CASE STUDY AND EMPIRICAL EVIDENCE FOR ASSESSING NATURAL RESOURCE MANAGEMENT RESEARCH: THE EXPERIENCE OF CIAT

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Natural resource management research emerged in the mid 1980's as a major concern for the global agricultural research system, both national programs and international centers. Assessing the impact of this research inevitably became a critical issue, both for prioritizing resarch and also for monitoring progress.

Impact assessment has become an especially thorny issue because natural resource management research has represented an expansion of the research agenda for many institutions a time when resources have become increasingly scarce. A variety of different methods and tools for assessing impact have been utilized, including indicators; spatial models and geographical information systems (GIS); economic surplus models; farmer participatory techniques; and empirical field surveys.

This paper explores some conceptual and methodological issues related to the assessment of impact of natural resource management (NRM) research and presents a brief overview of some research approaches. The experience of CIAT (Centro Internacional de Agricultura Tropical), with emphasis on Latin America, is used as a vehicle of this paper because it illustrates a number of the issues that are confronting a wide range of institutions and scientists today.

While CIAT can not offer a fully developed model that provides a comphrehensive solution to all the issues faced in impact assessment of NRM research today, examination of its experience may serve as a useful platform to stimulate an exchange of experiences and viewpoints in this workshop.

The first section of the paper attempts to appraise the broader context of impact assessment for NRM research. It briefly reviews some dimensions, approaches, and aspects of the reach of impact assessment of NRM research.

The second section of the paper sketches out the broad outlines of some methodological approaches to NRM impact assessment. Ex ante approaches are considered, and some aspects of poverty measurement, extrapolation, and cross scale analysis are noted.

The third and final section of the paper will present brief summaries of the findings of some studies focussing on the impact of NRM research.

Impact Assessment: Desperately Seeking Donors

The high level of current attention that impact assessment of NRM research is attracting, arises to a very substantial degree out of a concern by stakeholders to be able to demonstrate to their constituents that investment in NRM research is yields results in terms of the socio-economic development goals that motivate much research investment.

Generally donors investing in NRM research are not interested in means such as increased knowledge, better research methods or improved models. Rather, their investment is usually driven to attain ultimate development impacts.

These impacts are diverse. They can include increased productivity and efficiency; increased income or welfare for the poor; improved nutritional or health status; the welfare of women or particular social groups; empowerment of the less privileged; environmental quality; welfare of present or future generations.

Different investors in NRM research give different weights to these various ultimate impact outcomes, so almost inevitably impact assessment means different things to different people. These differences in what impact to assess, or how to measure it, are rooted ultimately in differences in values or differences in utility functions as economists might prefer to have it.

"At IDRC we do not strive for objectivity in the usual sense of being remote from the project being evaluated. Evaluation reflects the values and perspectives of those who design and implement the evaluation" (Love 1996). Thus, impact assessment, as a form of project evaluation, like evaluation ultimately rests on a base of subjective values.

Even where there is consensus about what type of impact is being sought of NRM research, the measurement of impacts can typically be approximated through a range of different variables. For example, if increased income is the desired impact, this could be measured as income in a current period, or future income over a number of periods, and could involve asset accumulation or the measurement of income variability.

Likewise, if improved environmental quality is the desired impact, this can be measured through a variety of indicators, for example, biodiversity might be assessed at the level of the plant genome, species, or plant community or ecosystem. Similarly, soil quality might relate to organic matter, profile depth, or soil texture. Gender welfare might be appraised, for example, through access to income, control of assets, or participation in decisions.

While impact assessment has to be based on some initial definition of impact regarding what and how impact is to be measured, equally important is the specification of how the output of NRM research will attain the desired ultimate impacts.

Development impacts like poverty alleviation, environmental quality, nutrition and health, gender welfare, and empowerment, depend on a wide range of other factors besides the outputs of NRM research. The overall performance of the general economy, episodes of violence or warfare, national policy, and social and cultural structures and changes can all have a major effect on the development impacts that NRM research is intended to influence.

Frequently the effects of these other factors will mask or even dwarf those of NRM research. Thus, even when NRM research may be making a contribution to the development outcomes of interest to investors in research, assessment of this impact can be made exceedingly difficult in the presence of other powerful intervening factors.

An Approach to Impact Assessment

Impact assessment does not optimally initiate as a retrospective exercise after a research program has produced an innovation that has entered into use. Impact assessment needs to be a crucial part of research planning and prioritization. Instead, optimal impact assessment should be an integral part of an ongoing monitoring of research progress and product development during the life of a research project. After the conclusion of a research project, impact assessment provides valuable feedback on the effectiveness of a research effort(Pachico 1994).

Logically impact assessment begins with a definition of the desired impact; where it is expected; and for whom it is anticipated. "Outputs can not be assessed fairly unless they are identified from the start," (Goldsmith 1993). Clarifying from the beginning the nature of the expected impact not only provides a basis on which the impact of NRM research will be assessed during the course of the research and at its conclusion, but also it can assist in the specification of research directions most suitable for attaining the desired impact.

Thus, whether ex ante impact assessment is done through structured formal methods or is based simply on the judgements and preferences of research managers and scientists, it largely conditions what impacts can and will ultimately be achieved. Consequently, a precise specification of the outputs expected of a research project outputs and a clear tracing of the logical link between these outputs and particular desired impacts, is the optimal base both for future impact assessment as well as for research planning and prioritization.

Once the expected impacts of NRM research have been determined, then the challenge for applied impact assessment then becomes the definition of how this impact will be measured. Some impacts are relatively straightforward to measure, for example, the direct consequences of adoption of an innovation such as changes in the frequency of spraying or types of agrochemicals used due to an IPM program or changes in yield due to a new variety.

However, the impacts of innovations on ultimate development outcomes like nutrition, poverty, or gender welfare, are far more difficult and often quite costly to measure with any precision. Since these are inherently complex phenomena, resort to indicators has become a key tool for policy and decision makers interested in impact assessment (Gallopin 1995).

The advantage of indicators is that they simplify information about complex phenomena and the are "easily detectable, relatively simple, and cost effective, and should resort, if possible to existing information"(Harrington et al 1995). An indicator can be usefully defined as "an easily observed variable that may be measured at low cost and is highly correlated with the state of a complex system of interest for decision making", in this case, for impact assessment (Pachico 1996).

To be convincing, indicators need to be theoretically and logically linked, preferably in some causal relationship, with the behaviour of the complex system of interest.There are a number of methodological issues involved in utilizing indicators for impact assessment, some of which are touched upon below. Nonetheless, early identification of the variables or indicators that will be used to measure impact is a key step in the impact assessment process.

After a research program has been designed, including specification of its expected outputs and their associated impacts on development objectives, prototype or intermediate outputs will emerge from the research in process. The assessment of the performance of these intermediate outputs will yield further information about the likely or potential impact of a line of research.

Ongoing assessment of research in progess can serve both as a crucial feedback loop to adjust or refine a scientific research project, and it can also lead to a reappraisal of the impact of a research project, for example that it performs different from expected in a particular environment or among farmers of a particular resource endowment. A variety of methods including regional trials, on-farm trials, farmer evaluations, participatory research and surveys can be useful in these continuing assessment of resarch in process.

As finished products emerge from a research program and diffuse among users, ex post studies of the impact that has resulted from this research is a culmination of the impact assessment process. It is important to note that measurement of the adoption or use of an innovation is not the same as measuring its impact on natural resources management or development goals. Measurement of outputs does not constitute measurement of outcomes. For example, farmers may be observed to use soil conservation measures, but this is not the same as measuring the impact of the conservation measures on the quality of the resource base, or the impact of the improved resource base on farmer welfare, be it farm productivity, income, or nutrition.

In sum, impact assessment is best conceived as an integrated dimension of the entire research process, rangeing from planning and priortizing research, to monitoring research progress, to appraisal of the ultimate outcomes or impacts of research. These are related in that information from intermediate evaluations and adoption or impact studies can feed back to modify ex ante assessment of ongoing or future research.

Ex ante assessment helps to appraise the selected indicators that can be used to measure the expected impacts of a research project. Continuing assessment monitors progess towards the production of a research output and can involve a preliminary assessment of whether it is likely to deliver the expected impacts. Ex post impact assessment adresses whether planned research outputs have in fact been generated and used, and the degree to which this use has led to the expected impacts among various potential beneficiaries

Reach and Impact Assessment

The discussion so far has focussed on what impacts are to be measured, how they can be assessed, and when impact assessment is relevant with respect to the stage of a research program. Equally important is the issue of the "reach" of the outputs of a research program. Reach has been defined by Smutylo and Carden of IDRC as "the groups that are touched by the results of a program".

Thus, the benefits of a NRM research project may reach producers and consumers, males and females, upstream and downstream resource users, current and future generations, land owners and laborers, and farms of different sizes, social status, or agro-environments.

Despite the substantial weight that many investors in NRM research may place on knowing the distribution of benefits, the relatively greater tractability of measuring the aggregate total of benefits of research programs, even though this is often far from a trivial matter, has tended to absorb more attention than fully tracing out the distribution of benefits. Although this may be more difficult and costly of research resources, stakeholder interest in these issues may demand that they receive more attention in the future.

Impact is also distributed spatially. Impacts occur at certain geographic locations, each associated with particular enviromental conditions and social groups. Utilizing geographical information systems (GIS) can assist impact assessment, for example, by helping to provide a framework for sample selection for impact study. Similarly, GIS can assist in the extrapolation of impacts from specific locations to wider areas. Some methodological aspects of using GIS in impact assessment are discussed below.

Impact occurs over many years, with significant time lags both between the initiation of a research program and the production of the research output, and between the delivery of a research output and its widespread diffusion among users. While NRM research is likely to take significant time, it should be remembered that the genetic improvement research of the CGIAR system that has had such an impact, took a minimum of a decade from the outset of a program to the delivery of its first outputs, and in many cases it took much longer. NRM research may not require a significantly longer horizon to produce results than did the initiation of international crop improvement efforts.

Moreover, frequently there are significant time lags between the availability of a new agricultural technology and its adoption. For a relatively simple technology in a well organized sector like irrigated rice in Latin America, peak adoption can be attained within six years. For more complex technologies which lead to greater changes in the production system or are more capital intensive, like forage technologies in Australia, peak adoption may be reached only after 20 years. Because of their generally more complex nature and the more gradual onset of observable impacts, the diffusion of NRM innovations may more closely approximate the path of forages than rice .

Nevertheless, the impact of NRM innovations are often less immediate and therefore less easily observed or measured. For example, decreased soil erosion or lessened loss of biodiversity typically will not have an immediately observable impact on agricultural productivity simply because the effects of resource degradation or its reversal occur over extended periods of time.

Impact Assessment of NRM: CIAT's Methodological Experience

In the context of the issues discussed above, this paper will now turn to a review of CIAT's experience with impact assessment of NRM research. This is done to share, review and critique approaches and methods, without any intention to present a definitive or normative model.

This section will be comprised of three parts. First, approaches to ex ante impact assessment of NRM research will be briefly reviewed. Second, a method of measuring poverty and extapolating up from local perceptions of poverty to regional poverty profiles will be briefly described. Third, methods for using the pressure-state-impact-response framework across different scales of analysis will be considered.

Methods for Ex Ante Impact Assessment

The cornerstone of CIAT's Strategic Plan for the 1990's and Beyond was the integration of a major research effort on resource management with its traditional efforts on germplasm development. This was premised on the proposition that traditional research pardigms based productivity considerations needed to give way to new technology design conceptualizations that met ecological performance criteria in an agroecosystems context(CIAT 1991).

To operationalize this vision, a major study was undertaken to identify research problems and opportunities in natural resource management research (Jones et al 1991). Broad environmental classes and within them, land use patterns (agroecosystems) were defined using GIS. These agroecosystems were then prioritized for research based on a number of criteria:

Economic growth and resource potential

Poverty alleviation

Resource Problems

Researchability of resource and agricultural problems

The first three criteria are essentially measures of the magnitude of the potential impact of NRM research, while the last criteria is a measure of the probability of acheiving the potential impact. Taken together, the criteria would assess the expected impact of natural resource management research. Scoring systems based on the above criteria with different weighting schemes were used to assess the impact of conducting NRM research for alternative agroecosystems (Jones et al 1991).

While there was broad acceptance within CIAT of this approach to set the initial priorities for NRM research, it has been suggested that, "scoring should be used sparingly. The results are unreliable and potentially very misleading," (Alston et al 1995 p. 487). In this view there is no adequate substitute for the use of economic surplus models for impact assessment.

Such an approach was used to estimate the expected impact from alternative crop pasture systems for the savannas of South America (Pachico et al 1993). Rates of return to investment in crop systems were derived from shifts in the supply functions of the commodities produced in the systems.

Nonetheless, it was judged that decision makers were interested as much in poverty alleviation and sustainability as in the crop productivity consequences of management systems. Consequently, scoring was used to assess the effect of project outputs on biodiversity, soil quality, water resources, pollution and pest ecology.

Extrapolating Local Perceptions of Poverty

Because poverty alleviation ranks high among the objectives of many investers in NRM research, a better understanding of how improved NRM impacts on poverty is a crucial issue. This in turn rests critically on the definition and measurement of poverty. Poverty measurement confronts a number of difficulties in terms of the measurement of income, of the importance of different measures of income relative to wealth or assests, and the intra-hosiehold and especiall inter-gender distribution of control over income and assets.

While external definitions of poverty such as income or expenditure are frequently used as a basis for measuring poverty, and thus the impact of NRM research on poverty, alternative approaches to poverty assessment are being explored (Ravnborg and Guerrero 1997).

Local perceptions are tapped through farmer interviews to develop indicators of well-being which can be used as indicators of poverty according to local perceptions rather than externally deived understandings of poverty. In a case study in Honduras interviews in a sample of 90 communities identified a number of indicators of well-being of widespread relevance. These include indicators such as agricultural laboring, non-farm income, land tenancy, livestock ownership, food availability, housing quality and crop choice. These various indicators were combined into a well-being index (Ravnborg et al 1997).

Pair wise correations were found between the ranking of indicators in 87 out of the 90 communities, thereby confirming that local definitions of well being are highly consistent across communities. Furthermore, GIS analysis was used to extrapolate the poverty measures nationally.

The sample communities were characterized on the basis of altitude, accessibility, public services, ethnicity, gender, and population density. The same combinations of sampling factors are found in a large number of communities outside the sampling area. Thus, the GIS demonstrates where the povert measures developed at the local community level are likely to be valid given similarities in community characteristics.

The methodology described above attempts to provide insight into local perceptions of poverty and to ascertain the extent to which such local perceptions can be extrapolated nationally. Such an approach offers the prospect of a better capacity to link natural resource utilization issues to the distribution of poverty through geo-referenced data bases. This in turn provides a powerful tool for assessing the impact on welfare of innovations in natural resource management.

Measurement of Impact Across Scales

The measurement of impact across scales is a central issue in the assessment of the impact of NRM research. For example, the impact of erosion on the natural resource base varies from the plot to the slope face to the watershed to the river basin. It is essentially a question of measuring impact across different levels of a systems hierarchy. While this is most easily envisioned as aggregation across scales in a spatial hierarchy, it is also an important phenomenon in other hierarchical systems. For example, biodiversity occurs at a genetic level within a species, among speicies in a plant community, and across plant communities within an ecosystem.

Figue 1 displays some cross scale vertical and horizontal linkages in the case of land use. Vertically the scales extend from the regional to the global, while horizontally impacts are shown from the environmental to the economic to the social. In the case of land use shown here, a land use change such as deforestation at a local level has a series of consequences for the local level (erosion), to the national level (loss of forests), to the regional level (increased frequency of droughts and floods, to the global level (climate change). Thus, both the nature and the magnitude of the impact of resource management decisions varies by the scale of the analysis.

To enable decision makers to grapple effectively with this complexity, not just for technology design but also for policy formulation and policy making, there is a need to integrate these various scales and dimensions in a way that linkds the issues operating at different scales while at the same time managing the complexity of the system and communicating it in a comphrensible form. The challenge then becomes to develop information systems that allow users the freedom to show many indicators at the same time, to choose the scale and to make their own assessments, conclusions and decisions regarding impacts.

A particularly appropriate conceptual framework for undertaking this challenge is the pressure-state-impact-response model. This use of this approach is illustrated with examples at two scales, one regional (the Amazon basin), the other national (Peruvian forest margins). As the user increases the scale (i.e. moves from region to nation) the nature of the indicators displayed changes to reflect the new scale.

For example, at the regional level in this land use example the pressure is increased accessibility driven by improvements of the road transport network (Figure 2). This accelerates colonization in the forests which changes the state, that is the surface area of the forests. The impact of this is fragmentation of forests, and a possible policy response is the development of legally protected areas. *In each case* indicators can be developed for the pressure-state-impact-response.

Within the same Amazon basin at the national level of the Peruvian forest margins, a different set of indicators for the pressure-state-impact-response model is displayed (Figure 3).

Using Participatory Research for Impact Assessment

The importance for impact assessment of defining the "reach" of an intervention in order to design the impact assessment strategy involves understanding who the stakeholders are. Participatory approaches to impact assessment take this stakeholder analysis one step further, in providing methods for impact assessment which actively involve the stakeholder.

Involving stakeholders in assessing the impact of NRM interventions can be done from the perspective of two main approaches which have different objectives. In the first approach which can de referred to as functional participation, stakeholder involvement in impact assessment is a means to an end --and is usually initiated by agents in need of a quick and relatively easy way to obtain an impact assesemnt , which can be qualitatively appealing. The second approach which is referred to as empowering, decision-making or capacity building participation, is an integral component of a process of building participatory and innovative management of natural resources , which requires stakeholders to have a capacity to monitor and assess changes in the status of those resources.

Involving local organizations in the design of technical innovations for soil water or forest conservation and in planning where to locate them in a landscape, is now widely recognised as a key element of successful innovation. When local organisations involve farmers in experimenting with principles of conservation and adapting these to meet their own needs and constraints, then innovative improvements in NRM are rapidly developed and adopted. Examples are the EPAGRI microwatershed catchment committees in Santa Catarina, Brazil, the Catchment Committees of the Kenyan Ministry of Agriculture, the Agha Khan Rual support Program in Pakistan, the CIPASLA watershed consortium in Colombia, Landcare in Australia (Ashby and Ravnborg, 1998).

An important feature of local organizations in NRM is that they provide a conduit for receiving and exchanging information about the impact of innovations which brings down the cost for the individual stakeholder of experimenting and of enforcing collective conservation . Particaptory impact assesment , when it involves all the relevant stakeholders making an impact on each other, provides information about transboundary effects of NRM interventions enabling stakeholders to arrive at a joint plan of action. Participatory impact assessment therefore, becomes a vital ingredient in a feedback or learning process that increases the effectiveness of the overall partcipatory NRM process.

Combining conventional and participatory monitoring and assessment of the transboundary or off-site impact of NRM interventions into an ongoing NRM program can be especially important when mobile as opposed to stationary resource flows are involved, or when multiple competing uses exist for a given resource. For example in common property resources with mobile flows that fluctuate unpredictably -- such as stream flow in a watershed-- it is very difficult for users to assess the effects of use by one stakeholder on the amount or quality of the resource (eg water) available to another stakeholder, or the benefits to either user from a conservation intervention (Schlager et al, 1992). When cause and effect cannot be determined readily, conflict over usufruct rights is more likely, and it is is easier to free ride.

Thus the implementation of a locally managed participatory process of impact assessment is an important element in sustained success of collective action to improve NRM. Landcare in Australia is an example, in which conservation extension groups involving a broad cross section of rural people with a stake in catchment planning are using techniques such as GIS and aerial surveys in an extensive voluntary participatory environmental monitoring and impact assesment .

CIAT's experience includes both functional and capacity building approaches to participation in impact assessment. Participatory methods have been developed at CIAT to provide ex ante asssessment of the acceptabilty to farmers of conservation practices, and these methods have been shown to be good at predicting future adoption behaviour.

A capacity building participatory approach is central to CIAT's experience with the development of community-based management of watershed resources for the Tropical American hillsides. In this approach, stakeholder planning involves the definition of indicators for monitoring the implementation and impact of NRM interventions. At the watershed level, beneficiary assessment of improvement in their quality of life as a result of the changes introduced in NRM is a basic feature of the approach. For specific projects which are co-sponsored and cofinanced by the local watershed inhabitatnts and by external agencies, a"comision" or task force of stakeholders is appointed by the watershed user association to make regular site visits, using indicators for monitoring and assessment which use local knowledge and also may draw on the GIS system developed by the participating research agencies, such as the poverty (or wellbeing) mapping referred to earlier in this paper. For example, CIAT is testing a "soil quality health kit" designed for use by farmers (level 1) and by extensionists (level 2 of the kit) providing simple diagnostic tools which enable users to build a rapid appraisal of the state of the soils in a microcatchment when there are no accurate soils maps available.

Differentiating among groups of stakeholders in relation to poverty or gender and understanding how impact is distributed among them is important for assessing the effect of NRM interventions on equity, and it is integral to participatory impact assessment . When stakeholder analysis is incomplete, and the relevant stakeholders are not represented in a participatory impact assessment, then not only is the picture of impact obtained likely to be incomplete, but the action based on the assessment is likely to be ineffectual because some important actors have been left out.

CIAT's experience with stakeholder analysis illustrates this. Community-based management of buffer zones around hillsides watercourses in Colombia failed to identify semi-landless migrant farmers as stakeholders. As a result, forest fires spread into the buffer zones as a result of the traditional slash and burn land clearance by these farmers. Subsequent stakeholder analysis enabled the participants to identify several legitimate but conflicting interests . Burning on the neighboring agricultural land was understood to be a rational practice for the farmers, but which had harmful externalities for the community. A set of norms were developed specifying when and how burning could be conducted and in some communities, groups formed to ensure compliance in making firebreaks to protect the bufferzones (Ravnborg and Ashby, 1996).

CIAT's experience shows that stakeholder analysis needs to be conducted with two objectives, each of which may be important and each of which needs to be evaluated independently for its importance to impact assessment. One is whether the relevant stakeholders in relation to a specified NRM problem are fully identified and represented. The other is whether stakeholders bring relevant expertise to the problem . Representation is important for the accuracy of any stakeholder-led participatory impact assessment, and for future ownership by all stakeholders of any action based on that assessment. However, the representative group may not be the most appropriate or most effective group for tapping specialised knowledge, and it may be essential to select stakeholders with special knowledge for certain assessments.

Some Case Studies in Ex Post Impact Assessment

While NRM research is a relatively new area of research, agricultural research has been having an impact—both positive and negative—on the environment since its beginning. The following examples of the impact of CIAT research on the natural resource base demonstrate that the CG centers' do in fact have a history of NRM impact from which to draw upon. They also show that NRM research cannot easily be separated from traditional commodity research, nor is such a distinction really necessary. Since many of the most important NRM decisions are and will continue to be made in the context of agricultural production, a more holistic approach to impact assessment may be most appropriate.

1. Traditional commodity research with unanticipated environmental impacts

Traditional crop research has significant direct and indirect impacts on the natural resource base. Some of these benefits are positive. For example, improvements in disease resistance of irrigated rice has led to reduction in the use of pesticides and fungicides in Colombia, Venezuela and Brazil (CIAT Rice Program Annual Reports). To the extent that use of these chemicals had negative environmental impacts, the improved varieties had a positive impact on management of natural resources.

In addition to the direct effects on chemical use, rice research has also had an indirect effect on land use. Between 1966 and 1996 rice production in Latin America grew by 2.5 percent a year, while price s fell by 30 percent. Eightly percent of the production increases came from yield increases rather than from expansion of area planted. Irrigated rice yields almost doubled from 3 to 5.5 tons per hectare, while upland rice yields remained unchanged. The result was that upland rice production became increasingly unprofitable, leading to a reduction in rice production in the Brazilian Cerrados and forest margins. Area planted to rice in these fragile areas declined from a peak of 6 million hectares in 1966 to 2.75 million hectares today (EMBRAPA data).

CIAT's research on improved forages for the South American savannas has included substantial work on deep-rooted grasses of African origin. These grasses--Andropogon gayanus and Brachiaria humidicola--were found to sequester significant amounts of organic carbon deep in the soil. The researchers concluded that the process could account for the sequestration of 100-507 Mt carbon per year in such improved pastures throughout South America (Fisher et al). As such, it is quite likely that the research initiated largely with the goal of increasing agricultural production is finding benefits in terms of offsetting CO_2 emissions from forest burning in the Amazon. Such an impact is of global relevance, as well as ironic to the extent that these pastures may offset some of the negative environmental results of conversion of tropical forests into pastures for cattle production.

In other cases, the impact of commodity research may not be so unequivocally positive. For example,

irrigated rice and other improved crops are often heavy users of chemical fertilizers, which can have direct, negative effects on environmental quality.
An impact assessment of a integrated production/ processing project for cassava on the north coast of Colombia found indirect, negative impacts on land use in the short run. Adoption of the processing technology designed to help small farmers capture some of the added value in processed cassava increased the demand for cassava, which led to an expansion in cassava production at the expense of pasture and fallow. In the absence of fertilizer or sound crop management practices, this intensification of production would contribute to a decline in soil fertility.

The story doesn't end here, however. Over time it was also found that farmers invested their cassava earnings in livestock, resulting in the eventual reconversion of cassava land back to pasture. It appears that farmers engaged in short term "mining" of a resource in order to get money for a long term investment that could lead to more sustainable production in the future as well as higher levels of income. What this examples shows is that both short and long term impacts need to be considered, along with the role played by factors such as income in decisions regarding short run and long run natural resource use (Henry, Izquierdo and Gottret; Gottret and Henry).

As these examples show, traditional crop research has important environmental implications. While such impacts are often included in *ex post* project evaluations, what remains to be adressed is the extent to which these types of concerns should be considered *ex ante* and should form part of the traditional commodity research agenda. Especially in the case of indirect effects, the causality that is relatively clear in hindsight might be difficult to establish *ex ante* because the outcomes depend heavily on the economic, political, and social parameters of the broader system in which agricultural production takes place.

2. Joint NRM and commodity research

One way to incorporate the NRM concerns into traditional crop research is through joint research projects. The important overlaps between the two research agendas offer many opportunities for collaboration.

Cooperation among forage, rice and soils programs has yielded interesting results about maintaining and enhancing soil quality in the tropical lowlands. Joint work by CIAT, CIRAD and EMPRAPA's Rice research program (CNPAF) showed that monocropping of upland rice has been shown to have a devastating effect on the populations of earthworms, which play an important role in maintaining soil structure. Rotations, on the other hand, can improve macro and micro fauna in the soil. Improved pastures are also associated with increases in the quantity and quality of worms (CIAT pastures and soils programs). What is clear is that adoption of new practices and varieties has a positive impact on the natural resource base. What remains is to measure the value of this improved soil quality through its contribution to crop productivity.

Similar cooperative research is being conducted in Asia. Cassava farmers in Indonesia, Vietnam, China, and Thailand are involved in different combinations of agronomic trials, testing new cassava germplasm and ways to conserve soils through the use of vegetative contour strips. Using simple plastic lined trenches instead of expensive and often complex concrete trenches, collectors, and volume counters to measure soil losses, farmers can see, measure, compare, and discuss results in the field. Participating farmers have adopted different combinations of new cassava varieties, agronomic practices, and soil conservation measures (PE-5 Annual Report, 1997.)

Farmers in Laos, Indonesia, the Philippines, Vietnam, Malaysia, Thailand, and China are also participating in a "Forages for Smallholders Project." Farmers are able to test forage germplasm for different uses ranging from improved dual-purpose livestock feeding systems to improved fallows or legume cover crops. Researchers and farmers, working as partners, are beginning to develop and adapt adoptable, problem-solving forage-based technologies (PE-5 Annual Report, 1997).

CIAT is also a participant in the global project "Alternatives to Slash-and-Burn". Much of the initial research has been to document the effects of current land use patterns in terms of deforestation, carbon emissions, and biodiversity losses. These measures will serve to help measure impacts as more sustainable land use systems are developed and adopted. Farmer participatory research is being employed in the Peruvian Amazon to develop such systems. Initial farmer testing of new rice and disease resistant banana and plantain varieties is intended to address problems most mentioned by farmers. As farmer and local national agricultural research system (NARS) confidence increases in the use of participatory methods, the research will shift more to improved fallows, secondary forest management, and the development of alternative crops and products (Fujisaka et al, 1998).

CIAT and national scientists have identified and counted frequencies of plants in different land uses--forest, cropping after forest, fallows of different ages, and cropping after fallows--in Acre, Rondonia, Pucallpa, and Yurimaguas. These studies look at plant species numbers, biodiversity losses in the affected areas, plant community succession as land uses in slash-and-burn systems are forced to change over time, the nature of weed invasions, and the effects of human exploitation of various forest products on plant composition. Such research seeks to understand the impacts of current land use in the forest margins in order to assist in the development of policies and technologies meant to preserve biodiversity (Fujisaka et al, forthcoming).

The cooperative commodity/NRM research has lead to a better understanding of the causal relationships between agricultural production practices and the environment. This information is an critical input into the process of setting research and technology development agendas. It also helps identify appropriate indicators of environmental impact to use in the evaluation of research projects.

As mentioned earlier, a remaining challenge in this area of research is to identify which of these biophysical relationships are also economically important. This is critical for priority setting. CIAT and IFPRI are currently working on a project in which soil erosion data will be incorporated into a traditional consumer-surplus economic impact assessment model to try to capture environmental costs.

The emphasis on participatory methods in these cooperative projects also helps keep the research focused on solving problems that farmers consider to be important. By targeting research to the specific needs of farmers and by incorporating farmer's knowledge and experience into the technology development process, participatory research can lead to shorter adoption lags and to higher levels of local adoption. However participatory research methods have their own problems with regard to impact assessment, namely difficulties associated with scaling-up the results beyond the initial study area. CIAT is working on using GIS to identify regions which are similar in terms of key economic and econological characteristics to the study site. The results of such research would help to target more precisely the release of new technologies and to increase the impact, especially in the short run.

3. NRM research

Distinguishing between NRM and commodity research is difficult, however there are some situations in which the short term goals of traditional agricultural or environmental research appear to diverge from those of NRM. Such situations demonstrate some interesting characteristics of NRM research and highlight challenges to impact measurement.

In 1992, participatory evaluation of contour barriers to control erosion was carried out in a pilot area in the

Cabuyal watershed in southern Colombia. Many technological options for controlling soil erosion are available to farmers, however adoption levels are low. One reason is that such techniques are designed and recommended on the basis of agronomic data, not necessarily on the basis of how well they meet farmers priorities. The results of the farmers' evaluations—which differed from those of the scientists--were incorporated into recommendations given out by extension programs. Over the next two years, adoption of contour barriers in this zone increased from 2 farmers to 261. More importantly, the farmers preferences as solicited in interviews were closely correlated with what farmers actually adopted, suggesting that participatory evaluation would be a valuable tool in estimating future adoption of technology and designing technologies to maximize impact (Ashby et al, 1996).

The impact of local involvement at the policy level can also be seen in the Colombia research site. In this watershed, an association was created which involves residents and outside organizations working in the watershed. It provides a forum in which stakeholders with diverse interests in the resources of the watershed can identify problems, set priorities, and negotiate solutions. Through concerted action of this group, residents achieved a change in the national policy regarding the maintainance of forested buffer zones around water courses. Colombian national environmental policy stipulated the creation of buffer zones measuring 50 meters for springs and 30 for water courses. Local residents considered this to be too big, and since official enforcement capacity was weak, compliance rare.

When this problem was taken up within the association, an agreement was reached with the regional watershed authorities and the local water management board that sizes of buffer zones would be determined on an individual basis, taking into conisderation the specific characteristics and features of the area. Technical advice would be provided to help make these determinations. As a result, over the next 18 months, over 135 hectares were enclosed and 150,000 trees planted. The community supplied 3,714 person days of labor to the effort. The local-level consensus and support for the policy also allowed the community to implement a highly effective enforcement mechanism. Anyone who did not participate would have their water turned off by the local water authority. (Ashby et al, 1997 and Ravnborg and Ashby 1996)

Both these examples represent cases where the recommendations based on narrow production or environmental protection considerations were rejected by farmers. On the surface, this does not look like positive impact. However the in terms of the amount of soil actually conserved or the number of hectares actually reforested, impact is higher with the "second-best" practices because they were adopted. Natural resource management problems are often characterized by the fact that the private and social costs and benefits of economic decisions diverge. Since decisions are made by individuals, special attention must be paid to the particular incentives facing each individual. An environmental technology or policy that is incentive compatible—and therefore feasible—may look quite different from one that derives from some concept of the "social good" without regard for whether it can be feasibly implemented. In reality, tradeoffs may have to be made between priorities of the different stakeholders in order to assure implementation.

In terms of quantifying impact, NRM research faces many of the same valuation problems mentioned in earlier sections. Since many resources do not have markets, it is difficult to put a monetary value on them. Research carried out within the context of a particular production system can be valued in terms of the contribution of the resource to productivity. However much NRM research is not that site or system specific. Work is underway by CIAT economists in Pullcalpa to use techniques such as contingent valuation to try put a value on resources, and thereby provide a basis for assessing the impact of projects that lead to changes in the resource base.

Finally, resource management associations such as the watershed user's association can have value to a community far beyond the achievement of their short term NRM goals. Improving the capacity of a community to organize and work cooperatively to achieve its goals will help it to address other issues that collective action. Incentive problems described above are not unique to NRM, and collective action is one way to help mitigate their effects on economic efficiency. There is increasing evidence that high levels of cooperation and organization can contribute to development(Putnam). Given the dynamic nature of NRM and of the broader economic system, the real impact of stengthening the ability of communities to better manage their own resources may be felt not through short term conservation projects but through its contribution to the better long run use of all community's resources—natural, mechanical, and human. CIAT and the Rockefeller Foundation are currently involved in research aimed at understanding and quantifying the short and long run impact of this "social capital" on NRM and community economic development.

Figure 1. Vertical and horizontal linkages: the case of land use

(Source: Winograd 1997.)

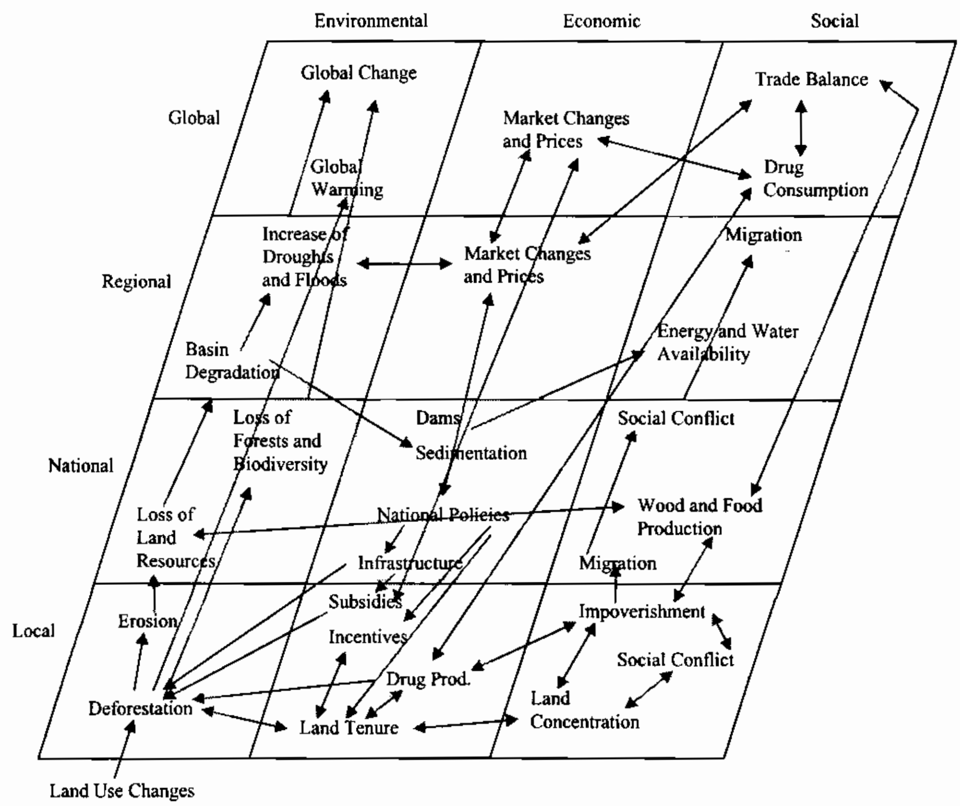


Figure 2: Amazonian Forests - Pressure, State, Impact and Response Indicators

2a. Pressure: Accessibility
State: Surface of Forests

2b. Impact: Fragmentation of Forests

2c. Response: Protected Areas
(Source: Winograd et al 1998)

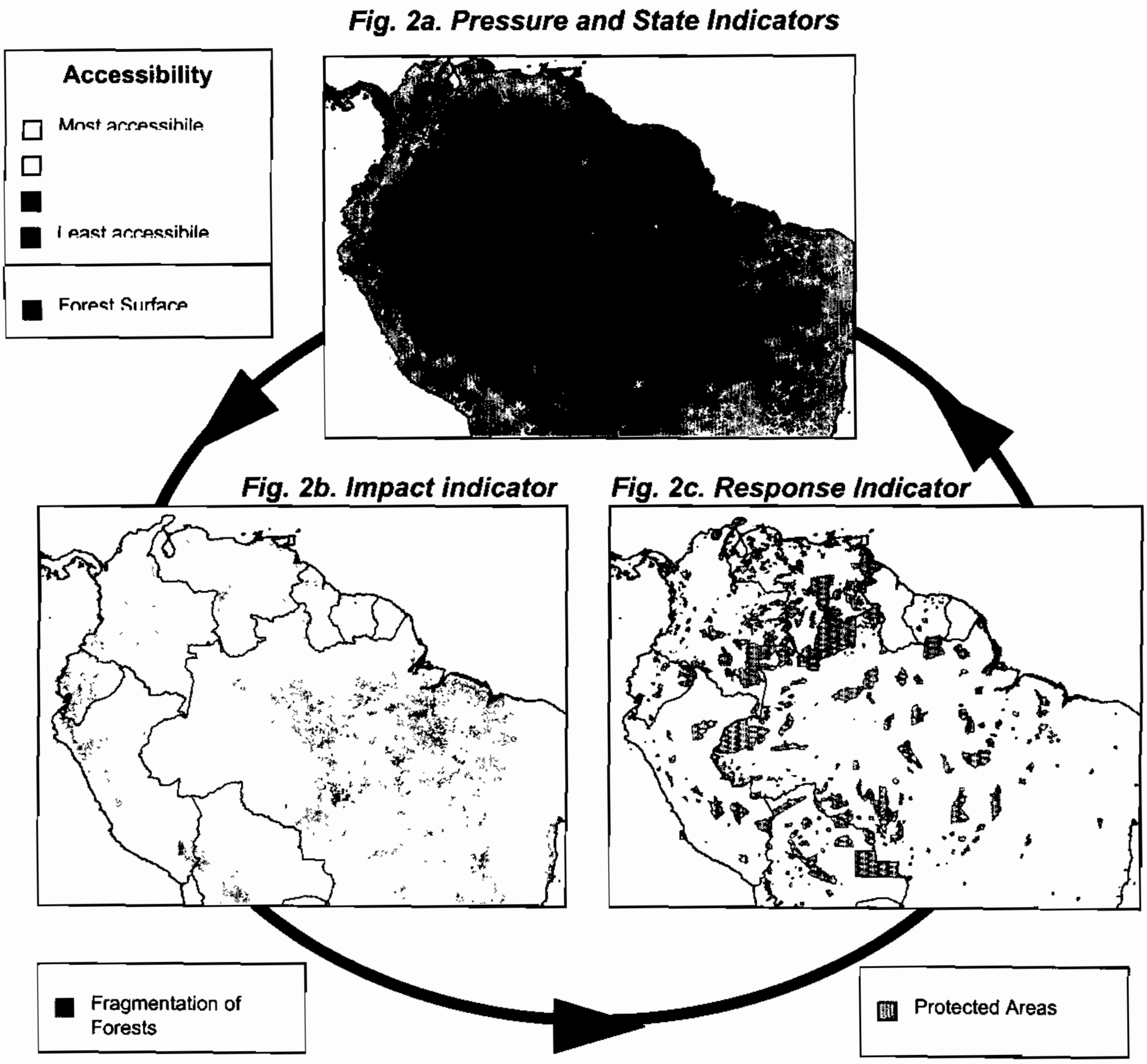
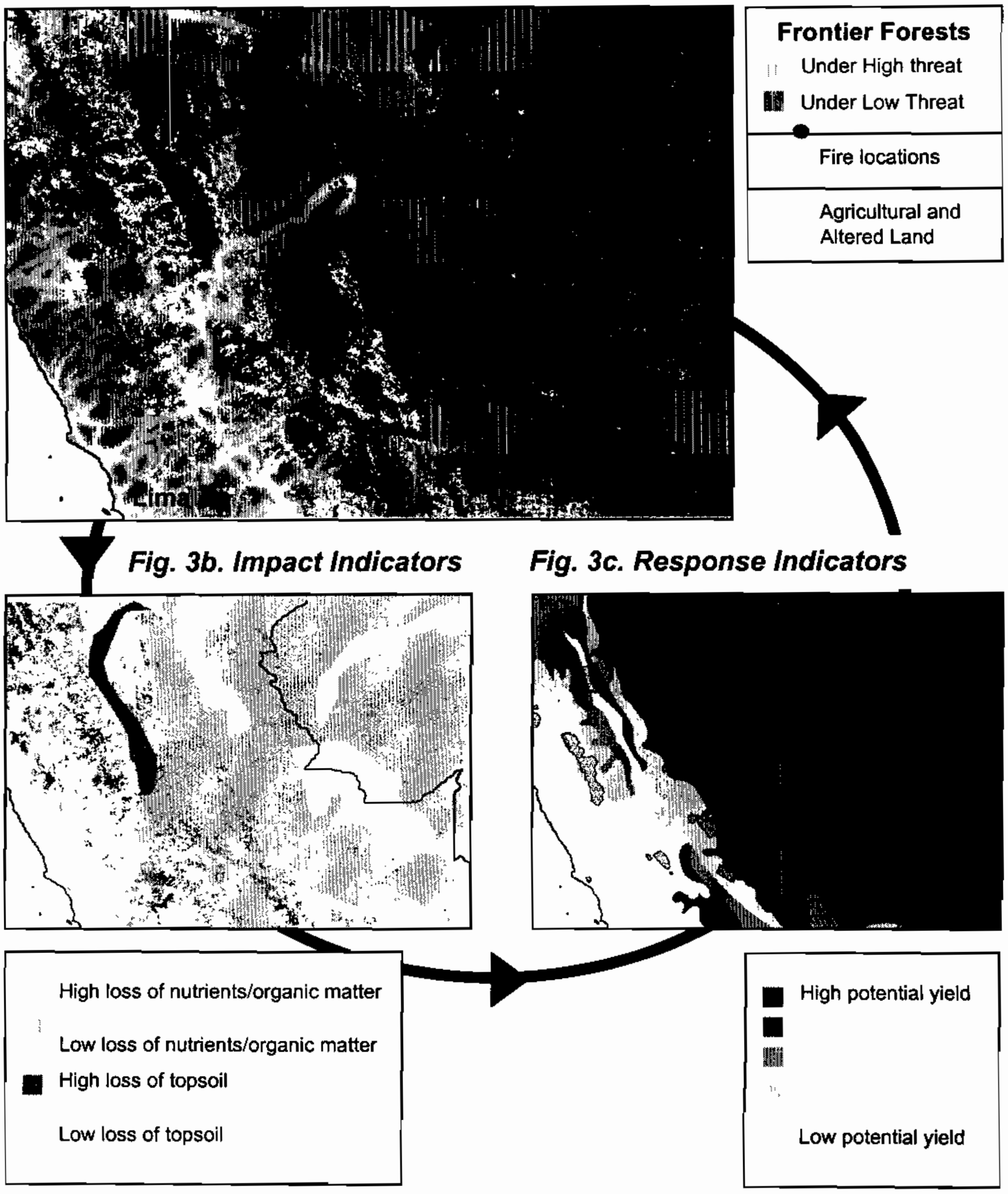


Figure 3: Peruvian Forest Margin - Pressure, State, Impact and Response Indicators
(Source: Winograd et al 1998)

3a.	Pressure:	Frontier Forests under threat Accessibility Distribution of Fires (January 1993)
	State:	Surface of Agricultural or 'Altered' land
3b.	Impact:	Soil degradation - loss of topsoil/nutrients/organic matter Fragmentation of Forests
3c.	Response:	Protected Areas Potential Yield

Fig. 3a. Pressures and State Indicators



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