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Ex Post Methods to Measure Natural Resource Management Research Impacts

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1. Introduction

The objectives of this paper are to identify methods and approaches for *ex post* impact analysis (IA) of natural resource management (NRM) research used within the CGIAR, and to provide an overview of Center *ex post* IA research activities. Based on our review of progress made in NRM research and associated IA, the paper also takes the position that IA cannot be limited either to economic analysis of more readily measurable variables or to process monitoring. The paper concludes with recommendations associated with a way forward.

Investments in NRM research in the CGIAR have increased substantially over the past decade. Both NRM programs within traditionally commodity-oriented Centers and the newer Centers oriented towards resource and environmental issues have been favored (Anderson and Dalrymple 1999, Barrett 2002, Kelley and Gregersen, forthcoming). CG NRM research has not only expanded, but has also made an irregular transition from work at the plot and farm levels to wider scales, and in so doing, from work to increase the private benefits of selected farmers to work with multiple stakeholders with differing objectives, both public and private. The need to strengthen this latter "Integrated Natural Resource Management" (INRM) research was recognized by the third CGIAR external review (CGIAR/TAC 1998). Researchers have modified IA methods as the research domain has grown. IA expanded from a largely economic focus to include considerations related to poverty, social and human capital, human health, "well-being", and the environment. While the "*ex post*" nature of IA of NRM crop productivity enhancement innovations is relatively straightforward, much of INRM research is seen as a long-term research and development cycle in which today's *ex post* IA becomes the basis of process changes and next-step *ex ante* IA. Participatory monitoring and assessment provides contemporaneous information to adjust the research and development interventions.

This paper: 1. categorizes four overlapping types of NRM research and associated IA methods within the CG, 2. provides examples *ex post* IA of the different categories of NRM/INRM research, 3. summarizes each Center's description of their methods and approaches, 4. considers the implications of IA methods in terms of questions or issues addressed, and 5. suggests "a way forward". The examples of NRM/INRM IA emanate from a large body of research identified by the authors, helpful colleagues throughout the CG system and from the web pages of the different Centers. The cases represent what eventually fit into the four identified categories of NRM/INRM research.

1.1 Four overlapping, evolving categories of NRM/INRM and associated IA methods

NRM/INRM research encompasses four overlapping sets of activities and associated sets of *ex post* IA methods.

1.1.1 NRM to increase crop productivity. Starting with the efforts that led to the "Green Revolution", CG research has worked to improve crop productivity through innovations in the management of resources such as soil, soil nutrients, and water.

Associated IA approach. IA of resource management research for enhancing crop productivity examines the effects of innovations on crop outputs at the field and farm levels under controlled conditions. Impact estimates are extrapolated after farmer adoption takes place. Cost-benefit analysis and returns to different factors of production are common tools. Comparison between large samples of adopters and non-adopters is used to estimate the impact of green revolution technologies such as irrigation and fertilizer.

1.1.2 NRM to increase farm productivity and resource use efficiency. Starting with what came to be known as Farming Systems Research, equally high investments have been aimed at developing means to increase whole farm productivity and resource use efficiency through innovations such as contour hedgerows for soil erosion control, alley cropping, agroforestry, cover crops, and conservation agriculture. In many cases, these innovations have been tied to the development, testing, and dissemination of adapted germplasm and of combinations and sequences of crops and cultivars (i.e., what was called "Cropping Systems Research").

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

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

Associated IA approach. A great deal of what can be considered IA is current scenario characterization using GIS data and *ex ante* modeling of future outcomes if mitigation does not take place. Although efforts at mitigation have yet to mature, if and when mitigation does take place, *ex post* impacts will be measured in terms of the particular resource or environmental measures of interest. Again, the desirable measures will be reductions in greenhouse gas emissions, area reforested, decreases in deforestation rates, mangrove areas saved, wetlands rehabilitated, preservation of biodiversity via creation of reserves, and rehabilitation of degraded lands. Valuation of these mostly public goods, however, remains problematic.

1.1.4 Integrated Natural Resource Management (INRM) research. Centers are currently engaged in integrated, more process-based efforts to enhance the outputs of both private (farm production) and public (environmental) goods in ways that reconcile the often-conflicting desires of different stakeholders working at different spatial and temporal scales. TAC states: "International integrated NRM research should be process oriented to ensure maximum contribution to production of international public goods" (TAC 2001).

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

2. Examples of IA of NRM/INRM

2.1 IA of NRM research to increase crop productivity

The impacts of research on soil nutrients and water management innovations have been assessed using tools from agricultural economics. In these studies, *ex post* economic impact analysis is conducted to estimate private benefits; and wider impacts are extrapolated as technology adoption takes place.

2.1.1 Impacts on crop yields; benefit-cost ratios, wider impacts extrapolated if/when adoption spreads.

IRRI examined the effects of different types of water supply (on-farm reservoirs in rainfed rice areas of the Philippines, tank and well water in South Asia) on rice yields. The potential impacts of on-farm reservoirs were assessed using benefit-cost ratios that considered increased wet season yields, addition of a dry season crop, fish as an additional benefit for some, as well as maintenance costs and reservoir life span (Moya *et al* 1994). Work in South Asia compared rice yields in water-excess and water-deficit years; and was assessed using a simultaneous equation model to examine water source, nitrogen, labor, and crop management impacts on yields (Palanasami and Flinn 1989).

2.1.2 Quantitative assessment after widespread adoption of those with and without (irrigation).

IWMI recently examined the socioeconomic impacts of irrigation in South Asia (Bhattarai *et al* 2002). The study, which in general sought to determine the irrigation impacts on income inequality and poverty, compared relative yield performance of irrigated and unirrigated agriculture at different scales in Asia; and analyzed income inequality and poverty in irrigated and unirrigated agriculture. Researchers also studied irrigation multiplier effects, irrigation and benefits to consumers through declining food prices, and head-tail inequity. Variables included crop production/yield improvement, farm income, cropping intensity and crop diversity, farm employment, farm consumption, permanent wealth, transaction costs including farm marketing costs, multiple uses of water, groundwater access and recharge, income effects of irrigation, and benefits to national governments from export tax revenues. Methods applied in the comparison of irrigated and unirrigated areas were largely standard benefit-cost ratios, gross margins, and Gini coefficients. Researchers plotted family income vs. number of households for different regions and types of irrigation representing different poverty reduction strategies in order to assess alternative policy options for reducing income inequality. Differential impacts for head- and tail-end farmers were compared using hypothetical production functions and the marginal returns to land. Analysis concluded with six policy options to improve the productivity and equality of irrigation systems.

Questions and issues addressed. Both cases examine private field and farm impacts of natural resource use (e.g. of water and soil nutrients). The first case implicitly extrapolates economic impacts based on observations of a relatively few “early adopters”). The South Asia example of IA is particularly suited to assessing the farm and regional economic impact of widespread adoption of more traditional green revolution technologies. Costs and benefits of modern varieties, irrigation, fertilizers, and pesticides, for example, can be calculated and compared for large areas and numbers of people using survey data and official statistics.

Questions and issues not necessarily addressed. Attribution of benefits: it is not necessarily certain in the South Asia irrigation example that people were “the same” prior to the construction of irrigation systems and that any current differences are due to irrigation. Public benefits related to watershed functions (e.g. from surface- and groundwater availability) are not addressed.

2.2 IA of NRM research to improve farm productivity and resource use efficiency

The impacts of research on soil, soil fertility, soil biology, and water management innovations have been assessed using tools from agricultural economics and some bio-physical measures (e.g. changes in soil erosion rates). In these studies, *ex post* economic impact analysis is conducted for a limited number of controlled plot and on-farm studies; and wider impacts are extrapolated as technology adoption takes place.

2.2.1 Quantitative economic analysis plus adoption analysis.

The economic impacts of ICRAF's experimental field research in Zambia on improved tree-based fallows over multiple seasons were examined using analysis of returns to land and labor and costs-benefits at the farm level. Adoption levels, which were reportedly substantial, and reasons for and against adoption provided by farmers were also considered (Franzel *et al* 1999). IA of this type has been repeated for other ICRAF research (Place *et al* 2002).

CIMMYT worked with farmers in El Salvador on combinations of productivity enhancing and soil conserving practices. Sain and Barretto (1996) combined quantitative and descriptive analyses. A logistic function estimated the cumulative adoption pattern of conservation tillage plus residue management and a production package centered on hybrid maize. Extension and adoption had taken place 15 to 20 years prior to the IA. Researchers assembled the analysis using farmer interviews, crop measurements taken in farmers' fields, and characterization of the institutional context present in the different areas visited at the time of technology introduction and adoption. Partial budgets were used to evaluate the adopted conservation and productivity components. Analysis took account of crop residues, number of cattle and duration of the grazing period, markets for grazing rights and processed stover. Marginal rates of returns for the combined set of innovations reflected that: "Although the conservation component showed a cost increase in the short term, the increase in production and gross benefits from the productivity package compensated for the higher variable costs" (Sain and Barretto 1996:318).

The development and spontaneous diffusion of a maize-mucuna system to the north coast of Honduras became a "success story" of sustainable agricultural practices for CIAT, CIMMYT, and partners. Unfortunately, adoption was followed by disadoption. Researchers from the Ford Foundation and Cornell University applied an empirical modeling approach, bivariate probit, to the sequential process of maize-mucuna adoption and abandonment (Neill and Lee 2001). Adoption-disadoption was found to depend on external factors, agronomic and biophysical factors internal to the maize-mucuna system, and management related issues. This comprehensive study combined a convincing, pieced-together descriptive picture of the interactions among a host of variables and analysis of technology choice using logit and probit models to compare adopters and non-adopters based on farm, household, and environmental characteristics.

Questions answered and issues addressed. Cost-benefit analysis of particular technologies provides a picture of potential economic impacts at the private, farm level that can and is extrapolated once adoption takes place.

Questions and issues not necessarily addressed. It is assumed but not necessarily certain that if and when adoption takes place that the economic impacts calculated at the field and farm level would hold true for the later adopters (as highlighted by the disadoption study). Augmentation of farm level natural resource capital was assumed through crop responses rather than explicitly measured.

2.2.2 Adoption equated to impact

CG researchers commonly employ adoption studies as a form of *ex post* IA. Much of the impact of NRM research has been assessed by examining numbers of farmer adopters and farmer reasons for adoption or non-adoption. Examples include IITA's work on alley farming and mucuna cover crops (Douthwaite *et al* 2003) and ICRAF's extension of agroforestry practices (Cooper and Denning, eds.1999).

The ICRAF work at various sites was presented through descriptive case studies. The "Landcare Movement" in the Philippines, for example, sought biodiversity conservation and agroforestry development. Impacts were expressed in terms of adoption of vegetative contour strips and maize yield increases without cost data (Garrity *et al* 2003). Biodiversity impacts were not measured. Participating researchers working on the combined set of case studies derived "ten fundamentals of scaling up" (Cooper and Denning, eds. 1999).

Questions answered and issues addressed. Adoption of improved technologies and management is and should be a goal of NRM/INRM research. ICRAF, for example, wants to reach 80 million people in 10 years. Numbers of adopters is a good indicator of impact and of scaling up.

Questions and issues not necessarily addressed. Adoption studies appear to assume positive impacts of the technologies and practices, although evidence of impacts and clarity in terms of what constitutes "adoption" itself are often lacking. Public benefits are not estimated.

2.2.3 Impacts of user participation and gender analysis on the research process.

2.2.3.1 Largely descriptive accounts

A large part of CGIAR *ex post* IA is descriptive accounting of the effects of user participation and gender analysis on the research process. For example, ICLARM's work on aquatic resources management in Vietnam found that women compared to men contribute more labor have less access to resources, have different roles in wetland management, and have different priorities (described in Saad 2003). CIAT used a "resource to consumption" approach in Uganda, finding that women's participation led to gaining better access to technologies (described in Saad 2003). CIFOR examined the strengths and weaknesses of consultative vs. collaborative participatory forest management in Nepal and Indonesia. Impacts were expressed in terms of local ownership and access to decision making (Milne *et al* 2002).

The effects of participation on adoption are often described. CIAT's work on soil conservation (Ashby *et al* 1996), for example, highlighted the importance of farmer participation in the design and farmer-to-farmer transfer of innovations if adoption is to take place. ILRI's assessment of the adoption of soil management emphasized the role of "site stakeholder committees" which allowed for the differentiation of farmers and a subsequent matching of different farmers to specific innovations (Jabbar *et al 2003).*

Questions and issues addressed. It appears clear that user participation, paying attention to gender, access to technologies, and decision-making power have positive effects on the development and adoption of more appropriate and more gender-equitable NRM innovations.

Questions and issues not necessarily addressed. Eventual economic impacts in terms of direct improvements to human well-being can be unclear.

2.2.3.2 A mixture of qualitative and quantitative methods to analyze effects of user participation on the research process; research to produce multiple types of impacts.

IA relying on combinations of qualitative, quantitative, and descriptive data and associated data gathering methods have been readily accepted as necessary, but have not been common in practice.

In one example, CIAT social scientists measured "…the impact of user participation in agricultural and natural resource management research" in three projects (Johnson *et al* 2003). Examined were a CIP-led integrated crop (sweet potato) management and farmer field school project in Indonesia, an ICRISAT project featuring participatory testing of soil fertility technologies in Southern Africa, and World Neighbors' soil conservation work in Honduras. Mixed methods were employed to assess technological, economic, human, and social impacts and the cost implications of participatory research. Impacts of participation on human and social capital were assessed qualitatively. Conventional adoption/adoptability studies examined the impacts of participation on adoption. Economic impacts of technologies were analyzed using conventional econometric analysis. Cost implications of participatory research were deduced based on project financial data. Because the research was conducted to determine incremental impacts associated with user participation rather than total project impacts, counterfactuals were carefully defined and compared (i.e., similar participatory vs. non-participatory projects). The researchers addressed the issues of causality or attribution, and selection bias. Can projects eventually take credit for helping to build social capital when, in fact, communities were self-selected or selected by researchers in part based on initial higher levels of social capital? IA specifically looked at the influence of user participation: on the setting of research goals and priorities, on the building of local experimentation and problem-solving skills, on adoption, on economic impacts of adopted technologies, and on costs of research. The bottom line, as in many similar studies, was that participation positively affected "…adoption and economic impact of technologies by improving relevance and appropriateness of the technology to the potential beneficiaries, and thereby enlarging the pool of potential adopters (Johnson *et al* 2003).

IRRI's work with upland farmers in the Philippines included initial farmer-to-farmer learning followed by participatory development and adaptation of soil erosion control measures. Farmers with researcher collaboration developed what were later called "natural vegetative strips". Costs largely in terms of labor inputs and benefits in terms of reductions of soil erosion and natural formation of terraces were quantified. Adoption was monitored and qualitatively assessed using farmer interview data. Farmer participation led to vegetative contour strips that were as or more effective in controlling soil movement and that had much lower establishment costs compared to planted strips first introduced as a "starter technology" (Fujisaka 1993).

A double hurdle statistical analysis of adoption of soil conservation in northern Ethiopia examined cause of adoption vs. intensity of use. Farmers' reasons for adoption or non-adoption were elicited. Stone terraces were adopted in he presence of land tenure security, available labor, proximity to farmstead, food-for-work, and yield benefits. Less intensive soil bunds were adopted where land tenure security and food-for-work were absent. How to arrive at appropriate public interventions was also discussed (Gebremedhin and Swinton 2003).

Questions and issues addressed. Different selected quantitative and qualitative measures can be used to assess the research process and adoption rates.

Questions and issues not necessarily addressed. Ultimate impacts in terms of human and environmental well-being are not derived.

2.2.4 "Good news" stories about NRM research results.

Various recent CG publications have been centered on supposed "success stories". Examples of multi-center efforts include: "Good News from Africa: Farmers, Agricultural Research, and Food in the Pantry" (Schioler 1998), "From the Rural Heart of Latin America: Farmers, Agricultural Research and Livelihoods" (Schioler 2002), the "Five-year Synthesis Report" of the Systemwide Program on Participatory Research and Gender Analysis (Saad 2003).

Participants in a session "Telling the story: how to articulate better what INRM and its impacts are" of the 2002 CG workshop "Putting Natural Resources Management in Action" planned to provide "Case examples of successful INRM projects underway", a "Booklet 'telling the whole story' by the INRM task force" and a "Manual for INRM scientists conducting the program", with the last based on the first two outputs (Turkelboom *et al* 2003). The workshop provided little in the way of *ex post* IA methods, other than the now commonplace exhortation favoring consideration of more factors and actors and against models of linear causality not appropriate to INRM.

Questions and issues addressed. These readable anecdotes often tell stories that consider and integrate a range of interacting variables and actors.

Questions and issues not necessarily addressed. Lack of data often obscures actual extent and degrees of livelihood impacts. "Failure stories" which cost as much as success are not presented or analyzed for equally valuable lessons learned.

2.3 IA of NRM research to protect, conserve natural resources and to reverse degradation

A relatively new area of CG NRM research is examination of global trends related to natural resources. Studies examine the dynamic effects of human activities on land, water, climate, forests, and biodiversity. Such research looks forwards and backwards to determine, among others, the impacts of alternative resource use systems, including those developed based on NRM research, on global environmental services.

2.3.1 Studies to determine the effects of innovations on observed impacts on particular resources

Deforestation is a now commonly measured impact of land use. Has NRM research led to more or less deforestation? Many researchers addressed the topic in a 1999 workshop and resulting book, *Agricultural Technologies andTropical Deforestation* (Angelsen and Kaimowitz, eds. 2001). The book deals with the impacts of technical and policy research on tropical deforestation. With historical records and, more recently, with remote sensing tools, the rates and magnitudes of deforestation are not difficult to obtain. The causes of the observed land conversion, however, are trickier to unravel. Many CG researchers hope or believe that agricultural innovations can reduce deforestation by leading to greater production on existing farmland. Others find that technologies that make agriculture more profitable promote expansion into forest lands. A third view (and one held by the authors of this paper; White *et al* 2001) argues that NRM innovations generally imply land use intensification; and intensification takes place only after land prices increase either after forests are chopped down or after steps to protect forests become effective. Findings presented in the book are based on careful case studies in which the factors leading to more or to less deforestation are reconstructed and explained.

Similarly, others observe that high human populations on fragile lands can lead to either productivity deterioration or to intensification to sustainable levels. Swinton and Quiroz (2001) asked how changes in natural soil capital in the highlands around Lake Titicaca came about and what policy tools might lead to soil maintenance. Analysis combined farm surveys using a hierarchical, stratified and clustered sampling design; Peruvian census data; documentation of soil erosion; and agroecological zoning. Empirical statistical analysis determined changes in soil capital, reasons for the changes, and yield losses. Results included that soil quality and depth were declining; agricultural practices were key determinants of soil status; and that social and human capital were tied to sustainable soil management (Swinton and Quiroz 2001).

2.3.2 Field studies to understand the implications of past land use change and to then set research and development targets

An effort by the Alternatives to Slash-and-Burn Consortium (ASB) of the CG assessed the effects of deforestation and subsequent different human land uses on two variables, carbon emissions and plant species loss, in a Brazilian Amazon colony in part in order to establish concrete targets for research-based alternatives to current land uses. Land uses were forest, fields cropped for different years after conversion from forest, fallows of different ages, and pastures. Plant species and numbers of individuals were sampled for the different land uses. Carbon was estimated for above and below ground biomass, charcoal, and soil carbon for the different land uses. Highest levels of carbon stocks and plant species diversity were, of course, found in the forest. One ASB goal was to reduce carbon emissions from forest conversion and to reduce plant species loss. The forest land use set the upper limits of the carbon and biodiversity targets (Fujisaka *et al* 1998). Other ASB research has addressed the same and similar economic and environmental issues at other forest margins sites around the globe (Gockowski *et al* 2001; Tomich *et al* 2001; Vosti *et al* 2001; Sanchez *et al* forthcoming).

2.3.3 Modeling to estimate future scenarios and research and development targets

Jones and Thornton (2003) from CIAT and ILRI respectively, combined crop models, a water balance model, and the generation of synthetic daily weather files (by Jones' MarkSim program "…used to estimate third-order Markov model parameters from interpolated climate surfaces") in order to examine long-term maize and pasture production risks associated with global climate change. The results of a global circulation model were used to extrapolate to the year 2055. The authors "…outline areas where further work is required before these tools and methods can address NRM problems in a comprehensive manner at local community and policy levels (Jones and Thornton 2003).

Questions and issues addressed. Present and future impacts of past and present resource use practices on natural capital and associated environmental services that they provide are measurable. Research can unravel how and why different outcomes occurred from either the same pressures on resources or from the adoption of NRM innovations meant to be resource conserving. Understanding causes of resource loss or degradation can lead to mostly policy based efforts to mitigate degrading processes and to protect remaining resources.

Questions and issues not addressed. Piecing together what happened in the past to explain the present is very deductive. Predicting the risks of the future based on today's huge data sets and state-of-the-art modeling is in itself risky.

2.4 IA of INRM

2.4.1 Ex post impact analysis is either inappropriate or necessary but not sufficient.

Researchers have taken up the challenge to achieve significant and sustainable impacts through INRM research. The very nature of the research has ruled against *ex post* IA. INRM research is characterized as working on multiple scales from the plot to farm to nation and region; as reflecting the interests of different interacting stakeholders--each having different objectives. Different sets of indicators are used to measure impacts on, for example, the five capitals established within the sustainable livelihoods approach (Scoones 1998). Researchers are seen as actors, often with an express role of facilitating negotiation among stakeholders. Farmer participation and *on-going* impact and process assessment within what are deemed decentralized adaptive-learning approaches are seen as essential to a dynamic, self-correcting process.

Many of the intellectual authors of INRM have a similar view as to the limitations of *ex post* IA:

- "Classic ex-post impact assessment tools can be compared to end-of-year school exams, whereas INRM impact tools should be seen as equivalent to continuous assessment" (Sayer and Campbell 2003).
- "It should be noted that IA is not a retrospective exercise to be conducted at the end of a research project, but rather requires systematic and continuous monitoring" (Pachico *et al* unpublished).

- "Ultimately, IWMI intends that its projects and programs will have a lasting and global impact on water and land management for the benefit of food production, livelihoods and nature. However, it is unrealistic to expect that IWMI's impact at this level could be easily measured or attributed (Giordano 2003).

Questions and issues addressed. The clear trend is that INRM requires *ex ante* analysis to help set research priorities and continuous monitoring in order to correct the course of research and development as projects unfold.

Questions and issues not necessarily addressed. How to figure out if donors are getting their money's worth can remain problematic. Returns on investments are unknown.

2.4.2 Although INRM research is ideally assessed using various indicators reflecting multiple scales and a range of stakeholders with respective goals, both public and private, a few, selected measurable variables are actually used to indicate the direction of outcomes.

In spite of the disclaimers, CG researchers have attempted to measure impacts of their INRM work. Evident, however, is that a limited number of measurable variables are employed where quantitative *ex post* IA is attempted.

CIMMYT's introduction of zero tillage and other resource conserving technologies (RCTs) in the Asian Rice-Wheat system has led to substantial adoption and to economic impacts that are now being documented and analyzed. Some of the adoption impacts were measured indirectly: e.g., number of zero till drills purchased times average area covered per drill per season. Although incomplete, IA is showing growing adoption and that: "…use of zero tillage after rice reduces costs, raises yields, cuts water use at the plot level by 20-30%, cuts fuel use by 70-90%, fosters improved weed control with less herbicide, improves N and water use efficiency, advances sowing dates, and creates flexibility in the cropping season for diversification crops" (Harrington, personal communication 2003).

TSBF's research on biological soil management conceptually considers the importance of multiple scales from plot to national; and the need to consider private and social costs and benefits. The case analysis provided looked at the adoption of manuring, mulching, composting (vs. inorganic fertilizer use) and at economic benefits of these innovations at the farm level (Swift *et al* 1994).

Douthwaite *et al* (2003) described a "follow the technology" actor-oriented, learning model approach in collaborative work by ILRI, ICRISAT, IITA, and IFDC on "best bets". At the end of the day, research found that farmer participation led to adoption of double cropping of a sorghum-cowpea intercrop using fertilizers and pesticide.

Similarly for INRM research conducted in the forest margins by ICRAF, researchers recognize that they are dealing with a complex reality, different scales relevant to different resources, and a large number of actors. Researchers accept that their role includes the facilitation of negotiation among stakeholders. In the supposedly illustrative case example of work by the ASB Consortium in Indonesia, *ex post* IA found that although farmers had some sustainable practices, almost all factors led to continued forest conversion (van Noordwijk *et al* 2003).

CIFOR and partners have worked on the performance of natural resource systems. Researchers provided interventions in the adaptive learning cycle and, in doing so, considered non-linearity, time lags, uncertainty, and multiple stakeholders with multiple objectives. Indicators for each of the five capitals were selected via stakeholder participation. In an actual example of INRM research in the Chivi micro-catchment in Zimbabwe: a) qualitative indicators were used to assess unexpected and/or favorable outcomes; and b) systems modeling using Principle Component Analysis considered basal area of wooded plants, cropland area, livestock, and disposable income per household. The trend identified was more cows acompanied by less crop and plant cover (Campbell *et al* 2003).

Questions and issues addressed. The measurement and evaluation of a few carefully selected, key variables may be a rapid and economical way to capture some of the most significant research impacts.

Questions and issues not addressed. IA falls short of the promise implied by the all-encompassing conceptualizations of INRM.

3. *Ex post* NRM IA methods by Center

Each of the Centers described their IA methods and approaches in the Impact assessment Workshop organized by SPIA and TAC. The following summarizes each Center's description of their respective *ex post* IA of NRM/INRM research. Some of these statements may be out of date given the rapid progress of INRM. Each center was asked to provide an update of their *ex post* NRM/INRM IA methods for this paper. Responses to this request are found in the appendices and referred to in the appropriate following center-by-center coverage.

3.1 CIAT

Ex post impact analysis includes acceptability, adoption, and impact (mostly case) studies. Acceptability studies obtain farmer feedback early in the development of innovations. Adoption studies examine extent of technology use, technology performance, associated farm management changes, and the diffusion process. Impact studies examine effects of research on the ultimate welfare of farm households. Impact studies have been few because of high cost and lack of feedback to the research and development process. CIAT's impact analysis project is attempting to develop IA tools and to quantify economic, social, and environmental impacts of research (Pachico 2000).

3.2 *CIFOR*

CIFOR is developing methods for IA of NRM research. Although measuring and quantifying impact is important, IA is viewed as a component within a system of problem identification, planning, producing outputs, promoting adoption, and securing positive outcomes. Key are: a) understanding relationships between target groups and intended sets of outcomes, i.e., of "impact pathways" and b) development and selection of appropriate indicators for NRM research in differing physical, biological, social and economic environments and at different appropriate scales (Spilsbury 2000).

3.3 *CIMMYT*

CIMMYT has shifted from adoption studies to impact analysis that asks, "What have been the consequences of adopting improved technologies? Has successful adoption led to increased incomes, improved nutrition, better health, greater empowerment, more sustainable livelihoods, and/or improved environmental quality?" (Morris 2000).

CIMMYT also provided a description of its NRM/INRM *ex post* IA for this paper (Harrington, personal communication 2003)

3.4 *CIP*

Applied to both germplasm and NRM research, Walker and Fuglie state, "*Ex post* assessment still requires a great deal of on-farm research and ground-truthing. In our opinion, improved methods and technologies have not improved the cost effectiveness of *ex post* assessment as much as they have enhanced the efficacy of *ex ante* evaluation"(2000). The authors cite the limitation that although CIP started NRM research in the early 1990s, "…it is unlikely that any one activity will generate enough impact during the next five years to warrant investment in a case study. On a more positive note, CIP's approach to NRM is intensive in its use of models; therefore, *ex post* evaluation will have a firm foundation to build on when adoption of NRM-related information is documented"(2000).

3.5 ICARDA

ICARDA has used economic surplus models to assess economic impacts of germplasm improvement research. Methods are needed for NRM IA: "Further development of methodologies …applicable to assessing the impact of agricultural research on natural resources, on the environment and on rural poverty is needed. Greater emphasis is needed in assessing the impact of agricultural research on specific target communities and on an array of objective variables such as income, poverty indicators, environment and natural resources" (Aw-Hassan, et al 2000).

3.6 ICLARM

Although ICLARM has demonstrated the impacts of specific aquaculture technologies such as genetically improved fish, IA of NRM is recognized as more difficult. The objective of *ex post* IA is to assess extent of adoption and final impacts against baseline parameters. IA of low input aquaculture techniques for small farmers in Bangladesh examined adoption and impacts on household income, rice yields, fish consumptions and decreases in inputs of fertilizer, pesticides and labor (Mohan Dey and Gardiner 2000).

3.7 ICRAF

ICRAF's IA strategy seeks to enhance both income and ecosystem functions from trees. *Ex ante* IA, stakeholder involvement, and early monitoring and evaluation are seen as more important than *ex post* IA because of the long time frames necessary in agroforestry research. *Ex post* IA is conducted for case studies, identifies indicators for research and development outputs and for ultimate impacts. Analysis of the chain provides evidence as to attribution. Sites for intensive data collection and quantitative analysis are selected strategically due to high costs of such IA (ICRAF 2000).

3.8 ICRISAT

Ex post IA results are fed back into the research priority-setting process. Information includes levels and rates of adoption, reasons for non-adoption, farmer perceptions of desirable features of innovations, on-farm gains due to alleviation of constraints, and infrastructural, institutional, and policy constraints or enabling characteristics. Farm-level adoption data is replacing the "guesstimates" of the past. Better adoption data is important: "Since research lag is a major parameter determining the present value of research benefits, the costs of miscalculations in terms of erroneous priority ranking can be significant (Bantilan and Dar 2000).

3.9 IITA

Ex ante IA is a part of the research-development process that provides understanding of the adoption process and of the benefits and disbenefits of wider adoption of innovations. Impact indicators include: economic indicators such as benefit cost ratio, internal rates of return and net present value; social and institutional indicators such as nutritional status, decision-making capability, and empowerment; and environmental indicators such as pesticide use reduction and carbon stocks (Manyong *et al* 2000).

3.10 ILRI

Economic, social and environmental impacts of ILRI's research were estimated in a 1999 priority setting exercise. Data gathered included a comprehensive poverty database and an economic surplus model to estimate costs and benefits for each geographic research area. Three *ex post* economic impact studies were conducted. Work resulted in the identification of four major questions/challenges and a conclusion relevant to this paper:

- What is our impact assessment really for? "…what is the role of *ex post* analysis, unless there is a great story to tell—the ILRI experience with these so far is not particularly cheering".
- Where are the rapid impact assessment methodologies? Thorough IAs cost about $80,000 each.
- Where are the data? There are "…pitiful amounts of data that pass for background and baseline systems information".
- Where are the data that show the linkages and pathways of impact of the technologies that we are disseminating?

- "But not all is gloom. We are slowly making progress on more appropriate tools (such as well-targeted participatory and formal surveys to delve into some of the tough questions regarding impact) and on using mixtures of tools (such as simulation models, GIS, participatory surveys, and economic surplus models) in the same study (Thornton and Kristjanson 2000).

3.11 IPGRI

IPGRI (as of 2000) planned to conduct several IA including: assessment of forest genetic resources diversity and impact of human activities on forest genetic diversity, impact of forest fragmentation on genetic diversity of forest trees, various crop genetic erosion studies, analysis of cost effectiveness of genebank management strategies, and a study tracing the linkage between collected and conserved genetic diversity and varietal improvement (IPGRI 2000).

3.12 IRRI

IRRI has conducted *ex post* IA not of NRM or INRM research, but on the impacts of agrochemicals on human health and the environment, on rice intensification and soil quality, and the impact of contour hedgerows on soil erosion in the uplands (Hossain 2000).

3.13 IWMI

IWMI developed methods and indicators to measure irrigation systems performance and impacts of the transfer of irrigation scheme management to farmer organizations. A standardized approach to measure and compare irrigation performance calculates productivity per unit of water consumed ("crop per drop"). Impacts of transfer programs have examined measurable physical impacts such as agricultural production, costs-benefits, and costs to governments; and farmer perceptions of water management services.

Interestingly, IWMI said it had no formal program to assess its own impact because of complexities and high costs for *seemingly* low returns:

- "With products that are largely intangible, multiple clients, and work carried out at many levels, from small farmers' fields to global water scenarios, formally and transparently assessing the impact of our work is extremely difficult. This difficulty is enhanced by the sensitive political nature of much of our work…. We are also not the only actors on the scene—often, ideas are developed through mutual cross-fertilization, in such a way that it would not be possible to attribute impact to a single institution" (Meerey 2000).

3.14 WARDA

As of 2000, WARDA's *ex post* IA was economic analysis of the returns to rice varietal improvement research (Lancon and Kassam 2000).

4. A way forward?

4.1 Summing up to date: four NRM/INRM research and IA approaches

What this paper has presented reflects the overlaps and contrasts among the four research and associated IA approaches. The four categories also represent CG development and change over time. The four NRM/INRM research and IA domains are summarized in Table 1. Each category is described in terms of: research scale, the natural resources of concern, the major types of research-based innovations developed or promoted, the research approach, the stakeholders, the types of expected benefits, the issue of externalities, IA approaches, presence and types of impacts to date, perceptions regarding the research process and results, the timeline of the approach within CG history, and some final comments.

4.2 Wisdom from the practitioners

There is no dearth of descriptions of the problems involved in *ex post* IA of NRM/INRM.

- "Key difficulties arise in defining 'adoption,' evaluating landscape-scale effects, considering the long time lags for many key impacts, the multiplicity of non-comparable metrics required, valuation of environmental effects, and involving the community in the analysis" (Scherr 2000).

- "NRM research outputs are not only often highly location specific but monitoring the multiple bio-physical consequences of NRM research outputs in the field is expensive, and the interplay between the economic and bio-physical domain is strong" (Maredia 2000).

Other intellectual authors of INRM call for greater problem clarity, identification of useful, appropriate indicators, and for specific measures not currently being used by practitioners.

- TAC also stated: "Experience in the CGIAR with integrated systems research has repeatedly demonstrated that the weakest link in the process is nearly always a lack of focus on a clear problem set and on areas for potential impact over wide areas" (TAC Secretariat: 2001).

- "…those evaluating the full impact of integrated, holistic NRM research and development programs must add appropriate indicators of both social and natural resource endowments and well-being to the limited, traditional economic indicators if they are to truly assess impact of NRM research" (Harwood 2003, unpublished).

- Needed is "Increasing CGIAR understanding of the enabling components and conditions along a successful research to development continuum. Research and technology development are only the tip of the iceberg, so to speak, if the ultimate goals are poverty alleviation, food security, and environmental enhancement…. The CGIAR needs to continue expanding its understanding of the appropriateness of varied dissemination and adoption pathways under different social, cultural and environmental conditions (TAC Secretariat 2001).

Kelley and Gregersen (forthcoming) paint an even bleaker (but accurate) picture in terms of some of the methods needed:

- "When addressing NRM research impacts, a whole range of other issues needs to be considered. Markets are largely missing for the environmental services provided. Different valuation methods exist, all of which are highly imperfect and tricky to use, and hence need bracketing attributing prices from different angles. Externalities are spread over different scales and hence difficult to capture as each level needs to be done with different tools. The time dimension is crucial and hence the choice of discounting key. There are also important problems of resilience and irreversibilities that need to be taken into account in constructing counterfactual scenarios. For these reasons, designing control groups for NRM treatments is particularly difficult because of the spatial and temporal dimensions involved".

There is similarly no paucity of recommendations regarding what IA of NRM/INRM should look like. Most of these emphasize the need to understand the research to development *process*:

- Rather than a few indicators, IA should be concerned with the processes of knowledge generation and diffusion, on collective ability to solve problems, and the development of innovation networks (Guba and Lincoln 1989, Douthwaite *et al* n.d.a).

- According to a GTZ-led donor group, IA should: identify the source of impact, state the model used for IA, identify the "impact pathway", state objectives and limitations of the IA, specify and test impact hypotheses, consider alternative causes, and consult others (Baur *et al* 2002, cited by Douthwaite *et al* n.d.).

- "Impact Pathway Evaluation" (Douthwaite *et al* n.d.b), "Paths to Development Impact (Gottret and White, 2001), and IDRC's impact mapping (Voss, keynote address, 1998 CIAT annual review) state the need to plot key outputs, outcomes, and influencing actors and factors while avoiding simplistic and inaccurate cause-effect analysis.

Scherr's "Hillsides research in the CGIAR: Towards an impact assessment" (2000) represents a conceptual forward stride. She proposes that IA first examine changes in NRM (adoption) and the resulting changes in natural resource conditions. Four types of development outcomes can be measured: the welfare of resource managers and local communities (e.g., crop productivity, income, consumption); societal welfare effects (food supply, water flow and quality downstream, sedimentation, forest industry revenue); environmental effects (agricultural soil degradation, water resources, forest loss and degradation, flora and fauna, habitat, biodiversity, carbon stocks); and governance of natural resources (norms and institutions for long term management).

Nelson (2000), however, flat out says that environmental impact assessment "should never be undertaken in absence of economic evaluation" and that the CG needs to work towards an integration of poverty alleviation, food security, and productivity of renewable natural resources and environmental sustainability. Maredia *et al* (2000), in discussing *ex post* IA in terms of impacts on natural resources and environment, thicken the plot by bringing up the problem that quantities of resource depletion or environmental degradation are easier to get (albeit costly) than estimates of correct prices to attach to the quantities. Although techniques exist to place economic values on environmental changes, they are data-intensive and require highly developed skills in collecting and manipulating large data sets.

Progress has also been made on conceptual frameworks to use the sustainable livelihoods approach in assessing the impacts of agricultural research on poverty. As is now well known, the approach considers natural, physical, financial, human and social capital or assets. IA requires an integrated, interdisciplinary approach that draws on quantitative and qualitative data collection and analysis. Data is pieced together from a variety of sources using a variety of methods (Adato and Meinzen-Dick 2002). Avoiding the blurred focus of previous Integrated Rural Development projects (Binswanger 1998) will remain a challenge for INRM.

4.2 Conclusions

IA of NRM/INRM will remain more process oriented than IA of germplasm related innovations. *Ex ante* IA and on-going monitoring and evaluation constitute key tools in research prioritization and in appropriately modifying the unfolding research and development learning process. Participation by and negotiation among different stakeholders and the consideration of impacts at different scales and time frames have been found to be essential elements of INRM research. As stated in a variety of ways, not only economic, but environmental, social, and institutional impacts must be considered in any holistic IA.

Ex post IA of NRM/INRM needs to additionally examine adoption rates, patterns and reasons; economic analysis of more direct, tangible innovations; and impacts on social, natural, and human assets. Different indicators will need to be identified and measured for the different stakeholders and impacts.

The section of this paper "Wisdom from the practitioners" (immediately above) downplays what apparently is a point of contention. Accordingly, one view supports economic IA and calls for more economic methods development:

- "Approaches are needed that capture environmental services and other (non-yield) outputs from NRM/INRM research such as maintenance and loss reduction, risk reduction, quality improvement, reduction of negative environmental externalities and compatibility with off-farm labour schedules" (Kelley and Gregersen: forthcoming).

The contending view supports the process orientation of INRM and downplays the econometric approaches:

- . "…current 'best practice' economic evaluation methods commonly used in the CGIAR system, which attempt to establish a linear link between a project's outputs and wider level impacts, ignore complexity" (Douthwaite *et al* n.d.).

This paper disagrees with the (perceived?) extent to which the SPIA position (Kelley and Gregersen, forthcoming) supports a greater economics-based approach to *ex ante* impact analysis. This paper likewise strongly disagrees with the idea that economic evaluation methods ignore complexity. We conclude with many others that different mixes of methods (including economic) is necessary to deal with the different types of impacts sought by INRM research:

- IA "has been dominated by economic…frameworks and methods. Designed as research studies, IAs have often served accountability and public awareness purposes. However,… There is an increasing awareness that appropriately designed and executed evaluations—going beyond traditional economic impact assessment—can contribute substantially to institutional learning and performance improvement" (Horton and Mackay 2003).

As stated earlier, however, operationalization lags behind conceptualization. By way of conclusion, several basic problems must be solved if the CG is to conduct meaningful *ex post* IA of NRM/INRM research.

1. *Researchers need to clearly identify, target, and maintain their ultimate development or environmental goals*. Adoption of, for example, agroforestry or contour hedgerows, or participation in farmer groups can be important steps towards achieving impacts. User or stakeholder participation of different types may lead to the development of more appropriate innovations and to the empowerment of people, communities, or segments of society such as women, children, or the landless. But these intermediate outcomes need to contribute to ultimate goals. Some suggest that it is still too early for INRM research to have had impacts. Others imply that the time is nigh for impacts, but that the centers have little to show (The SPIA has commissioned a number of NRM *ex post* impact studies to help settle the issue.).

2. *Good data gathering and analytical skills are needed to analyze impacts*. Gathering and analyzing data in the ways recommended by the conceptual framers of INRM will require skills not necessarily present in the CG today, although the ability to handle certain types of data (e.g., GIS-based, modeling, participatory tools) is growing.

3. Center NRM research proposals *must seek funding* not only for research, but *for IA* as well. IA of the type increasingly agreed upon to be necessary will not be cheap.

4. While case studies of successes may sway some of the donors some of the time, *case studies of failures* would help researchers to improve outputs all of the time.

5. Other than in simple, perhaps insignificant cases, *attribution will remain a problem*: "chains" of various sorts tracing from research to impacts are easy to recommend, attractive sounding, but probably filled with pitfalls in terms of implementation.

6. Perhaps *the main challenge is to find realistic, practical methods for the valuation of different types of goods and utilities* of different stakeholders. It is easy enough to agree to the need to consider different realms of impact such as the five capitals identified in the sustainable livelihoods approach. That approach is even more attractive in observing that stakeholders transform different types of assets into other types in order to meet their particular goals (e.g., cut down trees [natural capital] to get school fees [to build human capital] to get a job in the city and make more money [financial capital]). The problem lies in the valuation of goods relative to different stakeholders and in the integration of dynamic utilities in a way that would make

holistic IA possible (e.g., the tree cutting is frowned upon by tree huggers, many of whom represent growing green movements in developing countries; but how does valuation of the trees consider human capital gains against the loss of environmental services?).

7. Researchers and different stakeholders will each seek a balance of different types of goods. The need is for each to specify what they value. *What different people or entities seek is based on social and cultural values*. The different combinations of target impacts in terms of, say, social, financial, and/or natural capital need not be defended; but need to be clearly identified and specified so that goals are “transparent” to all.

As a final note, some *are* convinced that the returns to NRM research have been shown to be high, and that the next problem is “how governments and donors might stimulate necessary investment in improved NRM” (Barrett, Place *et al* 2002, Barrett, Lynam, *et al* 2002).

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Table 1. NRM/INRM research and impact analysis

Research objective	Crop productivity enhancement	Farm productivity & resource use efficiency	Natural resources & global environmental goods	Integrated natural resource management
Time line of paradigm	Green revolution to present	Farming systems to present	From 1980s when global environmental problems recognized, tied to agriculture	Either from 1960s integrated rural development or from 90s desire to do away with reductionist approaches
Research scale	Field plot	Field plot - farm	Field plot – global, Large ecosystems	Farm - global
Natural resources	-Soil nutrients -Water	-Soils: soil, nutrients, texture, organic matter, organisms -Water	-Forests -Biodiversity -Watershed functions -Greenhouse gasses	-Natural systems -Social systems -Economic systems -Cultural systems
Intervention	Germplasm, fertilizer, irrigation, pest management	Farm management, on-farm resource conservation plus germplasm	Policy, institutional change, trade in environmental services, other	On-farm management, user participation, stakeholder negotiation, researcher as actor, social & institutional change, governance & policy change
Research approach	Controlled, experimental	Controlled, collaborative, participatory	Field monitoring, modeling, GIS, remote sensing, case studies	Collaborative, participatory, learning, adaptive, follow the technology
Stakeholders	Farmers	Farmers, consumers, others in watershed	Global community	Farmers, consumers, researchers, civil society, institutions
Benefits	Private	Private, some public	Largely public	Private & public
Externalities	No	Some (descriptive)	Yes	Yes
Impact analysis	*Ex post;* quantitative, economic: benefit-costs, returns to production factors	*Ex post;* quantitative, economic; descriptive & quantitative adoption studies	Data from present & past records used to model forward; impacts projected if no mitigation	Dynamic process emphasizing *ex ante*, early monitoring & evaluation to modify process as needed, measurement of different types of impacts that differ by stakeholder
Impacts?	Yes	Yes if adoption numbers correct & adoption = impact	Past impacts of resource use w, w/o innovations	Yes; selected measurable impacts; process impacts; work needed on *ex post* IA tools & methods
Perception of process, results	Linear	Linear, complex	Non-linear, complex	Non-linear, complex
Comment(ary)	Simple economics	More complex economics vs. anecdotal case studies	Big questions about how the global ecosystem works & future impacts of human resource use	Admirable but difficult methodological challenges ahead; operationalization of concepts, valuation of goods; recognition of social-cultural value-based research and IA decisions