The Science of Sustainable Development

Local Livelihoods and the Global Environment

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Contents

Figures

Boxes

Tables

1 The challenge: alleviating poverty and conserving the environment

> One of the anomalies of modern ecology is that it is the creation of two groups, each of which seems barely aware of the existence of the other. The one studies the human community almost as if it were a separate entity, and calls its findings sociology, economics and history. The other studies the plant and animal community and comfortably relegates the hodge-podge of politics to the liberal arts.
>
> The inevitable fusion of the two lines of thought will, perhaps, constitute the outstanding advance of the present century.
>
> Aldo Leopold, 1935[1]

Sixty-five years ago, Aldo Leopold laid down the challenge of developing a science of integrated natural resource management. But a vast gulf still exists between the high priests of theoretical ecology, the gurus of social processes and the real world of resource managers (farmers, fishers and foresters). In this book, we will attempt to understand why the manifestly sensible goal of managing natural resources in an integrated manner has proved so elusive. Our concern is with developing countries and with the effectiveness of attempts to promote 'sustainable development' for the vast populations of the world's poor people.

Many development assistance agencies now aspire to the dual missions of alleviating poverty and conserving the environment. Meanwhile, conservation organisations are claiming that their activities are yielding benefits for the poor. All are implying that natural resources can be managed in ways that achieve immediate benefits for local people whilst sustaining long-term local and global environmental values. However, many critics say that the lack of success of both development and conservation programmes in developing countries results from this confusion of two inherently divergent agendas.

Huge amounts of money have been invested in various approaches to achieving integration in natural resource management. *Integrated rural*

[1]Bradley, N. L. (1998). A man for all seasons. *National Wildlife*. http://www.nwf.org/nationalwildlife/1998/tableam8.html.

development was widely attempted in the 1960s and 1970s but then abandoned. *Integrated conservation and development projects* came onto the scene in the 1970s but although they are still around their credibility as a development or conservation tool is now seriously questioned.[2] *Ecoregional approaches to development, integrated soil and water management projects, ecosystem approaches to conservation, integrated catchment management* etc. are the flavours of the first decade of the twenty-first century, but many claim that they are attempts to put old wine into new bottles. Many attempts to integrate complex sets of knowledge and the interests of diverse sets of actors into a common framework have yielded disappointing results. The desire to achieve integration persists but our seeming inability to translate the theories of integration into practical achievements on the ground is leading to widespread disillusion. In frustration, we abandon one set of integrative buzzwords and replace them with others. What is surprising is not the improvement of integrative methods over the past 40 years – rather it is their fundamental similarity. The words have changed but the paradigm remains similar (Box 1.1).

Box 1.1. Integrated natural resource management and its various manifestations

Integrated natural resource management is a conscious process of incorporating the multiple aspects of natural resource use into a system of sustainable management to meet the goals of resource users, managers and other stakeholders (e.g. production, food security, profitability, risk aversion and sustainability goals). To fulfil its aims, an integrated natural resource management approach is necessarily adaptive, interdisciplinary and involves a diverse set of stakeholders.[1]

Integrated catchment management is the process of formulating and implementing a course of action involving natural and human resources in a watershed, taking into account the social, political, economic and institutional factors operating within the watershed and the surrounding river basin and other relevant regions to achieve specific social objectives.[2]

Integrated water resource management is the coordinated planning and management of land, water and other environmental resources for their equitable, efficient and sustainable use.[3]

Community-based natural resource management is the integrated management of a multitude of open-access, common property and privately owned natural resources at the 'community' scale.

Integrated rural development was the dominant rural development paradigm of the 1960s. It shared many of the goals of integrated natural resource management as described

[2]McShane, T. O. and Wells, M. P. *Getting Biodiversity Projects to Work: Towards More Effective Conservation and Development*. New York: Columbia University Press, 2004, in press.

in this book but failed because the delivery mode was rooted in a top-down, western-science-knows-best mind-set.

Integrated conservation and development programmes are approaches to management and conservation of natural resources in areas of significant biodiversity value that aim to reconcile biodiversity conservation and socio-economic development interests of multiple stakeholders at local, regional, national and international levels.[4]

Ecosystem approaches are a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way.[5] The Convention on Biological Diversity has adopted a set of useful principles that define the ecosystem approach.

Landscape management is a term recently adopted by several international conservation groups, notably the Worldwide Fund for Nature and the International Union for Conservation of Nature and Natural Resources, to describe mosaic landscapes where one seeks to optimise environmental and production functions by managing the different landscape units in a complementary way. The French use the term '*Aménagement du territoire*' to convey roughly the same meaning.

Adaptive collaborative management is a concept promoted by the Center for International Forestry Research (CIFOR) that is based upon three linked processes: stakeholder interaction, communication and learning among stakeholders, and joint or collective action, resulting in changes or adjustments to management. These changes, in turn, affect the benefits people derive from natural resources and the quality of the resource.[6]

Multifunctional agriculture or forestry describes agriculture or forestry that deliberately avoids maximising crop yields in order to produce amenity or environmental benefits. The term has been controversial, as it is strongly associated with the European Common Agricultural Policy and its environmental payments, which are seen by competitors as hidden subsidies.

[1] Anon. *Report on the Workshop on Integrated Natural Resource Management Research in the CGIAR: Approaches and Lessons*, 21–25 August 2000. Penang: ICLARM. Online: http://www.inrm.cgiar.org/documents/workshop_2000.htm; Gottret, M. A. V. N. and White, D. Assessing the impact of integrated natural resource management: challenges and experiences. *Conservation Ecology*, **5** (2001), 17. Online: http://www.consecol.org/vol5/iss2/art17.

[2] UNESCO. Integrated water resource management: meeting the sustainability challenge. *IHP Humid Tropics Programme Series No. 5*. Paris: UNESCO Press, 1993.

[3] Calder, I. R. *The Blue Revolution – Land Use and Integrated Water Resources Management*. London: Earthscan, 1999.

[4] Franks, P. and Blomley, T. Fitting ICD into a project framework: the CARE experience. In *Getting Biodiversity Projects to Work: Towards More Effective Conservation and Development,* ed. T. O. McShane and M. P. Wells. New York: Columbia University Press, 2004, in press.

[5] Secretariat of the Convention on Biological Diversity. *Conference of the Parties Decisions. Decision V/6 Ecosystem Approach*. Geneva: United Nations Environment Programme, 2001. Online: http://www.biodiv.org/decisions.

[6] Buck, L. E., Geisler, C. C., Schelhas, J. and Wollenberg, E. (ed.) *Biological Diversity: Balancing Interests through Adaptive Collaborative Management*. Boca Raton, FL: CRC Press, 2001.

The lack of progress in achieving integration has led many to question its usefulness. Many have argued that the ideal of integration is conceptually appealing but is impossible to achieve in practice. For example, Sedjo (1996) has stated that 'ecosystem management lacks clear objectives and hence cannot be operationalised on the ground'.[3] Another view, and the one that we will explore in this book, is that the processes, tools and concepts that could underpin a new integrative science are not widely understood and not fully embraced, and that fundamental aspects of the way development science is organised are creating obstacles to change.

Getting researchers from different disciplines to work together with resource managers from different sectors seems sensible and easy enough. In practice, however, there seem to be language and cultural barriers that often bedevil attempts to get diverse groups of people to work together on a common problem. This is not the case in all areas of human endeavour. Large teams of diverse scientists collaborate to launch space probes, develop stunningly complex computer technology and unravel the complexity of life-threatening diseases. In a June 2000 issue of *Science* John Lawton commented that '. . . scientists and engineers from many disciplines routinely work together within institutions and organisations to improve human health. We would be startled if it were not so. The health of the planet is a different story . . . . We lack the organisations to nurture [the required integration]'.[4] The rewards of collaboration and integration for scientific endeavours with commercial applications are enormous, and the costs of reductionism are failure, bankruptcy and obscurity. However, the markets for the public goods products of integrated natural resource science are embryonic, at least in the developing world. Most natural resource organisations still reward individual achievement and fail to provide an environment where multidisciplinary teams and integration can flourish.

Nowhere is the need for integration and collaboration greater than in addressing the environmental problems confronting the developing world today. Yet most natural resource managers and researchers remain tied to their laboratories or their experimental plots. The costs of not integrating and not collaborating are colossal: the progressive deterioration of the agricultural, forestry and fishery systems upon which all life depends. These costs are not born by the scientists and government resource managers; the costs are manifest in the suffering of resource-poor farmers and deterioration of the quality of life of society at large.

[3]Sedjo, R. A. Towards an operational approach to public forest management. *Journal of Forestry,* **94** (1996), 24–27.

[4]Lawton, J. Earth science systems. *Science,* **292** (2001), 1965.

In this book, we will attempt to show why integrative approaches are essential and to demonstrate that successes from integrative science are possible and practical. We will attempt to elucidate the key processes, tools and concepts that need to be embraced if integration in natural resource management is to become operational on a scale sufficient to confront the crisis of achieving sustainable development.

The challenges facing research

The work of the research centres of the Consultative Group for International Agricultural Research (CGIAR) formed the basis of the green revolution. Scientific reviews and activist non-governmental organisations (NGOs) have all attacked the CGIAR for focussing on technological solutions to the problems of the poor and ignoring the complex realities of their lives. Critics have focussed on the harmful social and environmental externalities caused by some of the agricultural innovations that the CGIAR has produced. The harsh reality is that the benefits of more efficient production of commodity crops may accrue to better-endowed farmers and to urban consumers. The poorest of the poor may not have access to these innovations and may be further marginalised by them.

Jacqueline Ashby of the International Center for Tropical Agronomy (CIAT) at Cali in Colombia has been a leader in exploring the scientific basis for integration and participation in the work of the CGIAR. She has been responding in part to the drastic decline in the status and credibility of mainstream agricultural science since the Nobel prize-winning heights of the green revolution. In a recent article in *Conservation Ecology*, she claims that many now see conventional agriculture as a threat to the environment and to human health.[5] The perceived risks in the way food is produced and the effects of new food production technologies on the health of humans and ecosystems have become major political issues and topics for headline news. When the CGIAR was established in the 1960s, agriculture was seen as a major part of the solution to the development problems of the Third World; today, a significant body of opinion sees modern agriculture as a major part of the problem.

However, advances in agricultural science are still essential if we are to achieve the yield increases needed to meet the world's food requirements. The globalisation of trade and the food needs of a burgeoning world

[5]Ashby, J. A. Integrating research on food and the environment: an exit strategy from the rational fool syndrome in agricultural science. *Conservation Ecology,* **5** (2001), 20. Online: http://www.consecol.org/vol5/iss2/art20.

population will drive this process in the direction of the intensive production of uniform crop varieties by large-scale agro-industries. Poor farmers will not be able to compete in markets with modern industrial agriculture and will either have to seek their fortunes off the land or be relegated to a marginal subsistence existence. The idea that over a billion very poor farmers can be absorbed into manufacturing and services requires an exceedingly optimistic view of the potential for continuing global economic expansion. Furthermore, many fear that while food needs may be met under this scenario, it will be at the expense of climate, biodiversity and amenity values. For example, the World Conservation Strategy advocates 'reducing excessive [crop] yields to sustainable levels'.[6] Examples of well-documented public distrust in agricultural science and policy abound. Two examples are the 'mad-cow disease' scandal in the UK and the growing, international antipathy to genetically modified organisms and to uniform plantations of fast growing clonal trees.

The focus of this book is on attempts by governments and development assistance agencies to improve the livelihoods of poor people in the developing world. These poor people depend upon the 'natural capital' that supports their lives just as much as they do on the more tangible assets of money and property. Natural capital is the soil, water, climate and biodiversity upon which functioning ecosystems depend. People's concerns may be driven by a conservation ethic but this has its origins in compelling evidence of the poverty, famine and natural disasters that result from degraded ecosystems. The resilience of the poor in the face of external shocks such as war, climate variation and indebtedness depends on natural capital. The diversity of nature and the health of ecosystems are essential to people's survival in a turbulent and constantly changing world.[7]

In recent years, political support for investing development assistance money in natural resources research has weakened. Instead, funds are being channelled to better governance, public sector adjustment, disaster relief and the mitigation of environmental problems. There is a notable decline in support for agriculture, a reflection of the disenchantment with industrialised agriculture in high-income countries and the perception that development assistance to agriculture has not delivered the benefits that it promised. Agricultural research is not unique in this loss of credibility.

[6] IUCN 1990 cited in Adams, W. M. *Green Development*. Oxford: Oxford University Press, 1990.

[7] Conway, G. R. The properties of agroecosystems. *Agricultural Systems,* **24** (1987), 95–117; Pearce, D., Barbier, A. and Markandya, A. *Sustainable Development: Economics and Environment in the Third World*. Aldershot: Edward Elgar, 1990.

Robert Chambers of the Institute for Development Studies at the University of Sussex in the UK has analysed the way in which rural development practitioners have gone through a process of being proved consistently wrong and have lost credibility for their claims.[8] In the same vein, critics of mainstream agricultural science claim that the research establishment 'is incapable of delivering social equity, economic efficiency and ecological integrity in response to the decline of rural society and deepening crises in the depletion and degradation of water, soils, flora and fauna'.[9] The rates of return on investment in agriculture for developing low-income countries have indeed been disappointing. There is evidence that returns on investments in agricultural development projects have been even lower than in sectors such as health or education. The gains from agricultural projects are often not sustained after external donors withdraw.[10] Proponents of organisational change to support the development of sustainable agriculture do not always see a role for science in this process. Röling and Jiggins state that 'the old role of developing technologies for farmers seems to clash with the logic of [providing farmers with the adaptive skills to practice] ecologically sound farming, while a new role [for research] . . . seems not to have clearly emerged'.[11]

In the 1960s, a huge gap existed between the technologies used by resource managers in developed countries and those available to poor farmers and resource managers in the tropics and subtropics. The main objective of development assistance during the following 40 years was an attempt to transfer or adapt advanced technologies to conditions in poor tropical countries. These efforts are widely credited with having averted the large-scale famines that had been anticipated in Asia in the 1970s and 1980s. 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 more prosperous farmers, missing the poorest of the poor. The initial spectacular gains in productivity of the green revolution

[8] Chambers, R. *Whose Reality Counts? Putting the Last First*. London: Intermediate Technology, 1997.

[9] Campbell, A. Fomenting synergy: experiences with facilitating landcare in Australia. In *Sustainable Agriculture and Participatory Learning,* ed. N. G. Röling and M. A. E. Wagemakers. Cambridge: Cambridge University Press, 1998, pp. 232–249.

[10] Pretty, J. N. *Regenerating Agriculture: Policies and Practice for Sustainability and Self-reliance*. London: Earthscan, 1995.

[11] Röling, N. G. and Jiggins, J. The ecological knowledge system. In *Facilitating Sustainable Agriculture*, ed. N. G. Röling and M. A. E. Wagemakers. Cambridge: Cambridge University Press, 1998, pp. 283–311.

are unlikely to be repeated.[12] The impacts of such research have been more modest in addressing the needs of Africa.

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 such as the gathering of forest products and the raising of livestock (see Fig. 6.3, p. 131). Productivity enhancement is important but risk reduction, improved food security and the maintenance of natural and social capital are also vital. The farming systems of poor people in the tropics are subject to a multitude of exogenous influences. For instance, in semi-arid areas they are subject to highly variable rainfall. Economic conditions may change rapidly, with resulting swings in input costs and market prices. Other external shocks such as the massive rise in the acquired immunodeficiency syndrome (AIDS) in Africa or the widespread fires associated with el Niño events throughout the tropics all disrupt local resource management systems. Agricultural innovations must not only increase productivity, they must also help the poor to deal with the vagaries of their social, economic and biophysical environment.

Mainstream agricultural science has tended to try and reduce agricultural systems to their components. While reductionism has been crucial in the gains that have been achieved, it can miss the mark, as we illustrate in Chapter 6. Development assistance to agriculture has largely ignored the off-farm environment. In mainstream agricultural science, natural resource management has been synonymous with location-specific, adaptive research, mainly concerned with maintaining soil fertility. There have been few systematic attempts to help poor farmers to be resilient to the impacts of external economic, social or climatic changes.

Much development science has been portrayed as being in support of short-term growth at any cost. In many cases, agricultural research yielded short-term productivity gains at the expense of long-term degradation of the natural capital of soils, water, biodiversity and non-cultivated land. Much of this research targeted innovations that could yield quick benefits to respond to urgent needs. Researchers were committed to technologies that maximised biological uniformity and ignored the biological diversity and ecological services that might contribute to the stability and resilience of natural ecosystems. Good historical reasons explain this focus, and extensive critiques, justification and refutations of it abound. It is argued that this sort of science poses threats to the fragile societies and poor people of many

[12] Conway, G. R. *The Doubly Green Revolution: Food for All in the 21st Century*. London: Penguin Books, 1997.

developing countries. Poor countries lack formal safety nets to see their people through periods of crisis. Poor people lack the financial capital to help them to deal with crop failures caused by diseases, infrastructure breakdown, social turmoil or extreme climatic events. The capital that enables these people to deal with difficult times is the social capital that allows them to cooperate and share scarce resources. But they also need the natural capital of a diverse resource base to provide them with a range of options. The immediate need may be to see them through periods of environmental, economic or social stress, but the long-term need is for a natural resource base that can provide a range of options for economic growth and social development.

In many situations, there are clear trade-offs between productivity enhancement and price minimisation on the one hand and caring for social values and ecosystem health on the other. At present, the incentives in developing countries encourage producers to shift any environmental or social costs onto others. Individual farmers are faced with the stark reality that they will produce less and make less profit if they bear the full cost of resource conservation measures. The result is that many social and environmental costs are born by society at large rather than by individual resource managers. Development assistance has done little to help poor countries to build institutions to deal with these 'externalities'.

Dysfunctional development assistance projects

This book deals mainly with attempts to use international development assistance to address the natural resource problems of poor countries. The need for accountability and for donors to be able to target their support precisely has led to the emergence of the 'development project' as the main delivery mechanism for this aid. Donors work with their national counterparts to define discrete, time-bound, packages of development assistance. This enables the donor to identify with, and claim credit for, individual components of the broad development agenda of the recipient country. It allows the donor to apply its own accountability mechanisms and, significantly, it allows development to be reduced to bite-sized components for which donors can assume responsibility.

The construction of a road or bridge is readily amenable to the 'project' approach. Such activities can easily be packaged as a discrete, time-bound, pre-planned project. However, the problem with natural resources is that they are components of large complex landscapes. Diverse interest groups impinge upon them. They are subject to unpredictable pressures resulting from changes in local economies, access to markets, population

movements, climate change and a host of other exogenous forces. Many development projects are trying to shoehorn the complex and dynamic realities of a natural resource system into the constraints of a time-bound, tightly planned, highly predictable project. This does not usually work.

Chapter 7 describes the consequences of the application of strict project management in a research and development programme in the forests of Indonesian Borneo. Initially, flexible funding was available to support a complex programme to improve local livelihoods and conserve forests. Subsequently, special project funding from international agencies was obtained to support parts of this work. The reporting and financial management requirements of these agencies made it very difficult for all the participants in the programme to work as a team and deal with the issues in a holistic way. Meeting donor needs for quickly attaining specific milestones came to dominate over a participatory process of learning and experimentation.

Similar experiences have been reported from the Landcare programme in Australia.[13] This programme emerged spontaneously in a number of locations when farmers found that they could only deal with large-scale environmental problems by working collectively with other farmers. The programme became so successful that it began to receive significant government support. Gradually the proportion of the total funding that came from government sources increased until it exceeded that from private and philanthropic sources. In order to access this government money, it was necessary to go through significant bureaucratic hurdles – proposals had to be written and reports submitted. This became such a burden that recent commentators have suggested that the vigour and spontaneity that characterised the programme in its early years has now declined and Landcare is in danger of becoming just another government programme to subsidise better farming practices.

A main feature of the 'project' paradigm in development assistance is an attempt to reduce uncertainty. Projects seek to reduce the level of complexity and to tease-out a subset of issues that can have price tags attached to them and whose successful execution can easily be verified. This is very different to the real-life task of a natural resource manager. The job is not to attempt to reduce or eliminate complexity and uncertainty but rather to exercise judgement in dealing with the complex economic, social and biophysical environment. Good natural resource managers, for instance most poor farmers in developing countries, have always been 'adaptive managers', their success lay in their ability to make good judgements in response to the constant surprises that confronted them in their day to day activities.

[13]See Chapter 9 for further information on the Landcare project in Australia.

As donors have become more and more frustrated at their inability to integrate conservation and development successfully, they have reacted by more rigorous application of the tools of the development assistance trade. They have planned their projects in more and more detail. They have commissioned more careful diagnostic studies to reduce the possibility of surprises. They have developed more sophisticated monitoring and evaluation tools to ensure that everything is staying on track. The end result has been a generation of natural resource management projects that are so locked into a rigid donor-driven framework that they have little relevance to the real world in which natural resources and their managers have to survive.

One notable feature of the dysfunctional nature of projects is the commissioning of studies by teams of experts in order to characterise a location and diagnose its problems. These studies place great value on the knowledge that experts bring to an area. This knowledge has been gleaned from experience in many other similar situations. It typically costs between $500 and $1000 a day. However, such planning studies place little value on the knowledge of people who have lived their entire lives in the area under study. They might earn $1–2 a day as enumerators or field assistants if they are lucky. Yet it is this informal knowledge of local people that has to be the basis of most of the resource management decisions that will be taken by a project. It is the behaviour of these people that projects will strive to influence. This local knowledge is often the scarcest resource. One reason that projects often begin to become effective only after several years of operation is that it is only after quite a long period that the international project advisers become sufficiently attuned to local realities to begin to tap the informal local knowledge that is so important to success.

Pre-project studies often simply record in a form accessible to the donor a snapshot of the status quo. Their reports explain and present to funding agencies things that are self-evident and common knowledge to local people. Furthermore, the reports that are prepared in the process of project preparation inevitably tend to frame the problems from a donor or expert perspective. This has profound influences on the way in which all future interventions by the donor or its agent are oriented. Repeatedly, one finds examples of preparation missions identifying and describing problems in ways that must seem quite bizarre to local people.[14] One of us (JAS) vividly recalls the astonishment of a district officer in Tanzania when he was told that a major justification for a development project in his area was the

[14]Scott, J. C. *Seeing Like a State: How Certain Schemes to Improve the Human Condition Have Failed*. New Haven, CT: Yale University Press, 1998.

conservation of endemic birds and frogs. At the level of global biodiversity priorities, the birds and frogs were important. In terms of the livelihoods of local people, they were totally irrelevant.

We have included accounts in this book of natural resource problems as perceived by literate local people in areas targeted by projects. We asked these people to describe the conservation and development problems that they confronted in their everyday lives. The results were startlingly different to the assumptions underlying the projects.

Recent generations of natural resource management projects have generally been developed using participatory techniques, but they are still often based upon fundamental and incorrect assumptions made by donors and their advisors. Projects that seek to achieve both conservation and development are common. However, the conservation component usually addresses the conservation of species or landscapes of global value not the conservation of resources or options of immediate relevance to local people. Nonetheless, people will participate in these conservation and development projects even if given the choice, they would probably settle for the local development without the global conservation.

Everyone subscribes to the principle of ensuring 'ownership' of projects by local people, but frequently we have to invest a lot of effort in trying to secure 'their' ownership of 'our' project. There has been a notable failure for donors to accept the reality that conserving the global environment is simply not a very high priority for poor people living in rural areas in developing countries.

A common feature of project development is the preparation of maps and inventories. Participatory mapping is now a normal feature of the best natural resource management projects but still a lot is invested in maps based upon remote sensing or ground surveys by experts. James Scott has described how maps create realities and any map or chart is simply one out of an infinite number of ways of portraying those realities.[15] Even when maps are produced with local participation, the criteria or features that are mapped are often subject to the overriding influence of the outside specialists. They arrive with their own vision of what needs to be mapped. Douglas Sheil and colleagues from the Center for International Forestry Research (CIFOR) working in the forests of Indonesian Kalimantan have shown how local peoples' appreciation of forest condition and biodiversity differs markedly from the assessments of outside technical experts.[16]

[15] Scott, J. C. *Seeing Like a State.*

[16] Sheil, D., Puri, R. K., Basuki, I. *et al. Exploring Biological Diversity, Environment and Local People's Perspectives in Forest Landscapes.* Bogor: CIFOR, 2002.

The early planning stages of projects establish patterns. They launch the project upon a trajectory that is very difficult to change. If these early stages are influenced by incorrect assumptions, then major subsequent investments may be misdirected. Project planning is still frequently conducted too quickly and superficially. Some donors are now recognising that success depends upon the quality of the foundations established in the early periods of interventions. They are now allowing much more time to really get into the system – to see the situation as the principal local stakeholders see it. Some bilateral donors are now making long-term commitments to flexile support to areas or sectors. The recent USAID CARPE project in the Congo Basin and the UK forestry programme in Indonesia are excellent examples. Switzerland has for many years been exemplary in its attention to local sensitivities in its programmes in forest and mountain areas. The 'learning and adaptation' and 'adaptive programme loans' of the World Bank are also potentially useful innovations. However, the project preparation procedures of many donors are still inadequate. Many fundamental issues are settled before the process of participation has started.

Even some apparently trivial aspects of the 'project' are inimical to success. Most donors and their executing agencies want their contributions recognised. The same donors who require local ownership of projects still want their logos on the vehicles and on the cover page of publications. They still want their proposals and reports written in international languages and prepared in ways that only international experts can handle. Most donors reward creative writing ability of experts far more than they reward the resource management abilities of local people. Donors want to visit their projects, and preferably they want to bring politicians to see the good work. They want to see clear evidence of their own contributions and they also have high expectations of success. All natural resource management interventions enjoy successes and failures – often quite a lot of the latter. Yet, all the incentives favour the exaggeration of successes and the rationalisation or downplaying of any failures. Some international conservation NGOs are particularly prone to making extravagant claims of successful impact yet they also publicise the continuing decline of the habitats and species that they are claiming to conserve.[17] Yet it is these very failures that should teach us the lessons from which long-term success may emerge.

In recent years, log-frames have become popular management tools for projects. Properly used, a log-frame can indeed be a valuable basis for clarifying assumptions and facilitating a transparent process of negotiation of

[17] See for instance Lomborg, B. *The Sceptical Environmentalist*. Cambridge: Cambridge University Press, 2001.

desired outcomes. However, too many donors have allowed log-frames to be used to limit the flexibility of projects. The log-frame becomes the master rather than the tool. It ties participants into activities that were determined at the beginning of the project rather than being used to help to negotiate course changes and adaptability. Log-frames, like micro-management of project inputs, can be the enemy of the adaptability and resilience that is essential to ultimate success.

Yet another component of the project pathology is the preoccupation with delivery deadlines. For many donors, 'milestones' are the measure of success and the quicker they are reached the better. However, for natural resource management, learning and negotiation processes are far more important than technical deliverables; ultimately we are seeking behavioural change not the introduction of a particular technology. Change takes time and many projects have suffered the long-term costs of imperfect processes in their excessive haste to disburse funds and achieve deadlines. The more successful examples of natural resource management interventions have been those where small amounts of money were made available flexibly and sensitively over a long period of time. This has happened when local NGOs or even motivated individuals have championed some local conservation or development cause over a long period. There have been many failures when large amounts of money have been thrown at problems too rapidly.

One particularly worrying element of the fund disbursement paradigm is that little money reaches the ultimate beneficiaries on the ground, especially in the early phases of projects. The surveys, planning and participatory events needed to get started inevitably means that most of the money in the early stages of a project goes to the consultants. Local people often have to wait a remarkably long time before they can expect to receive any benefits. A surprisingly large number of natural resource management projects never do provide significant direct benefits to local people. They may make new technologies available and improve some social facilities, schools, roads, etc. Yet, often these benefits account for only a small proportion of the total budget and often the patience of local people is tried as they await the recompense for their investments of time and knowledge.

Projects also have a poor record at being well articulated with developments in other sectors that influence local outcomes. Failure of projects is often attributed to unpredicted changes in the macro-economic or political context. Local political support is often essential to the success of projects, but political changes may lead to this support evaporating overnight. An international market for a newly introduced crop may disappear because of changes in exchange rates etc. These are examples of the negative impacts of

project bounding. The tendency for donors to circumscribe a project into a self-contained package makes it difficult for projects to be managed in ways that make them responsive to changes in their external environment.

Towards a new role for science

The simple pursuit of economic efficiency may lead, in the long term, to better lives for the average person. However, economic efficiency poses threats to the hundreds of millions of poor people whose existence still lies largely outside the modern global economy. Economic growth leads to investments in education and organisations and the emergence of strong civil societies that tend to take better care of the environment. However, during the early phases of development, severe, and possibly irreversible, environmental damage may occur. As the populations and consumption levels of developing countries grow, natural resources are coming under ever-greater pressure. The risks of environmental harm from the pursuit of economic growth are critical during this period. The advent of economic globalisation and the increasing domination of agriculture by a few large companies create special threats for the poor.[18] Equity in the distribution of benefits is emerging as a major issue. Multi-faceted threats are emerging that will require integrative responses.

There is now widespread recognition that the sustained improvement of the lives of poor farmers in developing countries will require a new kind appearing in the literature of research. There are many calls for new approaches to natural resource science.[19] A prestigious group of scientists in the USA recently 'affirmed that a bold departure from the status quo of disciplinary science was needed to address pressing national needs'.[20] What they then described is a small component of the issues that we tackle here, reaffirming our view that the departure from the status quo should be more than bold!

While we use the word 'new', we recognise that many of the elements of this new research have been around for some time. The problem is that the elements are rarely put together in an integrated package involving concepts, processes and tools, and the buzzwords are rarely subject to

[18] Korten, D. C. *When Corporations Rule the World*. London: Earthscan, 1995.

[19] See for instance Kates, R. W., Clark, N. C., Corell, R. *et al.* Sustainability science. *Science,* **292** (2001), 641–642.

[20] Kinzig, A. P., Carpenter, S., Dove, M. *et al. Nature and Society: An Imperative for Integrated Environmental Research*. Executive summary of a report prepared for the National Science Foundation, 2000. Online: http://lsweb.la.asu.edu/akinzig/report.htm.

Table 1.1. *Characteristics of approaches that use integrative principles*

Approach characteristic	Farming systems research	Adaptive collaborative management[a]	Landscape approaches	Ecosystem management[b]	Integrated natural resource management (as conceptualised in this book)
Multi-scale work generally at different scales		(√)	√	√	√
Action research part of the approach		√			√
Empowerment an issue		√			√
Takes an adaptive management approach		√		√	√
Multiple stakeholders recognised		√	√	√	√
Process facilitation of key importance					√
Systems modelling used	√	√	√		√
Breakdown of the distinction between research, management and extension					√
Discusses new organisations for managing complex systems			√		√
Institutional analysis (rules, norms, devolution issues) and change are key to the approach		√	√	√	√
Knowledge management important, including informal knowledge		(√)		(√)	√
Focus on adaptive capacity, not specific technologies		√		√	√
Generalisable research products are based on descriptions of the learning cycle processes		√			√
Tools for measuring system performance are key to the approach		√	√		√
Embraces sustainable livelihoods perspectives			√		√
Focus on resources and/or people	Both	Both	Both	Resources	Both

[a] From CIFOR. See footnote 21.
[b] From Secretariat of the Convention of Biological Diversity. See footnote 22.

practical tests. In Table 1.1. we list some of the elements of the approach we put forward and compare them with the elements of some other approaches.[21,22]

Cutting-edge component research is still needed but it has to be set in local contexts and be applied in ways that recognise the special conditions of the poor. It will have to give more emphasis to management of risks, to reduction of dependence on agricultural inputs, to avoidance of long-term depletion of productive potential and to more careful control of environmental externalities.[23]

Harry Collins, the Convenor of the Centre for the Study of Knowledge, Expertise and Science at the University of Cardiff in Wales, has suggested that the role of science is analogous to that of marriage counselling. He draws the analogy with a person who goes to a marriage guidance counsellor for advice, but whose marriage nonetheless fails. Would that person feel the need to say that the marriage guidance counsellor had made 'mistakes'? Would she or he assume that in the fullness of time correct marriage guidance hypotheses would come along? Probably the person would accept that marriage guidance is not a precise science. Marriage guidance counselling is the model we need for the new complex science. In the twenty-first century, we will have to learn how to use science to increase options and make better choices and decisions rather than to provide precooked remedies. Science will have to deal with evolving situations and to be a joint venture between scientists and resource managers.

Integrated approaches to research on agriculture and resource management have to accomplish seven critical changes in order to achieve a paradigm shift to increase food production and enhance ecosystem and human health.

> *Acknowledge and analyse the complexity of natural resource systems*. We must acknowledge systems complexity and bring to bear the concepts and tools of systems analysis to deal with complexity (Chapter 2).
>
> *Use action research – become actors in the system*. We must become part of the system in a cycle of action research (Chapter 3).

[21] CIFOR. *Local People, Devolution and Adaptive Collaborative Management of Forests. Researching Conditions, Processes and Impacts.* Bogor: Center for International Forestry Research. Online: http://www.cifor.cgiar.org/acm/download/ACMFlyer.zip.

[22] Secretariat of the Convention on Biological Diversity. Conference of the Parties Decision. Decision V/6 Ecosystem Approach. Geneva: United Nations Environmental Programme, 2001. Online: http://www.biodiv.org/decisions.

[23] Conway, G. R. *The Doubly Green Revolution.*

Consider effects at higher and lower scales. We must routinely conduct cross-scale analysis and action (Chapter 4). This means that our action research will invariably consist of cycles within cycles, and we will have to interface these with simulations of longer-term processes.

Use models to build shared understanding and as negotiating tools. We must confront complexity with conceptual and systems models, but a new type of model is needed (Chapter 5). We must have models that can facilitate discussion and stakeholder interaction: 'working' models that may be thrown away after a short period of use.

Be realistic about potential for dissemination and uptake. Is the detailed knowledge about a specific research and development site of any significance beyond the site (Chapter 9)? Anderson believes not.[24] He has portrayed natural resource management as an area for research of little strategic value, unlikely to produce internationally useful public goods and not worthy of significant levels of public sector investment. We believe otherwise: dissemination of the processes involved in successful integrated approaches will yield widespread benefits.

Use performance indicators for learning and adaptation. We need tools to monitor and evaluate system performance (Chapter 10). However, this is not 'impact assessment' as envisaged for 'transfer of technology'. Performance indicators will be essential in the learning process of adaptive management.

Breakdown the barriers between science and resource users. We will have to change the organisation of science (Chapter 11). Elite, monolithic research centres will be of little value for integrated research.

The chapters in this book treat each of the above themes in detail. In addition, in Part II, there are three case studies, covering semi-arid smallholder systems in Zimbabwe (Chapter 6), the rainforests of Borneo (Chapter 7) and the hillsides of the Andes (Chapter 8). These are not meant to illustrate best practice in approaches to complex conservation and development situations; rather, they illustrate different approaches, elements of best practice, components of success and the problems inherent in trying to use science

[24] Anderson, J. R. Selected policy issues in international agricultural research. On striving for public goods in an era of donor fatigue. *World Development*, **26** (1998), 1149–1162.

to improve development and conservation outcomes. Throughout the book, we use examples illustrating the lessons from integrated approaches, drawing on diverse situations (e.g. Botswana wildlife systems (see Box 1.3, below), Zimbabwean smallholder agriculture (Boxes 3.3 and 10.1), integrated conservation and development (Box 4.5), Thailand water management (Box 5.1), Indian watersheds (Box 9.1) and Australian rainforests (Box 11.1).

How integrated do we need to be?

Why, if so many people are talking about integrated approaches, are successful cases so hard to find? Part of the reason is that there has been an influential school of thought that portrayed integrated approaches as being all-embracing and integrating everything. Integrated management was often seen as requiring an ability to have a complete understanding of all the facets of a complex system. Early attempts at integrated natural resource management sought to understand the total behaviour of the system and to develop the ability to predict the outcome of any management intervention. The underlying logic of the UNESCO-led Man and Biosphere programme was an example of this approach to resource management. In reality, the skill or professionalism of integrated natural resources management lies in making judgements on what to integrate. It only makes sense to integrate those additional components, stakeholders or scales that are essential to solving the problem at hand. Natural resource scientists must have sufficient understanding of the system to make choices about where to focus attention. If this more limited view of integrated research is accepted, then there are very many examples of successful integrated research (Box 1.2).

Box 1.2. Successful examples of integrated research and management

- Integrated management of vegetation and soil in a plot or field to achieve higher nutrient use efficiency: in the research phase one would expect the researchers to have considered the volumes of organic materials available at the household and landscape levels, and perhaps national fertiliser policies.
- Interventions in the ecology of farms to achieve integrated pest management: the research would be expected to consider the group dynamics and the resources available to support pest management at the landscape level.
- Management of forested landscapes to achieve balance in yield of forest products and water, whilst retaining biodiversity.
- Adaptation of farming systems at large scales to enhance carbon sequestration.

The fundamental issue is that the marginal costs of adding each additional component, stakeholder or scale into the system under study have to be considered and have to be less than the marginal benefits of such additions. This highlights the need for a clear articulation of the problem, the establishment of appropriate research hypotheses and, above all, judgement of what has a high probability of yielding tangible benefits within reasonable time frames. Perhaps the most difficult problem facing practitioners of integrated research is the decision as to when to stop adding additional components into the system. Integrated analysis should be seen as a careful extension of the research or management domain to include those additional variables, stakeholders, scales and drivers of change that can reasonably be expected to have an influence on the sustainability and adaptability of the interventions being designed.

This is not to say that intractable problems should be abandoned because of their complexity. For instance, stakeholders may decide that the objective for a specific district in Borneo may be to eliminate poverty and conserve forest cover. Such an objective is complex in the extreme; it requires an approach that integrates across numerous components of the system – almost nothing can be left out! Research will not yield a single solution to this problem, but it may provide understanding that improves the quality of management decisions.

In Box 1.3 we demonstrate the successful 'conclusion' of an integrated approach to wildlife management in Botswana; this has centred on a hugely complex set of issues that appear to have been successfully resolved for the moment. However, further changes will occur and the adaptive management approach must continue – there is no point at which all problems are solved and further research and experimentation are no longer required. Evidence that the system is about to breakdown must be met with further institutional or management interventions. This example demonstrates the value of the integrated approach; its success was built on learning from experience in neighbouring Zimbabwe, where success was more elusive.[25] In the short term, integrated approaches to natural resource management will be more costly than sector- or discipline-based approaches. In the long term, they are more likely to yield sustainable management systems, stronger institutions and a better natural resource base. The knowledge needed for social learning and adaptive management accumulates slowly. In the Botswana case, the history of the success can be traced back to interventions in

[25] Campbell, B. and Shackleton, S. The organisational structures for community-based natural resources management in southern Africa. *Africa Studies Quarterly,* **5** (2001). Online: http://web.africa.ufl.edu/asq/v5/v5i3a6.htm.

Zimbabwe in the 1970s! The time and resources invested in social learning will determine how quickly development can become sustainable.

Box 1.3. Empowering local communities to benefit from wildlife in Botswana

Nico Rozemeijer and Corjan van der Jagt have documented the success of a community-based natural resource management programme in Botswana.[1] They focus on the Nqwaa Khobee Xeya Trust in Kgalagadi District, one of many such schemes. The end result is a community that has responsibility for the wildlife resources in an area of 12180 km^2, a vast area with three villages and 850 people. In 2000, they received US$63 000 from a safari operator in a joint venture involving hunting, photographic safaris and cultural activities. This provided about US$450 to each household. In addition, there were 75 jobs created, on average one job for every second household. In earlier times the local population had no benefits from the wildlife resource, apart from subsistence hunting. The success is based on a number of key elements.

A long history of trial and error (informal adaptive management)

In southern Africa, there has been close interaction of the key players in wildlife management in different countries so learning about successes and failures was possible. These key players, many of them ecologists, were already committed to adaptive management in the early 1980s, but it is not clear if they saw this management applying to the broader policy and institutional environment that was developing, or whether they confined it to on-the-ground wildlife issues. All key players had noted the success of giving control of wildlife to commercial farmers in Zimbabwe in the 1970s and the resulting massive expansion of wildlife as a land-use. This was followed by early, but unsuccessful, attempts of returning some benefits of hunting safaris to peasant farmers living in or next to safari areas. Then, in the 1980s, there were more empowering approaches such as CAMPFIRE in Zimbabwe.

A focus on local institutional arrangements

The architects of Botswana's wildlife programme had noted the problems in other countries, where full control was not given to local communities. They set about establishing a system whereby communities could apply for corporate status, with far-reaching management responsibilities. A community in or adjacent to a Controlled Hunting Area, allocated for community management, could apply for a wildlife quota provided it had organised itself in a participatory and representative manner that was approved by the district and wildlife authorities. The quota can be used for subsistence hunting. If the community wants more secure access to the wildlife quota and wants joint ventures with the private sector, it may decide to lease the Controlled Hunting Area from the land authority, in which case it has to comply with three conditions.

- The community had to organise itself as a representative and legally registered entity such as a trust or cooperative and demonstrate to the district authorities that a participatory process was observed.
- In this process, the community should design and adopt regulations and procedures (constitution and bylaws) that not only define its natural resource management functions but also its accountability and responsibility towards the community members.
- A land-use and management plan conforming to the wildlife management area regulations had to be prepared for the Controlled Hunting Area and approved by the land authority. A 15-year 'Community Wildlife Lease' could then be obtained.

In the study area, an attempt was made to develop a management structure that would reflect as closely as possible the ethnic and gender composition of the three settlements. Based on information obtained from the in-depth research phase, a system was agreed whereby all residents formed groups largely based on kinship. Ethnically mixed groups generally did not emerge. A man and a woman in the village committee represented each group, and two men and two women in the overall board of the Trust represent each village. Various powers have been given to the different organisational layers.

A long history of facilitated community development

The Trust, as a new organisation, needs to be given time to establish a transparent and accountable mode of operation. Some NGOs have been working for years in one community to assist in capacity building. Communities are now better prepared for negotiations with the private sector. They do not simply sell off their entire quota, creating problems of reinvestment, but are increasingly empowered to undertake economic activities under joint management, which, in turn, enhances local employment and management skills. In the study area it took three years, starting in 1996, to develop a management structure, a constitution and a land-use and management plan. The Trust was registered in 1998 and obtained user rights in 1999. The Trust then developed a tender document based on its land-use and management plan, selected a private sector partner, and signed a sublease agreement for an initial one year period.

Attention to the ecological context

To ensure ecological sustainability, the hunting quotas are set by the wildlife authorities, usually after an aerial survey. Trusts are encouraged and trained by the wildlife authorities to monitor wildlife populations in their areas but a system has yet to be put in place whereby the data can feed into the annual quota-setting process.

Attention to multi-scale multi-sector analysis and intervention

This Botswana case demonstrates very nicely that one sometimes cannot intervene in only one part of a system. The operational framework that has emerged demonstrates the

need to have interventions at multiple scales. Local communities apply to district and wildlife authorities in the first instance, and then to the Land Board for a lease. The framework for the system has been set in place in terms of national legislation and policies, involving local government and land and wildlife departments. NGOs work closely with communities to build capacity in organisational development, financial control and tendering procedures and wildlife management; but they were also important in lobbying for appropriate national policies. The wildlife department sets quotas and monitors the harvest.

Summary

This is not to say that the system can now be left to run on its own. New challenges emerge and these must be met by appropriate interventions. The system must be adaptive. Two emerging challenges are the lack of clear connection to district authorities, who get little benefit from wildlife management, and the jealousy of those outside the benefit zone, especially the cattle barons belonging to other ethnic groups.[2]

[1] Rozemeijer, N. and van der Jagt, C. Botswana case study: community-based natural resources management (CBNRM) in Botswana. How community based is CBNRM in Botswana? In *Empowering Communities to Manage Natural Resources: Case Studies from Southern Africa*, ed. S. E. Shackleton and B. Campbell. Lilongwe: SADC Wildlife Sector Natural Resource Management Programme; Pretoria: CSIR; Harare: WWF (Southern Africa); Bogor: Center for International Forestry Research, 2000, pp. 1–7. Online: http://www.cifor.cgiar.org/publications/pdf_files/Books/Empowering.pdf.

[2] Postscript! This text proved rather prophetic. When returning to this text only three months later, the situation had indeed changed. The Department of Local Government had issued a directive for all funds earned by community-based natural resource management projects to be transferred to District Councils for management by them. This caused an outcry and is seen as a serious threat to community incentives and the long-term sustainability of these projects. Other surprise announcements included a ban on lion hunting and a dramatic increase in game license fees. In neither case were the wildlife management trusts consulted: see Shackleton, S., Campbell, B., Edmunds, D. and Wollenberg, L. Devolution and community-based natural resource management: creating space for local people to participate and benefit? *Natural Resource Perspectives 76*. London: Overseas Development Institute, 2002. Online: http://www.odi.org.uk/nrp/76.pdf.

Conclusion

A number of 'external' environmental, economic and social problems are now threatening the long-term performance of the agricultural, forestry, livestock and fishery systems upon which poor people depend. This creates a significant challenge for the researcher in agriculture and natural resources. It is going to be increasingly necessary to grapple with the issues of scale and complexity in natural resource systems. Integrated approaches have been

used in the past, but a comprehensive framework has rarely been applied at an operational scale. There are major challenges to experimenting with such frameworks and to work out modalities to carry out effective research to manage entire natural resource systems. This in itself will be a major learning effort that requires new competencies of researchers and ways of organising research. Research organisations will need to reflect on their *modus operandi* and scientific culture and rise to the challenge of reorganising for maximum effectiveness in a more interconnected world. Our contention is that the case for more 'integrated' approaches to natural resource management is compelling. The ultimate integration of the elements of management of any natural resource may not be achievable. However, an attempt to modify existing research and development efforts to achieve higher levels of integration does, on balance, seem to be a sensible thing to do.

The challenge of integrated science laid down in the quote from Aldo Leopold at the beginning of this chapter is only beginning to be met. There are fundamental aspects in the way that science and development assistance are organised that make such innovations difficult to achieve. These obstacles are those discussed by Thomas Kuhn in his classic work on the difficulties of achieving revolutions in science.[26] Kuhn's contention is that such revolutions can only occur when a state of crisis is reached. The environmental and poverty crises that are now confronting the world may provide the trigger that is needed for change. Kuhn claims that 'Scientific revolutions are inaugurated by a growing sense, . . . often restricted to a narrow subdivision of the scientific community, that an existing paradigm has ceased to function adequately in the exploration of an aspect of nature to which that paradigm itself had previously led the way . . . the sense of malfunction that can lead to crisis is prerequisite to revolution'.

We will argue in this book that concepts and tools now exist for a science-based approach to the integrated management of natural resource systems. We will cite examples of successful natural resource management research that indicate that some of the barriers to integrated systems management are beginning to break down. We will present examples of integrative tools and concepts from different disciplines and scientific fields. We will argue that we are now at the threshold of innovative approaches to resource management that differ fundamentally from earlier discipline-based studies of natural resource problems. The methodological and conceptual problems need constant attention in order to avoid the danger of simply using the rhetoric of 'integration'.

[26]Kuhn, T. S. *The Structure of Scientific Revolutions*. Chicago, IL: University of Chicago Press, 1970.

If the real needs of the rural poor in developing countries are to be met, then science must deal with the natural resource system upon which they depend for their livelihoods. The farmers, fishers and foresters themselves are practising integrated management of their resources, basing their management on knowledge acquired over generations.[27] Effective research should link seamlessly with the knowledge of these clients. If scientists continue to operate in a simple technological world, they will fail to achieve the potential pay-offs that could be obtained by linking modern science to traditional knowledge and practice. However, as importantly, change is occurring in the world that defies the understanding of the local resource manager. Macro-economic changes and increased climate variability will be major determinants of the condition of human life in poor countries, and science must contribute understanding of how these phenomena will impact on ordinary people.

Similarly, the development pathways followed by people in poor developing countries will have major implications for the global environment. The world is becoming more connected and integration is emerging as an important concept in natural resource management: there is a need to integrate across disciplines, across scales (space and time), across stakeholders, across components.[28] We have to understand processes operating at scales from organisms to farms to global resource systems. Similarly, we also have to span the range from households to villages to districts up to international agreements.

The keys to integrated natural resource management

There are several features that are central to integrated natural resource management.

- In the short term, integrated approaches to natural resource management will be more costly than sector or discipline-based approaches. In the long term, they are more likely to yield sustainable management systems, stronger institutions and a better natural resource base.
- We never know enough about natural resource systems to manage them with certainty. Therefore, human interventions should

[27] Berkes, F., Colding, J. and Folke, C. Rediscovery of traditional ecological knowledge as adaptive management. *Ecological Applications,* **10** (2000), 1251–1262.

[28] Lal, P., Lim-Applegate, H. and Scoccimarro, M. The adaptive decision-making process as a tool for integrated natural resource management: focus, attitudes, and approach. *Conservation Ecology*, **5** (2001), 11. Online: http://www.consecol.org/vol5/iss2/art11.

always be experimental and should contribute to learning about the system.

- The knowledge needed for learning and adaptive management accumulates slowly. The time and resources invested in learning will determine how quickly meaningful development will occur.
- Integrated approaches to natural resources science will not yield precise recipes for managers, but they will help managers to make the right decisions and even more importantly to learn from their mistakes.
- The successful application of science to natural resources management requires changed relationships between scientists and local resource managers. Formal scientific knowledge and local knowledge must be combined in an adaptive management framework. All management must be treated as experimental and the role of science is to learn from these experiments.