View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by ICRISAT Open Access Repository

16 Towards Comprehensive Approaches in Assessing NRM Impacts: What We Know and What We Need to Know

S.M. Swinton[1], B. Shiferaw[2] and H.A. Freeman[3]

[1] *Michigan State University, East Lansing, Michigan, USA*
[2] *International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Nairobi, Kenya*
[3] *International Livestock Research Institute (ILRI), Nairobi, Kenya*

Introduction

The deliberate use of ecosystems by mankind to meet food, feed, industrial, and social and environmental needs inevitably alters the natural ecosystem functions and services. While flux is inherent to ecological systems and their evolution, the natural resource base is currently facing unprecedented human pressure due to population growth and rising consumer demand that follows rising incomes. This human pressure creates a growing need to improve the productivity of existing natural resources and to counter processes that deplete their productive capacity. Governments around the world have responded to the degradation of the natural resource base with projects aimed at sustaining productivity levels and environmental quality. The rising proportion of research funds directed at natural resource management (NRM) at the Consultative Group for International Agricultural Research (CGIAR) is indicative of strong interest (Kelley and Gregersen, Chapter 15, this volume). The increase in funding brings with it an increased need for accountability, *ergo* the urgency of improving impact assessment of NRM investments.

The introduction to this volume summarised the special difficulties in measuring the impacts of agricultural technologies that are designed to enhance the sustainability of natural resources needed for human survival. The technologies themselves are diverse; they range from genetic improvements that allow crops to grow in inhospitable places to conservation practices that reduce soil loss and water pollution. Although a few NRM innovations boost

©CAB International 2005. *Natural Resource Management in Agriculture: Methods for Assessing Economic and Environmental Impacts* (eds B. Shiferaw, H.A. Freeman and S.M. Swinton)

farm revenues (e.g. via enhanced yields), most of the benefits to resource users come from cost-savings, reduced vulnerability to risk (e.g. yield stability) and the avoidance of declining productivity. Examples of such technologies include biologically based soil fertility management, soil and water conservation, water harvesting, integrated pest management, water-saving irrigation, minimum tillage, agroforestry and forest management, rangeland management, and biodiversity conservation. These innovations when adopted provide significant positive environmental and sustainability benefits both on-site and off-site.

The special characteristics of NRM technologies mean that a balanced economic impact assessment must be able to measure environmental and sustainability impacts above and beyond what would have occurred in their absence, a task that has often been ignored in impact assessments heretofore (Nelson and Maredia, 1999). As outlined in the introductory chapter, comprehensive NRM impact assessments pose special problems for establishing the counterfactual, measuring environmental effects, placing a value on those effects, and integrating the final results into a unifying framework.

This book has focused squarely on addressing the methodological challenges for evaluating the impacts of NRM. The preceding 15 chapters have presented and discussed the key issues, challenges, indicators, and valuation and evaluation methods. The sections that dealt with methodological advances were further enriched through case studies that illustrate how impact evaluations can integrate economic and environmental impacts. As agricultural research and development enters a new era through harnessing biotechnology and integrating genetic and resource management, diverging perspectives are emerging on how future impact assessments need to be carried out. The book has highlighted some of these views and outlined areas for future research.

This concluding chapter synthesizes the conceptual, methodological and empirical issues for evaluating the impacts of NRM technology and policy interventions. The intention is to highlight the salient features raised across the chapters and offer some insights on the key lessons, policy conclusions, knowledge gaps, and areas that need further research.

What We Know: The State of the Art in NRM Impact Assessment

Substantial experience has now been gained in applying economic impact assessment methods to productivity-enhancing agricultural research. Measuring changes in economic surplus associated with improvements in agricultural technologies is the most commonly used method in evaluating social net gains from research investments. Alston *et al.* (1995) and Maredia *et al.* (2000) provide a good review of best practices for *ex post* impact evaluation of the economic impacts of agricultural research programs. Despite extensive work on environmental valuation and benefit–cost analysis, there is a dearth of literature on methods for valuation of ecosystem services from NRM technology. Likewise, there are few empirical studies of the social impacts of NRM. Recent years have witnessed a gradual shift in the evaluation literature towards looking at the non-productivity related environmental and sustainability impacts of crop and resource management interventions (e.g. Traxler and Byerlee, 1992; Pingali *et al.*, 1994; Gumtang *et al.*, 1999; Gupta and Abrol, 2000; Pretty *et al.*, 2000). Improved methods are now being developed for comprehensive evaluation of the economic welfare impacts of agricultural interventions – including the productivity and environmental costs and benefits.

Beyond market-based assessments

A recent survey of 1100 agricultural research impact assessment studies found that only 11 included environmental impacts (Alston *et al.*, 1998). In the face of rising expenditures on NRM projects, the fact that 99% of past impact studies relied on measures of economic efficiency alone highlights the need for better assessment of impacts related to sustainability and environmental quality. Because many NRM problems involve economic externalities and/or public goods, neither the problems nor the impacts of NRM technologies designed to solve them are readily measured in markets. It is now widely accepted that impact assessment of NRM interventions should look beyond conventional market-based techniques. Non-market valuation methods, now widely in use in the developed countries for assessment of environmental impacts, can be tested and adapted for evaluating the non-marketed impacts of agricultural and NRM practices. One major challenge is how to measure or find indicators for the dynamic and multidimensional impacts of NRM technologies in agriculture.

Measurement problems

In order to assign economic values to changes in the flow of ecosystem goods and services, the essential first step is to understand how the new interventions affect the quality or quantity of the resource in question and how that translates into changes in goods and services that people value. Changes in ecological functions and processes may be very gradual and take a long time to manifest. Moreover, the dynamic, interdependent nature of ecosystems makes it hard to measure a clear cause–effect relationship from an NRM technology intervention. A basic hurdle in measurement and quantification of biophysical changes therefore has been the incomplete understanding of how NRM practices affect ecosystem health and sustainability.

However incomplete, human knowledge about ecosystems is growing. Long-term experimentation in selected systems has provided useful information about system dynamics and how crop and resource management interventions affect agricultural productivity and resource conditions. The need for such experimentation is even stronger in locations where variability of production conditions is high and data from a short time-series will fail to capture the underlying variation. Simulation models that emulate soil, water, nutrient and crop interactions are now widely used. If properly validated using site-specific biophysical and climatic conditions, such models can be very helpful in evaluating the impacts of multiple changes. This is particularly the case for the integrated interventions of what has now come to be known as integrated natural resource management (INRM). Satellite imagery and geographic information systems are becoming useful tools for monitoring the spatial and temporal dynamics of changes in patterns of land use, vegetation cover, drought stress, surface water, water logging and land degradation. These tools are also gaining importance in yield forecasting and assessment of production risks.

A combination of these scientific advances is making it possible for biophysical scientists and agro-ecologists to estimate physical, chemical and biological changes in agro-ecosystems associated with NRM interventions. When such changes can be understood or predicted, certain measurable indicators can be developed to quantify the magnitude of change associated with a given intervention. Indicators may be developed through experimentation and proper monitoring of changes over a sufficient period of time or through the application of exploratory and predictive simulation models. Chapters 3, 4 and 5 in this volume examined specialised indicators of soil quality, water quantity and quality, and changes in other agro-ecosystem services.

For impact assessment purposes, the most useful indicators of ecosystem functions and services show impacts within 3–5 years of an NRM intervention. For soils, Pathak *et al.* (Chapter 3, this volume) find that biological indicators like soil respiration, microbial biomass, and C and N mineralisation are useful, as are physical indicators such as nutrient runoff and soil loss. Relative to changes in soil quality indicators, changes in surface and groundwater quantity and quality can be observed in a relatively short period of time (Sahrawat *et al.*, Chapter 4, this volume). In order to measure NRM impacts on agro-biodiversity, Wani *et al.* (Chapter 5, this volume) suggest the following indicators for observation within 3–5 years: the index of surface percentage of crops, crop agro-biodiversity factor, and surface variability factors. Changes in biodiversity indicators related to genetic variability, species diversity or richness require longer periods to become visible, indicating the need for long-term follow up and monitoring. Changes in the level of carbon sequestered in soils and vegetation may require even long periods, making simulation modelling a promising approach for predictive purposes.

Valuation problems

When public funds have been invested in developing environmental services and measurable indicators of those services have been identified, a natural question is how to value changes in their status (as a step toward measuring return on investment). The value of a given resource or environmental service is measured in terms of trade-offs that consumers face with or without the change. The techniques for eliciting this information depend on the kind of markets at hand. For marketable goods and services, observed market behaviour can be used. Two such methods, applied by Drechsel *et al.* to valuing soil fertility changes, are the calculation of replacement cost and the value of a productivity change (Chapter 9, this volume). Even when a natural resource service is not traded, so long as there exist marketed substitutes, the behaviour observed in markets for the substitute can be used for valuation of changes in quality or quantity. However, markets for factor inputs (e.g. land and labour) in developing countries are often imperfect, limiting the usefulness of market prices in valuation studies. Even when markets function well, NRM technologies may not generate goods and services that are traded in markets. As Shiferaw *et al.* (Chapter 2) show, the social benefits associated with changes in NRM are typically non-marketed, ruling out the use of actual markets to measure the economic values of changes in natural resource service flows due to NRM technologies. However, techniques exist for estimation of non-use values and indirect use values that are not traded in markets. In particular, contingent valuation and similar non-market valuation techniques need to be tested and developed for application to NRM impacts in agriculture. Although benefit transfer methods have been proposed to reduce the cost of estimating non-market values, they are of limited relevance when economic and ecological conditions differ markedly between the original location and the one where the values would be applied.

Attribution Problems

Establishing a cause–effect relationship between NRM programme interventions, intermediate outcomes and developmental or environmental impacts can be challenging. First, *ex post* impact assessments often rely on scanty cross-sectional adoption data, making it difficult for the impact evaluator to see the full picture of technology dissemination. Second, crop and resource management research often is not embodied in an observable physical entity that farmers can adopt or reject. The improved management practices are knowledge-intensive techniques transmitted as a recommendation or as a cognitive framework regarding such topics as pest management or soil conservation. Among the multiple sources of such information, it may be difficult to attribute changes in management practices to any given source (Traxler and Byerlee, 1992). Third, in contrast to crop improvement research, NRM research frequently involves multiple interactions, multiple stakeholders, and participatory processes. These characteristics pose formidable complications to the attribution of project impacts to a given research or development intervention (Freeman *et al.*, Chapter 1, this volume). Douthwaite *et al.* (Chapter 14, this volume) discuss the rationale for qualitative, step-wise and adaptive monitoring and evaluation methods for understanding the innovation process and how adoption begets outcomes that in turn beget impacts.

Beyond attribution, NRM impact analyses must measure impacts against the counterfactual case of what would have occurred in the absence of the NRM intervention – whereas scientific experiments typically include a control treatment as a baseline against which to judge other intervention effects. Although social programmes are often practically (or ethically) constrained from including a true control treatment, impact assessments must still characterise and try to measure the counterfactual case.

Various quasi-experimental approaches are suitable alternatives (Cook and Campbell, 1979). Baseline data are essential for reliable estimates of the changes attributable to the NRM intervention. One practical approach is the double-difference comparison. This method involves comparing relative changes in performance indicators before and after the NRM intervention between participants and non-participants. Careful research design and statistical analysis can help control for selection bias and other attribution problems (Pender, Chapter 6, this volume).

Integration of Resource and Environmental Impacts into Economic Impact Assessment

The economic surplus (ES) framework is the most desirable approach for summarising the economic welfare impacts of agricultural research investments. The classic ES approach measures the shift in a product supply curve resulting from technological change. The supply shift triggers changes in consumer surplus and producer surplus. Although benefit–cost analysis has been applied to a number of NRM projects, there have been scarcely any attempts to apply the ES approach (Alston *et al.*, 1995; Swinton, Chapter 7, this volume). The ease with which resource and environmental impacts can be integrated using this framework depends on the type of NRM intervention. Because non-market environmental or health effects often are not directly tied to agricultural output, productivity and environmental impacts must be calculated separately. Estimating ES for environmental impacts will require a simulated or surrogate market in which the marginal willingness to pay (WTP) (demand) curve can be estimated separately. Further research is needed to define the conditions under which the total ES may be measured as a sum of the economic surplus from productivity changes in the marketed commodity plus the estimated economic surplus from the simulated markets for environmental and health services. NRM may also change the quality of the products, which may induce a shift in consumer demand as well as in producer supply. Impact evaluation in this case will require measurement of the supply as well as the demand shifts (Swinton, Chapter 7, this volume).

At present, however, the suggested methods for integrating quantitative estimates of both marketed productivity impacts and non-marketed environmental impacts are untested. The current state of the art is exemplified by Bantilan *et al.* (Chapter 11, this volume), which combines an estimate of economic surplus based on marketed productivity changes with an inventory of environmental benefits and costs. The authors conduct a qualitative assessment of the environmental benefits vs. costs, concluding that environmental net benefits are positive. Based on this result, they infer that the market-based net benefits estimated from productivity enhancement alone are a lower bound for the true combined net benefits from both productivity and environmental dimensions.

Two broad classes of empirical methods are used to estimate changes in ES. When past data are available about the performance of NRM interventions, econometric regression methods can be used for several important purposes. First, econometrics is widely used to test the potential effects of NRM changes on productivity (Pender, Chapter 6, this volume). When data from a sufficiently large sample is available, econometric methods are useful in testing whether investments in specific crop and resource management practices had significant effects on productivity or on the quality of the resource base (Pender, Chapter 6; Kerr and Chung, Chapter 10, this volume). Careful econometric analysis can substantially reduce the problems of attribution. Second, econometric inverse demand models are used to estimate the price elasticity of demand for marketed (and non-marketed) products. Third, econometric models can identify the factors determining both: the likelihood of adoption of an NRM innovation; and the degree of NRM used by those who have adopted.

When sufficient data are not available for econometric estimation, an alternative useful approach for estimating the magnitude and form of production and environmental effects is bioeconomic modelling (Kruseman and Bade, 1998; Barbier and Bergeron, 2001; Okumu *et al.*, 2002; Holden and Shiferaw, 2004). Using mathematical relationships, bioeconomic models link economic behavioural objectives with key ecological and production processes that determine biophysical outcomes (Oriade and Dillon, 1997). As discussed by Holden (Chapter 8, this volume) such integration allows the analysis of efficiency, distributional and sustainability impacts of proposed technology and/or policy interventions (Ruben *et al.*, 2001). The approach can also be used to measure the impact of these interventions *ex post*. A household-scale example is the impact analysis of soil and water conservation technologies (Shiferaw and Holden, Chapter 12, this volume). At the regional scale, computable general equilibrium (CGE) models become very useful to capture the economy-wide impacts of technology and policy interventions (Holden and Lofgren, Chapter 13, this volume). CGE models are particularly suited for assessing price effects and distributional issues associated with technical and policy interventions.

What We Need to Know – Areas for Future Research

Despite recent progress in developing methods for evaluating the impacts of productivity enhancing technologies on the one hand and for measuring natural resource service flows and their value on the other, these advances have not been unified in NRM impact studies. With very few exceptions, NRM impact evaluations have failed to incorporate the non-productivity related impacts (resource and environmental service flows) into economic impact assessments. This volume has brought together some of the methodological tools that can be used to integrate the sustainability impacts with the productivity impacts of agricultural NRM interventions. But the state of the art does not yet permit us to advocate 'best practices' for comprehensive evaluation of NRM impacts. Several knowledge gaps first beg the attention of researchers.

How does NRM affect ecosystem functions and services?

Our understanding of the impacts of human interventions on ecosystem functions and services at different scales and how this affects productivity, sustainability and environmental outcomes is still inadequate. The concept of 'natural resource management' itself is very broad, ranging from crop and livestock management practices to strategies for managing natural resources such as soils, water, biodiversity, fish and forests. Agricultural activities may have important externalities, such as global warming. Improved NRM enhances the provision of essential ecosystem services that reduce such negative environmental externalities. How different types of NRM interventions affect the flow of ecosystem services at different spatial and temporal scales is, however, not clearly understood. While there are several reports on the environmental impacts of intensive agricultural activities (e.g. the Green Revolution), there are few empirical examples for crops other than wheat and rice (Maredia and Pingali, 2001). The limited evidence and insufficient understanding of the key links between agricultural activities and how NRM would regulate this link, prevent quantification and measurement of key outcomes and potential impacts on human welfare. As Altieri has argued, 'what is lacking … is the explicit description of the scientific basis of NRM and of methods to increase our understanding of the structure and dynamics of agricultural and natural resource ecosystems and providing guidelines to their productive and sustainable management' (Altieri, 2002, p. 7). Such understanding is a key first step in enhancing attribution of certain environmental outcomes to NRM interventions. Progress toward better definition of agro-ecosystem functions and services is urgently needed. Simulation modelling offers an increasingly valid and cost-effective tool for understanding the biophysical dynamics of NRM interventions.

Indicators of ecosystem performance

To the extent that agricultural natural resource functions *are* understood, the measurement of their status and service flows remains too costly for practical impact assessment purposes. Inexpensive but reliable indicators continue to be needed. A core set of environmental and sustainability indicators would allow researchers to check for deviation from trend by gathering time-series data for regular ecosystem monitoring, not to mention establishing the counterfactual to NRM interventions. Some preliminary steps have been taken by the Heinz Foundation (http://www.heinzctr.org/ecosystems/index.htm), which started to monitor the state of US ecosystems in 1999. Their efforts offer useful criteria for consideration, although their indicators obviously need adaptation to the developing country settings of most NRM projects.

How to enhance attribution of impacts?

More systematic thinking is needed about how to measure the dissemination of knowledge-based technologies that are not embodied in improved tools or germplasm. Knowledge-based innovations appear less well suited to the reduced form input demand approaches that economists have used for embodied technologies like improved seeds. Better indicators for ecosystem performance measurement can help. So too can direct approaches to measuring farmers' knowledge and attitudes and how they affect the choice of management practices. The knowledge–attitudes–practices (KAP) model from epidemiology may be a start, as the explicit measurement of changes in knowledge and attitudes of a treatment group compared with a control can confirm attribution to project interventions. Indeed, explicit attribution becomes doubly important – albeit doubly complicated – when NRM technologies are introduced in tandem with genetic technologies or a newly supportive public policy. Careful adherence to sound impact assessment methods (especially the double-difference method) and strict adherence to avoid or measure selection bias among beneficiaries will have to be joined to closer scrutiny of knowledge and attitudes.

Can we properly value non-market ecosystem services?

Even when we can understand and measure cost-effectively the resource and environmental service flows from NRM interventions, shortcomings in our ability to measure the welfare impacts of these changes can impede accurate assessments. The reviews in this volume have identified several techniques used for valuation of non-market outcomes in the developed world (Shiferaw *et al.,* Chapter 2). Valuation methods for non-marketed ecosystem services (e.g. carbon sequestration in soil or biodiversity preservation) need to be tested and refined.

Many methods for measuring WTP for environmental services presuppose that consumers directly demand the service in question. Yet many agricultural NRM services do not fit that description. Few consumers would pay for the presence of *Rhizobium* bacteria in soil, yet the nitrogen-fixing services that they perform provide plant nutrition and, if carefully timed, may reduce nitrate leaching into drinking water supplies. In short, the demand for the services of *Rhizobium* bacteria is indirect, not direct. As such, it is analogous to the demand for other agricultural inputs. Two key factors differ, however. First, whereas conventional derived input demand arises solely from market prices and factor endowments, part of the derived demand for NRM services originates in a direct demand for health that affects the non-market valuation of exposure to reduced drinking water quality. Second, that same health component involves externalities to neighbours of the producer, a stakeholder group whose members' utility is not included in an indirect demand function based upon the marketed agricultural product. Moving from theory to practice in measuring indirect WTP for environmental and health services will be complex. A major desirable innovation is to find lower cost – yet accurate – ways to estimate downward-sloping inverse demand curves as a basis for estimating elasticities of demand for non-market environmental and health services.

For policy purposes, a simpler approach than measuring WTP is to measure farmers' willingness to *accept* compensation for the non-marketed health and environmental services that they provide. This will be a compensating surplus measure for farmers to provide essential services to society. Such measures will require more bioeconomic modelling in order to estimate the opportunity costs implicit in providing cost-increasing health and environmental services.

Can the economic surplus approach be extended for integrated assessment?

Despite its strengths, the economic surplus approach has been criticised on several counts. For purposes of NRM impact assessment, the most serious of these is its failure to account for environmental impacts that are external to functioning markets. One of the goals of NRM is to reduce the undesirable on-site and off-site externalities associated with agricultural production. Two chapters in this volume (Swinton, Chapter 7 and Bantilan *et al.*, Chapter 11) have discussed the ways to extend the economic surplus approach towards comprehensive evaluation of productivity and environmental impacts. However, progress in this area has been hampered by measurement problems, the high cost of WTP estimation, and the difficulties of mixing values assessed from different market settings (e.g. real markets and hypothetical ones). Initial efforts to integrate productivity and environmental impacts in a comprehensive assessment should focus on simple cases where price elasticities of demand can readily be estimated. Serious thinking is needed on how to combine productivity and environmental effects in computing a single, comprehensive measure of impact from NRM interventions.

Alternatively, the economic surplus approach to productivity impact assessment may be supplemented by qualitative information. Some audiences uncomfortable with the demanding assumptions required for many WTP estimation studies may consider these methods more valid. The participatory methods for interdisciplinary analysis of adoption pathways, processes and outcomes may also contribute to participant empowerment that can enhance impacts, whether or not they enhance impact assessment *per se*.

What do we know about economy-wide impacts?

In addition to direct effects associated with supply shifts, agricultural productivity interventions also generate indirect economic effects through product and factor market linkages. The overall effect of technical change from research and development (R&D) interventions hence depends on system-wide growth and multiplier effects induced through input use, factor markets and production linkages (Maredia *et al.*, 2000). For comprehensive evaluation of large-scale NRM impacts, it would be useful to include these general equilibrium or economy-wide effects. While this can be done using a CGE model (Holden and Lofgren, Chapter 13, this volume), there is limited experience in developing CGE models that incorporate environmental and sustainability impacts. In situations where substantial impacts occur from both general equilibrium market effects and sustainability effects, it could be very rewarding to develop and employ such methods. Standard CGE models (Lofgren *et al.*, 2002) are now being developed for many developing countries, and these models deserve research into possibilities for adaptation to evaluate NRM technology and policy impacts.

Simple steps toward better impact assessments

Advance planning can greatly improve the quality of NRM impact assessments. The classic principles of quasi-experimentation remain relevant: to compare affected and unaffected groups before and after the program intervention, taking care not to bias results due to non-random selection of participants (Cook and Campbell, 1979). The few NRM impact assessments available have had adequate baseline data only on the productivity dimension, not on environmental and health dimensions. In some instances, this is because intended environmental and health outcomes had not been clearly specified at project outset.

For effective impact assessments, baseline data on all intended outcomes dimensions is necessary. Acquiring such data calls for projects *before implementation begins:* 1. to specify clearly the intended outcomes; 2. to choose acceptable indicators of important outcome dimensions; 3. to identify comparable, paired groups inside and outside the intervention area; and 4. to budget for and to conduct baseline studies on the intended outcomes and related variables for the paired groups within and without the NRM intervention zone. It goes without saying that planning and budget are also needed for one or more follow-up studies to measure progress toward the intended outcomes – again, among comparable households both affected and unaffected by the NRM programme. Ensuring that appropriate baseline and follow-up data are collected is not only possible; it will also greatly facilitate advances in the methodological areas listed above.

Institutionalising NRM impact assessment

If it is to affect institutional decision making, NRM impact evaluation needs to be integrated into programme planning in research and development institutions. An institutional learning cycle from programme planning to implementation to impact analysis and back to programme planning can help to ensure that lessons are learned and plans modified systematically. Such a process is more likely to prevent uncorrected flaws from turning well-conceived programmes into vaunted 'failures'.

NRM impact assessment can be conducted internally within R&D institutions or subcontracted to external evaluators. But there are compelling reasons for R&D institutions to institutionalise IA capacity 'in-house' if they are to be effective in influencing internal programme planning. Some R&D institutions have institutionalised impact assessment within an independent economics or social science programme. However, given the trend toward replacing disciplinary research areas with thematic research areas, a promising approach is to institutionalise IA capacity into a specialised impact assessment unit that reports directly to senior management. Staff in this unit should be drawn from both the social and the biophysical sciences, in order to provide comprehensive analysis of the multi-dimensional and non-monetary impacts of NRM interventions. Such a unit can provide intellectual leadership for all IA studies and can provide a platform for integrating the results from impact assessment studies into institutional learning and research planning for the purpose of enhancing future impacts.

An independent IA unit can be effective at forging strategic alliances between research institutes, development partners, and advanced research institutes. The chapters in this volume demonstrate how comprehensive assessment of NRM impacts can emerge from strategic partnerships between university-based researchers (with a comparative advantage in development of theories and methods for assessing NRM impacts) combined with researchers in R&D institutions (with comparative advantages in empirical applications of these methods, synthesis of experience, and scaling-up results).

Research managers also need to think carefully about how much to invest in impact assessment. A standing IA unit can be expensive, and R&D institutions exist primarily to generate impacts, not to measure them. Yet in a world where many institutions claim to generate impacts and compete for funds to sustain their efforts, a competitive advantage can be built from the institutional capabilities to perform high-quality impact assessments and to adapt programme planning systematically based upon the lessons learned. Building such capabilities will require a modest proportion of core funds on a continuing basis, with the understanding that the IA unit will help to attract competitive funds through collaboration with thematic units on project design.

Conclusions

Reducing poverty and ensuring livelihood security for the millions of impoverished people whose subsistence depends on agriculture will not be possible without judicious management of the productive resource base. But failure to demonstrate desired impacts could undermine current R&D efforts in developing and disseminating new innovations that provide dual productivity and sustainability benefits. Although many NRM interventions do not provide direct short-term net economic benefits to producers, they do generate non-marketed ecosystem goods and services that are essential for sustaining agricultural productivity and environmental quality. Failure to incorporate the value of environmental and health outcomes of agricultural NRM investments will lead to bias and likely underestimation of their social net benefits, followed by underinvestment from the standpoint of social welfare. The mirror image of such misallocation of R&D resources is equally troubling, for it entails overinvestment in agricultural programmes that may cause environmental and health damage.

Methods for comprehensive economic impact assessment that would integrate productivity, environmental and sustainability impacts are only just beginning to emerge. This volume has assembled recent methodological advances from this nascent area. It has critiqued the methodological *status quo*, and sought to define new horizons for experimentation to refine current practices and to develop second-generation methods that address existing and emerging challenges. The key challenges relate to measurement, indicators, valuation and attribution of impacts.

As we look into the future, NRM is entering a new era. With the emerging recognition that participatory NRM projects can empower individuals and communities, empowerment is shifting from being an unintended to an intended benefit. As it becomes an explicitly intended outcome of integrated NRM projects, empowerment begs the same needs for measurement, attribution and valuation that have challenged assessments of environmental and health dimensions of NRM interventions. Likewise, INRM projects typically prioritise poverty alleviation, making measures of income distribution effects another newly important dimension of NRM impact assessment.

In addition to application of new methods from environmental and resource economics, future NRM impact assessments have much to gain from employing a mix of quantitative and qualitative approaches. This can enrich interpretation and communication of outcomes and assist in their attribution. Qualitative methods can be especially helpful at elucidating *how* outcomes came to be. Such process understanding has particular value for unanticipated outcomes, with an eye to ensuring that desirable ones can be replicated and undesirable ones avoided in future.

Participatory impact assessments by NRM project beneficiaries may also enhance the empowerment outcome and associated impacts. However, the role of such participatory assessments should be recognised as a self-monitoring activity that is part of the project effort, not a true impact assessment of what would have occurred without the project. Accurate impact assessment, even of environmental and empowerment dimensions, must adhere to the basic principles of: 1. freedom from participant selection bias; 2. before vs. after comparisons aided by baseline information; and 3. 'with vs. without' measures of what the intervention accomplished.

The needs for improved methods for economic and social impact assessment are matched by needs for improved understanding of ecosystem performance. Following Altieri's call for increased 'understanding of the structure and dynamics of agricultural and natural resource ecosystems and providing guidelines to their productive and sustainable management' (Altieri, 2002, p. 7), the need for close future interdisciplinary collaboration is clear. Forging strong linkages and effective dialogue among ecologists, economists, and other social scientists is a *sine qua non* for future advances in scientifically sound natural resource management interventions and for thorough and balanced evaluations of their impacts.

References

Alston, M.J., Norton, W.G. and Pardey, P.G. (1995) *Science Under Scarcity. Principles and Practice for Agricultural Research Evaluation and Priority Setting.* Cornell University Press, Ithaca, New York, and London, UK, 585 pp.

Alston, J.M., Marra, M.C., Pardey, P.G. and Wyatt, T.J. (1998) Research returns redux: A meta analysis of returns to agricultural R&D. *EPTD Discussion Paper No. 38.* International Food Policy Research Institute (IFPRI), Washington, DC, 44 pp.

Altieri, M. (2002) Agroecology: the science of natural resource management for poor farmers in marginal environments. *Agriculture, Ecosystems and Environment* 93, 1–24.

Barbier, B. and Bergeron, G. (2001) Natural resource management in the hillsides of Honduras. Bioeconomic modeling at the microwatershed level. *IFPRI Research Report No. 123.* International Food Policy Research Institute (IFPRI), Washington, DC, 59 pp.

Cook, T.D. and Campbell, D.T. (1979) *Quasi-Experimentation: Design and Analysis Issues for Field Settings*. Houghton Mifflin, Boston, Massachusetts. 405 pp.

Gumtang, R.J., Pampolino, M.F., Tuong, T.P. and Bucao, C. (1999) Groundwater dynamics and quality under intensive cropping systems. *Experimental Agriculture* 35, 153–166.

Gupta, R.K. and Abrol, I.P. (2000) Salinity build-up and changes in the rice-wheat system of the Indo-Gangetic plains. *Experimental Agriculture* 63(2), 273–284.

Holden, S.T. and Shiferaw, B. (2004) Land degradation, drought and food security in a less-favoured area in the Ethiopian highlands: a bioeconomic model with market imperfections. *Agricultural Economics* 30(1), 31–49.

Kruseman, G. and Bade, J. (1998) Agrarian policies for sustainable land use: bio-economic modeling to assess the effectiveness of policy instruments. *Agricultural Systems* 58, 465–481.

Lofgren, H., Harris, R.L. and Robinson, S. (2002) A Standard Computable General Equilibrium (CGE) Model in GAMS. *Microcomputers in Policy Research.* Volume 5. International Food Policy Research Institute (IFPRI), Washington, DC, 69 pp.

Maredia, M. and Pingali, P. (2001) *Environmental Impacts of Productivity-Enhancing Crop Research: A Critical Review*. Standing Panel on Impact Assessment (SPIA), Food and Agriculture Organization of the United Nations (FAO), Rome, Italy, 36 pp. http://www.sciencecouncil.cgiar.org/publications/ispubs.htm.

Maredia, M., Byerlee, D. and Anderson, J. (2000) *Ex post* evaluation of economic impacts of agricultural research: A tour of good practice. *Paper presented at the workshop on the Future of Impact Assessment in the CGIAR: Needs, Constraints and Options. Standing Panel on Impact Assessment (SPIA), May 3-5, 2000, Rome, Italy*, 39 pp. (unpublished) http://www.cgiar.org/who/wwa_spiameet.html.

Nelson, M. and Maredia, M. (1999) Environmental impacts of the CGIAR: An initial assessment. *Paper presented initially at the International Centers Week, 25–29 October 1999, Washington, DC. Standing Panel for Impact Assessment. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy*, 71 pp. (unpublished) http://www.sciencecouncil.cgiar.org/publications/ispubs.htm.

Okumu, B.N., Jabbar, M.A., Coman, D. and Russel, N. (2002) A bioeconomic model of integrated crop–livestock farming systems: the case of Ginchi watershed in Ethiopia. In: Barrett, C.B., Place, F. and Aboud, A. (eds) *Natural Resource Management in African Agriculture*. CAB International, Wallingford, UK, pp. 235–249.

Oriade, C. and Dillon, C.A. (1997) Developments in biophysical and bioeconomic simulation of agricultural systems: A review. *Agricultural Economics* 17, 45–58.

Pingali, P.L., Marquez, C.B. and Palis, F.G. (1994) Pesticides and Philippine rice farmer health: A medical and economic analysis. *American Journal of Agricultural Economics* 76(3), 587–592.

Pretty, J.N., Brett, C., Gee, D., Hine, R.E., Mason, C.F., Morison, J.I.L., Raven, H., Rayment, M.D. and van de Bijl, G. (2000) An assessment of the total external costs of UK agriculture. *Agricultural Systems* 65(2), 113–136.

Ruben, R., Kuyvenhoven, A. and Kruseman, G. (2001) Bioeconomic models for ecoregional development: Policy instruments for sustainable intensification. In: Lee, D.R. and Barrett, C.B. (eds) *Tradeoffs or Synergies? Agricultural Intensification, Economic Development and the Environment*. CAB International, Wallingford, UK, pp. 115–134.

Traxler, G. and Byerlee, D. (1992) Economic returns to crop management research in a post-green revolution setting. *American Journal of Agricultural Economics* 74(3), 573–582.