Research to Integrate Productivity Enhancement, Environmental Protection, and Human Development

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ABSTRACT

To meet the challenges of poverty and environmental sustainability, a different kind of research will be needed. This research will need to embrace the complexity of these systems by redirecting the objectives of research toward enhancing adaptive capacity, by incorporating more participatory approaches, by embracing key principles such as multi-scale analysis and intervention, and by the use of a variety of tools (e.g., systems analysis, information management tools, and impact assessment tools). Integration will be the key concept in the new approach; integration across scales, components, stakeholders, and disciplines. Integrated approaches, as described in this Special Feature, will require changes in the culture and organization of research.

KEY WORDS: adaptive capacity, decision making, impact assessment, integration, scale, social learning, systems modeling.

INTRODUCTION

In the 1960s, a huge gap existed between the technologies used by farmers in developed countries and those available to poor farmers in the tropics and subtropics. International development assistance agencies have made major investments during the past 40 years in attempts to develop advanced agricultural technologies for poor tropical countries. The research centers supported by the Consultative Group for International Agricultural Research (CGIAR) have been major conduits for this aid. The CGIAR supports 16 international research centers with a combined budget of U.S.$350 million per annum. These efforts are widely credited with having averted large-scale famines that had been anticipated in Asia in the 1970s and 1980s. The impacts of such research have been more modest in addressing the needs of Africa. Much of this research adapted technologies from developed countries to conditions in developing countries; it targeted innovations that could yield quick benefits to respond to urgent needs. Major investments went into genetic improvement of a few commodity crops to enhance productivity and improve resistance to pests and diseases. The gains were largely confined to areas of high agricultural potential, and they often benefited the more prosperous farmers, missing the poorest of the poor. In many cases, this research yielded short-term gains at the expense of long-term degradation of soils, water, biodiversity, and noncultivated land. The initial spectacular gains of the green revolution are unlikely to be maintained (Conway 1997).

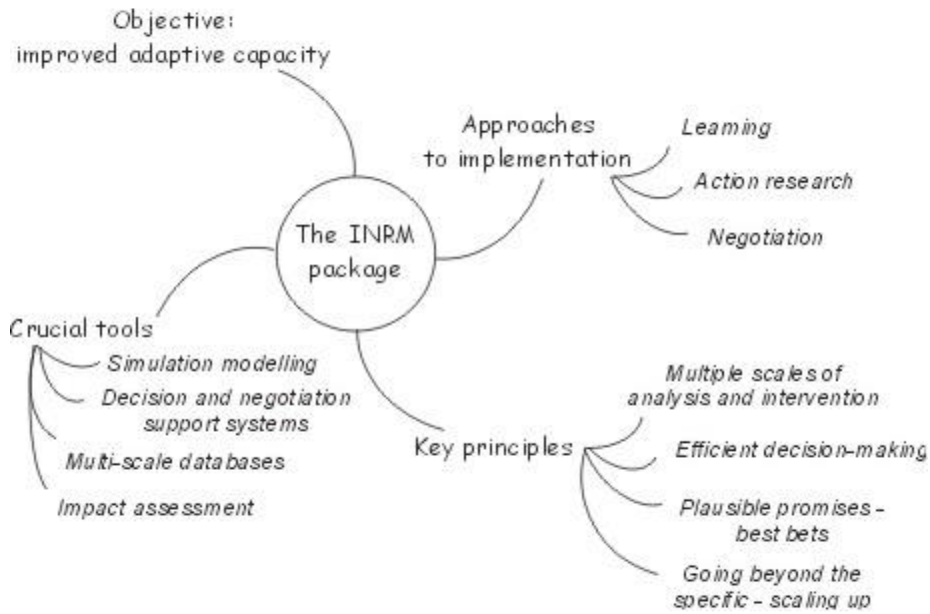
There is now widespread recognition that the sustained improvement of the well-being of poor farmers in developing countries will require a different kind of research. Cutting-edge agricultural technology is still needed, but it has to be set in local contexts and be applied in ways that recognize the special conditions of poor farmers. It will have to give more emphasis to management of risks, reduction of dependence on agricultural inputs, avoidance of long-term depletion of productive potential, and more careful control of environmental externalities (Conway 1997). The advent of economic globalization and the increasing domination of agriculture by a few large companies poses special risks for the poor (Korten 1995). Equity in the distribution of benefits is emerging as a major issue.

Green revolution science underestimated the complexity of the systems in which small-scale producers operate. Crop production, for example, is usually only a small part of a broad livelihood portfolio that may encompass a wide variety of off-farm activities, the gathering of forest products, the raising of livestock, etc. Productivity enhancement will remain important, but risk reduction, improved food security, and the maintenance of social capital will assume greater importance. The farming systems of poor people in the tropics are subject to a multitude of exogenous influences. For instance, they are subject to highly variable rainfall, especially in semiarid areas, a constantly changing economic climate with resulting swings in input costs and market prices, dynamic land use changes, and various other episodic events (e.g., the massive rise in AIDS in Africa; widespread fires associated with el Nin˜o[ERRATUM 1: corrected spelling: el Niño] events in southeast Asia, etc.).

Research on complex systems is not simple, because of multiple scales of interaction and response; a high frequency of nonlinearity, uncertainty, and time lags; and multiple stakeholders with often contrasting objectives and activities. Furthermore, many earlier attempts to conduct research at the level of large, complex systems are widely seen to have generated needs for excessive amounts of data, to have been very costly to conduct, and to have yielded few results of immediate practical value. This problem has become particularly important in the context of funding allocation strategies based upon ex-post analysis of the impact of research on production. It has been very difficult to attribute any direct impact to much of the research that has been conducted on complex farming systems. This has led many to conclude that natural resource management or agro-ecosystem research is an expensive luxury.

In August 2000, the CGIAR convened a meeting in Penang, Malaysia to address these dilemmas faced by natural resource researchers and to examine ways in which research might be redirected to meet the challenges. This volume brings together a selection of the papers that formed the subject of the Penang meeting. Papers and discussion at the meeting yielded significant new insights into the ways in which the CGIAR and similar research institutions might modify their way of doing business. The focus was on the use of techniques and approaches drawn from a number of fields of science to yield results with short-term benefits for the poor and their environment. The key components of this new vision of integrated natural resource management (INRM) will be discussed. They involve an interlinked package (Fig. 1) including: (1) the reorientation of the objectives of research, (2) adding weight to participatory approaches to implementing the research, (3) a series of principles that underlie the research (e.g., broadening temporal and spatial scales of analysis), and (4) the use of a variety of analytical tools (e.g., systems analysis, information management tools).

Fig. 1. Some of the key features of INRM research.



THE OBJECTIVE OF INRM: TOWARD ADAPTIVE CAPACITY

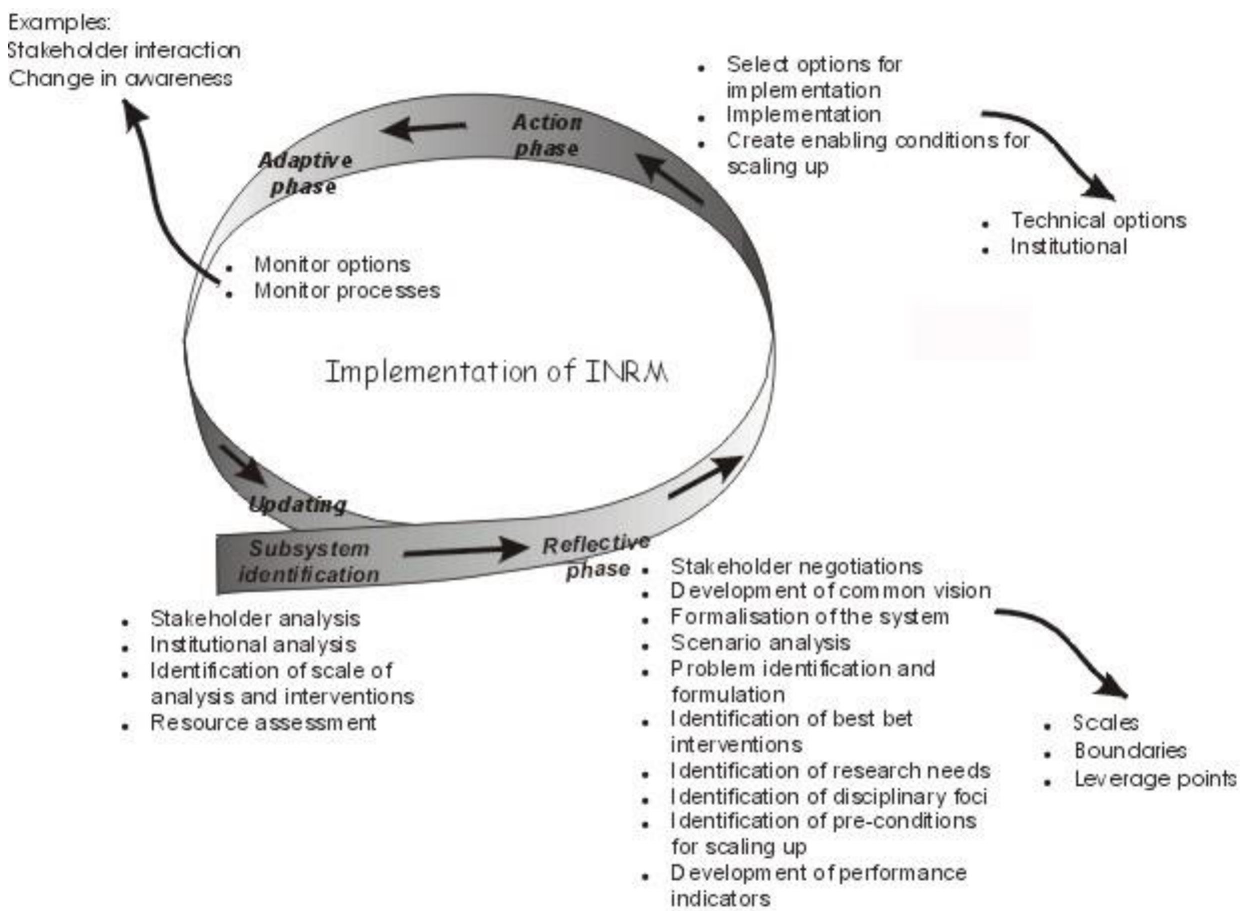
In mainstream productivity enhancement research, the prime objective is to improve yields of the dominant crops using plot-specific technologies. In a multi-stakeholder situation with small-scale producers, there will be multiple objectives, and it is unlikely that any single production objective will suit all stakeholders. Standardized technologies that work in many contexts will be only part of the solution. Given the complexity and dynamism of systems, one of the prime objectives will be to improve the adaptive capacity of the system, i.e., its ability to sustain a flow of the diverse products and services that poor people depend upon, and to do so under constantly changing conditions. Research will need to strengthen the farmer's ability to manage a broad range of production factors, thus increasing her flexibility and her ability to respond to exogenous influences (Hagmann et al. 2002). Considerable focus will be on the managers themselves, helping them to achieve the skills and acquire the technologies that will enhance their control over their own destinies (Lynam et al. 2002, Lal et al. 2001). High-technology research on the components of agricultural systems is still vital, but it has to be placed in the context of specific biophysical and socioeconomic conditions.

THE APPROACH: LEARNING TOGETHER FOR CHANGE

Three key elements form part of the approach to implementing INRM: (1) management needs to be adaptive; (2) INRM must move further along the research –management continuum; and (3) the approach must provide for, and be based upon, negotiation among all stakeholders. INRM research draws heavily upon, and reflects the advances in, our understanding of social learning (Daniels and Walker 1999, Hagmann 1999, Maarleveld and Dangbégnon 1999). Thus INRM must be based upon continuous dialogue and deliberation among stakeholders; this incorporates adaptive management as well as political processes related to conflict among stakeholders. Ultimately, in the ideal scenario, all management is experimental and all research involves managers; there is little distinction between management and research (Roussel et. al. 1991). Natural resource management is like jazz; it requires constant improvisation. This implies that researchers can no longer remain exclusively external actors, but need to engage themselves in action research to develop appropriate solutions together with resource users (Hagmann et al. 2002). Good process facilitation is an essential component of its implementation. This process facilitation is a formal scientific equivalent of the rituals and traditions that socialize complex resource management processes in all human societies.

Natural resource managers are constantly confronted with surprises. Stakeholders change their aspirations, and exogenous factors have unpredicted influences on the system. Managers have to deal with uncertainty and changing targets. One of the key lessons in dealing with complex systems, therefore, is that management must be organized in a way that promotes active and conscious individual and social learning. The inverse relationship between the complexity of systems and our ability to make precise, and yet significant, statements about their behavior suggests that sustainable management of natural resources must be adaptive (Zadeh 1973, Holling and Meffe 1996). The steps within our adaptive management cycle (Fig. 2) are (1) subsystem definition; (2) reflection and negotiation; (3) action; and (4) evaluation, readjustment, and adaptation. As a result of the evaluation, we move back into the reflective phase and update our conceptualization of the system. This adaptive management cycle is discussed in several papers in this volume (Hagmann et al. 2002, Harrington et al. 2001, van Noordwijk et al. 2001, Lal et al. 2001, Lynam et al. 2002, Douthwaite et al. 2001).

Fig. 2. The learning cycle in INRM research.



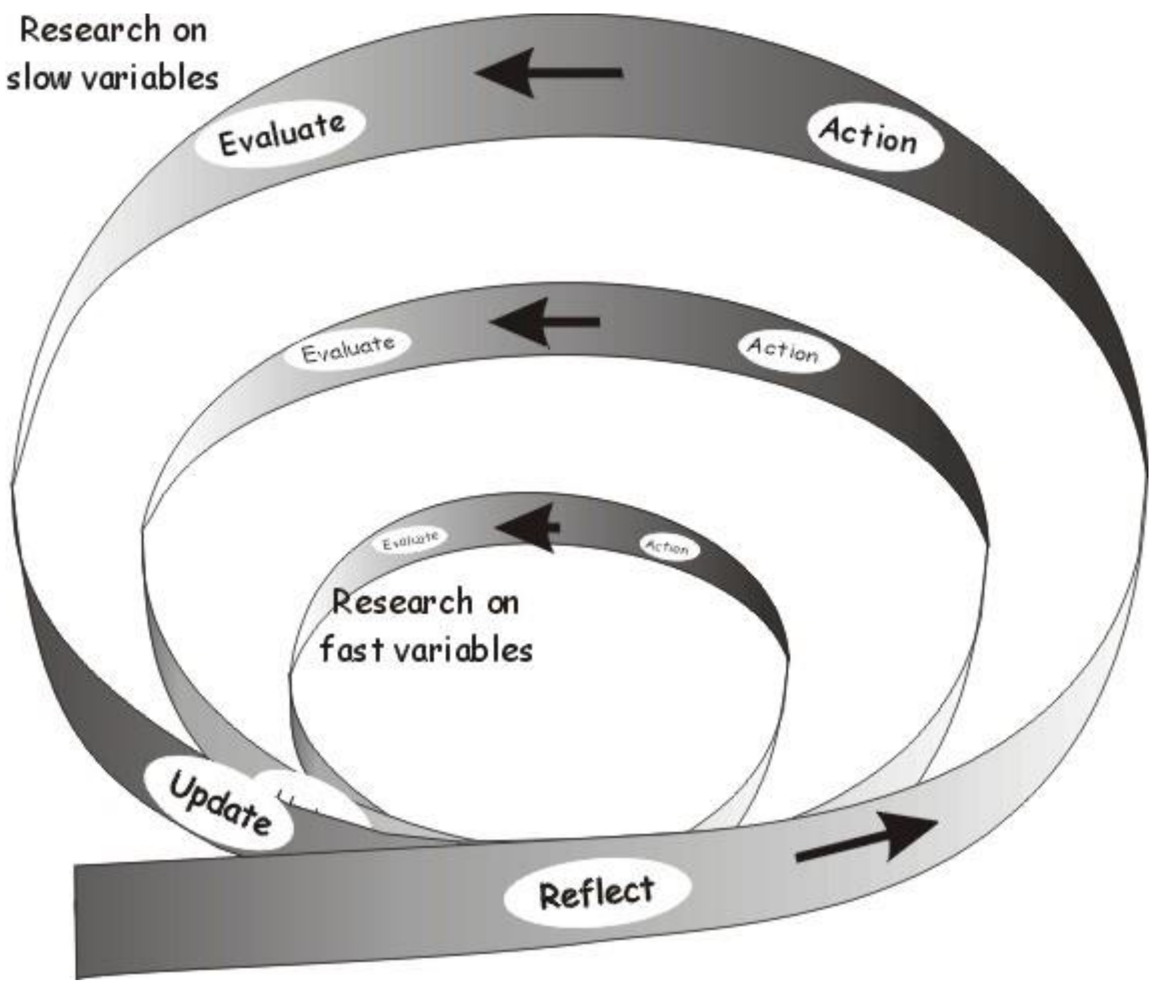
In the adaptive learning cycle, researchers are one, among many, stakeholder groups. The research is conducted as part of an experimental management process involving the full range of stakeholders. Thus, participatory approaches are fundamental and collective action is the norm (Douthwaite et al. 2001, Hagmann et al. 2002). Because numerous stakeholders are involved, negotiation processes are key to the action cycle; thus, actions are an outcome of various negotiation processes. Negotiation occurs throughout the adaptive management cycle, in particular in establishing a common vision during the reflective stage, and in selecting options for implementation in the action phase. Given the emphasis on multiple stakeholders, it is not surprising that many of the successful cases of INRM have as a key objective the development of social capital (Garrity et al. In press, Lovell et al. 2002).

UNDERLYING PRINCIPLES: GOING TO SCALE BUT REMAINING PRACTICAL

Multiple scales of analysis

A key feature of INRM is its attempt to integrate across spatial and temporal scales. INRM research should never involve just a single snapshot in space or time. In the real world, different processes are taking place over different time frames; some processes will be studied using short time frames, whereas others may have to be studied over decades, usually only possible through simulation (Lovell et al. 2002). As a result, INRM research usually does not involve a simple learning cycle. It will normally depend upon a number of interlinked and superimposed learning cycles (Fig. 3), as some phenomena will have been through many learning cycles, whereas others may not even complete a single cycle within the project timeframe. It is particularly important for INRM research to take slow variables into account. These slow-changing variables affect the dynamics of more rapidly cycling processes and may exceed thresholds or trigger breakpoints, thus causing sudden and surprising shifts in systems. Accumulations of toxic chemicals in soils, water, and organisms, gradual erosion of soil fertility, and depletion of groundwater are all slow variables that need to be tracked in studies of complex resource systems.

Fig. 3. Overlapping learning cycles for different INRM processes.



Generally, INRM research will never be conducted at a single spatial scale; work often will be required at three scales (Allan and Starr 1982, Holland 1995). Thus, work at the farm/household level may require component studies at lower levels, such as the plot level or the intra-household level, to understand the important processes that lead to the emerging characteristics at the farm/household level. Work at the farm/household level will also generally require work at higher levels, e.g., at the institutional framework established by local government. Two components of spatial scale can be recognized, a biophysical component (from plots to global scales) and an institutional component (from household norms of behavior to global policy instruments). These are not usually congruent, thus adding further complexity (Lovell et al. 2002).

Decision-making processes

Many conceptual models of INRM focus on decision-making processes. Lal et al. (2001) go so far as to term the learning cycle in INRM the "Adaptive Decision-Making Process". Decisions by individuals or households to adopt or not adopt new technology or land use practices depend on a multitude of factors and external influences that will vary from situation to situation, and will be dependent on incentive structures, information flows, etc. (van Noordwijk et al. 2001). Central to the decision-making process is the analysis of trade-offs and competing interests (Garrity et al. In press, van Noordwijk et al. 2001). In much INRM research, the farm household is selected as the main decision-making unit (Lal et al. 2001). Although this may be appropriate in many circumstances, there are situations, most notably involving common property systems, in which other stakeholders at other spatial scales may be key.

Plausible promises

INRM should lead to tangible benefits on the ground; it must be a problem-solving approach (Hagmann et al. 2002,Harrington et al. 2001, van Noordwijk et al. 2001). The motivation to jointly engage in experimentation and research is that there is some "plausible promise" of a beneficial change (Douthwaite et al. 2001). Plausible promises are often made with reference to "best-bet" interventions involving technological and/or institutional innovations. The successful INRM cases are invariably built around very specific intervention possibilities that achieve adaptation and uptake (Garrity et al. In press, Hagmann et al. 2002).

Scaling up: going beyond the specific

INRM research, because it considers numerous variables, many of which are locality specific, has been criticized for yielding only local solutions. However, if natural resource systems are characterized adequately and variables are measured across the full range of variation of the system, then INRM models will yield results that have application across broad ecoregional domains.

The dissemination of conventional agricultural technology research products, e.g., high-yielding crop varieties, follows a simple linear route from researcher to extension worker to farmer (the "transfer of technology" model). INRM research does not yield technological packages amenable to this sort of dissemination (Douthwaite et al. 2001). In INRM, the farmers, extension officers, and researchers are all stakeholders, participating from the initiation of the research. Lovell et al. (2002) conclude that scaling up to benefit many people is largely a function of planning and investment at the outset to create the enabling environment that will meet various pre-conditions for scaling up. One of the conditions for scaling up is the adequacy of social capital (Lovell et al. 2002, Hagmann et al. 2002). Scaling up is most likely to happen in the INRM approach if top-down and bottom-up approaches to development are properly reconciled. Both are likely to be needed for an effective delivery of benefits from INRM research (Lovell et al. 2002). The adaptive management cycle is key to scaling up: repeated learning cycles ensure an improvement in the "plausible promise' through its adaptation to existing systems by ever larger number of producers (Douthwaite et al. 2001).

Any INRM research endeavor should usually have impacts at a number of spatial and temporal scales (Harrington et al. 2001, Lovell et al. 2002, Jones and Thornton 2002). The work of Hagmann et al. (2002) provides an example of impacts at multiple scales. These authors undertook research that spanned from the plot to the policy scale; their work resulted in successful interventions at the plot level and important reorientation of thinking within the national extension service.

THE TOOLS FOR INRM: CONFRONTING COMPLEXITY

Systems modeling

The problems of nonlinearities, unpredictability, and time lags in natural resource systems suggest that systems modeling is a fundamental tool for INRM research. Systems modeling is appropriate at many points in the adaptive management cycle. It can be used to conceptualize the system, to build a common understanding among stakeholders, to identify leverage points for interventions, to analyze different scenarios, to form the basis of decision support systems, to assist in stakeholder negotiations, to identify systems performance indicators and to assist in evaluation of impacts (Campbell et al. 2001, Lal et al. 2001, Lynam et al. 2002, van Noordwijk et al. 2001).

Negative attitudes toward modeling abound, often based on the heavy data requirements of large and complex simulation models. Although such complex models undoubtedly have their place, we are attracted by the concept of "throw-away" models, working computer-implemented models that are built in a few days to solve a particular problem and then are discarded. Much recent INRM research has used participatory modeling, in which stakeholders assist in the development of models and model results are fed back to communities using participatory techniques such as role plays (Lynam et al. 2002).

Across-scale modeling is in its infancy in NRM. Jones and Thornton (2002) demonstrate a method whereby plot-level models can be run for large extrapolation domains and the results can be aggregated to provide useful information at the regional level. Jones and Thornton (2002) also demonstrate the use of a series of interconnected models, ranging from global to plot models.

Decision and negotiation support tools

Given the complexity of INRM systems, it is likely that some kinds of decision or negotiation support tools will be necessary. The term "decision support system" suggests that a single management authority will make decisions that will then be imposed on the various actors and stakeholders. Thus, van Noordwijk et al. (2001) prefer the term "negotiation support system". To function adequately, a negotiation support tool, itself, must be the subject of negotiation and shared development efforts between stakeholders (van Noordwijk et al. 2001, Garrity et al. In press). Lal et al. (2001) conclude that using a decision support tool that is built in a participatory manner will increase the chance of achieving a shared vision.

Multiscale databases

Increasingly, decision support systems or systems models are being linked to a variety of databases. Even when not linked in this manner, INRM will invariably require that data from different sources be managed in some kind of database. Data can be of a spatial or nonspatial nature, and both qualitative and quantitative data can be included. Geographical Information Systems are usually involved in the data management system. Jones and Thornton (2002) demonstrate the use of databases at various scales that are linked to models at various scales. GIS and modeling are also crucial for scaling up. As Harrington et al. (2001) note, such tools should not be abused to support top-down mechanical extrapolation of technologies; rather, stakeholder decisions should be informed by spatial analysis.

Impact assessment

Impact assessment is a key feature of INRM, being a tool for adaptation, learning and performance enhancement; providing data for further negotiation among stakeholders; and for resource allocation decisions. Hagmann (2001)[ERRATUM 2: this reference should read Hagmann et al. (2002)] pleads for more focus on developing plausible strategies on how research contributes effectively to impact, and then for regular monitoring of the implementation of these strategies, rather than carrying out impact assessment studies that are not linked to the learning cycle. Indicators for evaluation must be selected at an early stage of the work. To select indicators from the vast array of possibilities, Campbell et al. (2001) and Gottret and White (2001) suggest that the capital assets concept may be an appropriate organizing principle, whereas Bossel (2001) suggests that systems concepts should guide indicator selection. A number of papers in this volume focus on the use of indicators (Bossel 2001, Campbell et al. 2001,Gottret and White 2001). The approach advocated here is unlike that used in conventional impact assessment of agricultural research, which generally focuses on ex-post measures of crop yields. Classic ex-post impact assessment tools can be compared to end-of-year school exams, whereas INRM impact assessment tools should be seen as equivalent to continuous assessment.

THE WAY FORWARD

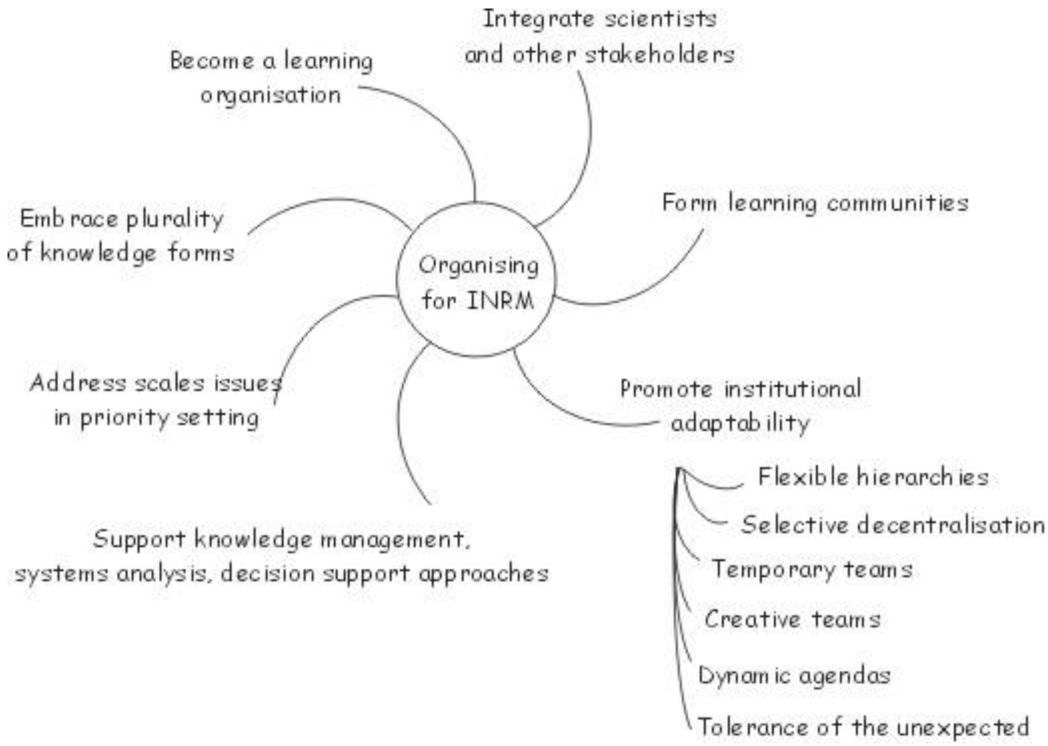
The successful examples of INRM research are those that have drawn upon and have integrated tools and concepts from different disciplines and scientific fields. This is what distinguishes modern approaches to INRM from some earlier discipline-based studies of natural resource problems. If the real needs of poor farmers in developing countries are to be met, then integrated approaches are essential. The farmers themselves are practicing integrated management of their resources, basing their management on knowledge acquired over generations (Berkes et al. 2000). Effective INRM research should link seamlessly with the knowledge of the client farmers. If scientists continue to operate in a simple, reductionist, technological world, they will fail to achieve the potential pay-offs that could be obtained by linking modern science to the traditional knowledge base. More importantly, however, changes occurring in the world defy the understanding of the small farmer. Macro-economic changes, increased climate variability, etc., will be major determinants of human well-being in poor countries, and science must contribute understanding of these phenomena to research on the system. Similarly, the development trajectories followed by the poor will have major implications for the global environment.

The world is becoming more integrated, and integration emerges as the most important concept in the INRM approach: there is a need to integrate across disciplines, across scales, across stakeholders, and across components (Lal et al. 2001). However, the marginal costs of adding each additional component into the system have to be considered and have to be less than the marginal benefits of such additions. A clear articulation of the problem, plausible solutions, and tangible potential benefits must still underlie all research investments.

A common criticism of the ecological approach to NRM is that it attempts to describe a multi-component system in which everything is connected to everything else, and that such complexity defeats useful analysis. Recent theory and supporting observation suggest, however, that this complexity is not boundless, but has its own natural subdivisions and boundaries, and that 3–5 key variables often drive any particular system (Holling et al. 2000). Thus, defining a set of key processes and components can yield progress toward a goal of sustainable production.

Integrated approaches to natural resource management, as described in this volume, will require major changes in the culture and organization of research (Ashby 2001, Hagmann et al. 2002). It is a new way of doing business. The management environment is faced with a long-term future that is unknowable; it has to deal with non-equilibrium conditions, multiple aspirations, and ambiguity. Although we see INRM being built on a social learning process, we also see the organizations involved in INRM becoming learning organizations, in which top management promotes institutional flexibility, conditions favorable to complex learning, integration of scientists with other stakeholders, etc. (Fig. 4).

Fig. 4. Proposed characteristics of organizations undertaking INRM research (based onAshby 2001).



Many of the arguments used in this paper are similar to those that predominate in the modern management science that is taught in business schools. Many of the problems of managing complex natural resource systems are similar to those of running a commercial company in a rapidly changing world. However, agricultural, forestry, and other NRM institutions have mostly evolved to deal with much simpler and more predictable conditions. They now have to change. Reconciling the need for increased supplies of food and fibers with the need to maintain the environment and to do this in a way that can bring a billion people out of absolute poverty is not a problem that can be solved by laboratory science alone. We need a predictive science that can enable us to produce more, to do so sustainably, and to do so on the basis of a limited resource base. This is the modern science of INRM that we describe in this volume.

RESPONSES TO THIS ARTICLE

Responses to this article are invited. If accepted for publication, your response will be hyperlinked to the article. To submit a comment, follow this link. To read comments already accepted, follow this link.

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