaches for evaluating the impacts of watershed management projects	John Kerr (MSU)
1700	Livelihood and distributional impacts of watershed development programs in India	V Ratna Reddy (CESS) and John Soussan (SIE)
	Panel Discussion:	Discussants: P.K. Joshi (NCAP) and A. Ramakrishna
1730	Assessing the impacts of NRM research: a conceptual framework	Meredith Giordano (IWMI)

7 December 2002

Session 5: Future directions

Chairperson: H.A. Freeman

Rapporteur: P. Pathak and P.N. Jayakumar

0900	NRM impact assessment in the CGIAR: SPIA's perspective	Tim Kelley (SPIA-CGIAR)
0930	Panel discussion	Discussants: S. Twomlow; S.P. Wani; B. Shiferaw; J. Pender (IFPRI); C. Scott (IWMI)
1030	Coffee/Tea break	
1045	Panel discussion continued	
1230	Vote of thanks	Steve Twomlow

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Abbreviations and Acronyms

AGY	Adarsh Gaon Yojana
ARIs	Advanced Research Institutes
CESS	Centre for Economic and Social Studies (India)
CGI	crop germplasm improvements
CGIAR	Consultative Group on International Agricultural Research
CGE	Computable General Equilibrium
CIP	Centro Internacional de la Papa
CPRs	common pool resources
CRIDA	Central Research Institute for Dryland Agriculture (India)
CS	consumer surplus
CVM	Contingent valuation method
DSP	Discrete stochastic programming
ENR	environmental and natural resources
GIS	geographical information systems
iSC	Interim Science Council of the CGIAR
IAO	Impact Assessment Office
IARCs	international agricultural research centers
ICAR	Indian Council for Agricultural Research
ICARDA	International Center for Agricultural Research in the Dry Areas
ICRAF	International Centre for Research in Agroforestry
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IFPRI	International Food Policy Research Institute
IGWDP	Indo-German Watershed Development Program
ILRI	International Livestock Research Institute
INRM	integrated natural resources management
IPDM	integrated pest and disease management
IV	instrumental variable
IWMI	International Water Management Institute

LP	linear programming
LQIs	Land quality indicators
MSU	Michigan State University
NARS	national agricultural research systems
NCAP	National Center for Agricultural Economics and Policy Research (India)
NGOs	non-governmental organizations
NLH	Agricultural University of Norway
NLP	non-linear programming
NNP	net national product
NRM	natural resource management
NVP	net village product
NWDPRA	National Watershed Development Program for Rainfed Areas (India)
OED	Operation Evaluation Department of the World Bank
OLS	Ordinary Least Squares
PRA	Participatory Rural Appraisal
PS	producer surplus
QMS	Quality Management System
SAT	semi-arid tropics
SAMs	Social accounting matrices
SEAMs	Social and Environmental Accounting Matrices
SIE	Stockholm Institute of Environment
SPIA	Standing Panel on Impact Assessment (iSC)
SQ	soil quality index
SRL	sustainable rural livelihood
TAC	Technical Advisory Committee (CGIAR)
TEV	total economic value
TSFP	total social factor productivity
UPE	universal primary education
USAID	United States Agency for International Development
WEPP	Water Erosion Prediction Project
WTP	willingness to pay
WTA	willing to accept

About ICRISAT

The semi-arid tropics (SAT) encompass parts of 48 developing countries including most of India, parts of southeast Asia, a swathe across sub-Saharan Africa, much of southern and eastern Africa, and parts of Latin America. Many of these countries are among the poorest in the world. Approximately one-sixth of the world's population lives in the SAT, which is typified by unpredictable weather, limited and erratic rainfall, and nutrient-poor soils.

ICRISAT's mandate crops are sorghum, pearl millet, chickpea, pigeonpea and groundnut—five crops vital to life for the ever-increasing populations of the SAT. ICRISAT's mission is to conduct research that can lead to enhanced sustainable production of these crops and to improved management of the limited natural resources of the SAT. ICRISAT communicates information on technologies as they are developed through workshops, networks, training, library services and publishing.

ICRISAT was established in 1972. It is supported by the Consultative Group on International Agricultural Research (CGIAR), an informal association of approximately 50 public and private sector donors. It is co-sponsored by the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP) and the World Bank. ICRISAT is one of 16 nonprofit, CGIAR-supported Future Harvest Centers.

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Science with a Human Face

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