GENETIC RESOURCES MANAGEMENT IN ECOSYSTEMS

Report of a workshop organized by CIFOR for the SGRP
CIFOR, Bogor, Indonesia, 27-29 June 2000




Editor: Dr. John Poulsen

CIFOR and SGRP are affiliated with the CGIAR. Established in 1971, CGIAR is an informal association of nearly 60 public and private sector donors that support a network of 16 international agricultural research centers. The CGIAR's mission is to contribute to food security and poverty eradication in developing countries through research, partnership, capacity building and policy support. The CGIAR promotes sustainable agricultural development based on environmentally sound management of natural resources.

CIFOR was established in 1993 as part of the Consultative Group on International Agricultural Research (CGIAR) in response to global concerns about the social, environmental and economic consequences of forest loss and degradation. CIFOR research produces knowledge and methods needed to improve the well-being of forest-dependent people and to help tropical countries manage their forests wisely for sustained benefits. This research is done in more than two dozen countries, in cooperation with numerous partners. Since it was founded, CIFOR has also played a central role in influencing global and national forestry policies.

The System-wide Genetic Resources Programme (SGRP) joins the genetic resources programmes and activities of the CGIAR Centres in a partnership whose goal is to maximize collaboration, particularly in five thematic areas. The thematic areas - policy, awareness, information, knowledge and technology, and capacity-building - relate to issues or fields of work that are critical to the success of genetic resources efforts. The SGRP contributes to the global effort to conserve agricultural, forestry and aquatic genetic resources and promotes their use in ways that are consistent with the Convention on Biological Diversity. IPGRI is the Convening Centre for SGRP and the Inter-Centre Working Group on Genetic Resources (ICWG-GR), which includes representatives from all Centres and FAO, is the Steering Committee.

Published in April 2001 by:

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ISBN: 979-8764-63-3

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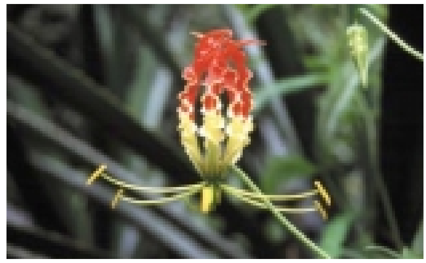

Genetic Resources Management in Ecosystems

Report of a workshop organized by the Center for International Forestry Research (CIFOR)
for the CGIAR System-wide Genetic Resources Programme (SGRP)

CIFOR, Bogor, Indonesia, 27-29 June 2000

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Foreword

In recent years, a growing number of people in the international scientific community have come to support a more holistic approach to solving problems concerning the sustainable use of natural resources. Underlying this attitude is greater recognition that ecosystems provide a wide range of benefits and must be managed to achieve a balance of uses that meet multiple needs of society. As a result, the Consultative Group on International Agricultural Research (CGIAR) has encouraged its constituent centres to pursue research according to an ecosystem framework, especially through inter-sectoral and inter-centre programmes.

A further push in that direction came from the Conference of the Parties to the Convention on Biological Diversity (CBD) at its 5th meeting in May 2000 (COP-5). The 'Description of, and Operational Guidance for, the Ecosystem Approach' that it endorsed, along with associated 'Principles', represents a synthesis of modern thinking on holistic approaches to balanced management of natural resources. Clearly, to play a key role in implementation of the CBD through its work on agricultural, forest and aquatic biodiversity, the CGIAR must take an ecosystem approach.

The heightened interest in combining related aspects of natural resources has also led to the emergence of a field known as 'Integrated Natural Resource Management' (INRM). Unlike traditional approaches, INRM focuses on all the elements within a given landscape — land, water and biological and atmospheric resources — and their interactions, rather than addressing a natural resource issue in isolation. Moreover, INRM is grounded in social and cultural perspectives as well as environmental and productivity concerns. In September 1999, in the Netherlands, the CGIAR held its first major meeting to discuss INRM and its implications for research by the CGIAR centres and their partner institutions. A follow-up workshop held in August 2000 in Penang, Malaysia, laid the foundation for future INRM-oriented research within the CGIAR.

These events and other activities within the CGIAR have explicitly acknowledged the central role of genetic resources and the management of them within integrated resource management. To consider how genetic resources should be managed in the context of ecosystem-and INRM-oriented approaches, the CGIAR's System-wide Genetic Resources Programme (SGRP) recently held a workshop on 'Genetic Resources Management in Ecosystems'. Geneticists, natural resource specialists and social scientists from most of the CGIAR's 16 research centres and several other organisations participated in the workshop, which was held 27-29 June 2000 and hosted by the Center for International Forest Research (CIFOR) at its headquarters in Bogor, Indonesia. This report summarises the ideas discussed at that meeting, with some additional information provided for greater context.

Many individuals did much to help make this workshop on Genetic Resources Management in Ecosystems successful. The workshop organiser, John Poulsen of CIFOR, received invaluable help from Stewart Grant on the International Center for Living Aquatic Resources Management (ICLARM), in particular with regard to the preparation of text for this report. Jane Toll, Coordinator of the SGRP, Paula Bramel of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and Tony Simons of the International Centre for Research in Agroforestry (ICRAF), assisted with the planning of the workshop on behalf of the SGRP.

Several people from organisations outside the CGIAR system joined the workshop and provided knowledge and vision that complemented the expertise of the CGIAR participants. They included Jeff McNeely, Chief Scientist at The World Conservation Union (IUCN); Roger Leakey of the Centre for Ecology and Hydrology in the U.K. (CEH); Doug Williamson of the United Nations Food and Agriculture Organization (FAO); V. Arunachalam of the Swaminathan Research Foundation in India; Bob Ward of Commonwealth Scientific and Industrial Research Organisation (CSIRO), Marine Research in Australia; and Pipin Permadi of the Centre for Research in Forest Products in Indonesia.

In addition, the organisers are grateful to the three keynote speakers: Jeff McNeely, Roger Leakey and Jeffrey Sayer, Director General of CIFOR and chair of the CGIAR INRM Task Force.

The workshop discussions were highly participatory, reflecting a wide range of views insights, and ideas, and much of the credit for that is due to Jürgen Hagmann for his skillful guidance as the facilitator. Special thanks also must be given to Layla Daoud, at the SGRP

Secretariat in Rome, for her tremendous support before, during and after the workshop. Thanks to Diana Parsell and Stewart Grant for help on the editing of this report. The team at CIFOR included Endah Soemarsono and Purnomo Djatmiko, who we thank for their enormous efforts and congratulate for maintaining their good humor during even the most hectic periods, and Grace Kurniawan, who assisted Jürgen Hagmann in documenting the workshop results. Finally, Yahya Sampurna and Widya Prajanthi of CIFOR's Information Services Group deserve thanks and recognition for designing the logo for the workshop and setting up a related Web site.

Bogor and Rome
April 2001
John Poulsen and Jane Toll
On behalf of the CGIAR System-wide Genetic Resources Programme

1. Workshop Process

The Workshop Process Steering Group[1] developed a draft agenda for each day of the workshop, based on the objective. The agenda was subsequently discussed in plenary session and modified according to feedback. This and the participatory format ensured that the ideas and concerns of all the participants would be addressed in the workshop and reflected in the results.

2. Workshop Objective

The participants agreed that the workshop objective was to:

- Define key genetic resource issues and their relative importance in natural resource management in the context of the CGIAR.

To pursue this objective, the participants agreed they would work to:

- Develop a shared understanding of the concepts and terms used in relation to ecosystems, *in situ* conservation, genetic resources management (GRM) and use, natural resource management (NRM) and integrated natural resource management (INRM);
- Develop a shared vision in regard to the integration of GR and NRM, including what they have in common and how they differ; and
- Identify issues and areas of interest for possible action or further attention.

3. Keynote Presentations

Three papers, presented by Jeff McNeely (IUCN), Jeffrey Sayer (CIFOR) and Roger Leakey (CEH, United Kingdom), summarised aspects of genetic resource management and integrated

[1] Members of the Workshop Process Steering Group were Michael Jackson (IRRI), Paula Bramel (ICRISAT), John Poulsen (CIFOR), N. Quat Ng (IITA), Jane Toll (IPGRI), Stewart Grant (ICLARM), Saidou Koala (ICRISAT) and Jürgen Hagmann.

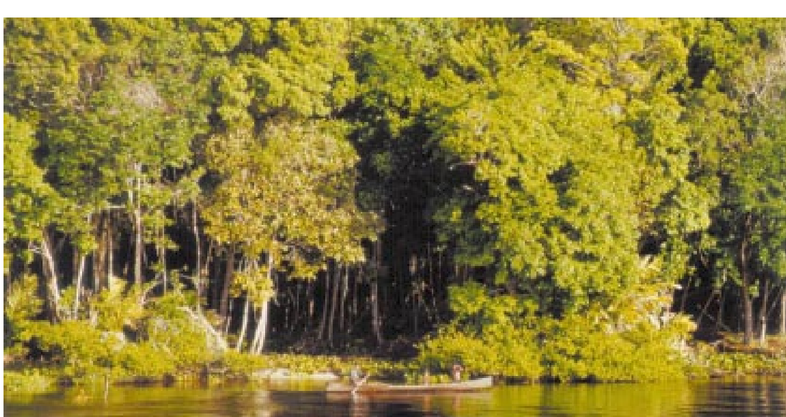
natural resource management. Issues that arose from the keynote presentations and the discussions that followed centred on four topics relevant to CGIAR activities:

- The influence of the Convention on Biological Diversity (CBD);
- Variation in definitions;
- The value of genetic resources; and
- Scales and complexities of ecosystems.

The CBD has raised awareness about holistic approaches to the conservation and sustainable use of biodiversity, including genetic resources, and particularly to the sharing of benefits arising out of their use. This has led to heightened attention on the economic value of genetic resources, access to them and associated property rights. The CBD calls for 'facilitated access', but the belief that genetic resources are a 'gold mine' of untapped wealth is giving rise to restrictions on genetic resources access. The CBD has also heightened attention to biotechnology, with intense debate and widespread public concern about the use of some biotechnologies in its fora. These developments are affecting how the CGIAR centres pursue their work on genetic resources.

The large number of definitions of ecosystem management has generated scepticism about the approach. These definitions vary according to factors such as the focus of the work and the background of whoever is proposing them. Arguably, 'integrated natural resource management' is a synonym for ecosystem management. 'Biodiversity' is generally viewed comprehensively as the full range of diversity within an ecosystem — genetic diversity within and among populations, species diversity and diversity among the different elements. The term 'ecosystem' itself suggests holistic and systems-oriented thinking. Ecosystem-based management entails the use of science, a process approach and practices or policies; participatory action research (PAR) is also an important aspect. '*In situ* conservation' of genetic resources is a dynamic process that is also comprehensive and integrated in approach.

Genetic diversity enhances the functioning of an ecosystem and its products and services. An ecosystem management approach encompasses biological, economic and social



considerations, and may not be successful unless it takes into account concerns such as local history, property rights and patterns of productivity. The nature of research and development for ecosystem-based management is influenced by inherent constraints; technical issues, for example, must be addressed within a social and economic context. The conservation of biodiversity entails three interlinked actions: saving, studying and using resources. Conservation may appear to be in conflict with the use of biological resources, yet successful conservation requires giving value to the genetic resources of an ecosystem in relation to all the other components — products, processes and people. Conservation can be achieved effectively by using resources (e.g., *circa situ*) and adding value to an ecosystem (by domesticating a resource and creating markets, for example). In the end, conservation of genetic resources requires recognition of the full costs associated with any management action, a realistic assessment of the benefits and a willingness to assume the cost of those benefits.

The domestication of indigenous fruit trees in Cameroon offers an example of integrated natural resource management and *circa situ* conservation of forest genetic resources. Genetic improvement was integrated with management of complex agroecosystems (e.g., cocoa agroforests). The trees produced as a result of these efforts enhanced the livelihoods of farmers, provided export commodities and contributed to international public goods (biodiversity, carbon sequestration and reduced greenhouse gas emissions). The rewards from this integrated management approach serve as an incentive to encourage poor farmers to manage their land for sustainable production. The domestication strategy involved training farmers in propagation techniques so that, in line with requirements of the Convention on Biological Diversity, the farmers could retain indigenous knowledge and their rights to improved germplasm (fruit tree cultivars).

Our planet has a wide continuum of ecosystems, ranging from highly managed to ‘natural’. People change natural ecosystems in ways that are both positive and negative. Protected areas, for example, may be managed to maximise cultural, social and economic benefits (they are protected *for*, not *against*, people). Management actions must address issues on several temporal and geographical scales; action is needed at all levels (from local to international) and in all areas of biodiversity (sectors, systems and so on). Ecosystems undergo cycles of change — of destruction and recovery, as in the case of Southeast Asian forests, for example — but this is often not recognised because the cycles are usually lengthy. The length is affected by factors such as climate change and human population growth. Because high levels of biodiversity appear to enhance the resilience of ecosystems (their ability to recover), efforts to restore ecosystems requires that diversity be restored and that ecosystem functions be understood.

Ecosystem dynamics are determined in part by slow variables; this means that human influences on landscapes, climate and oceans may become apparent only after decades of activity. Measuring the impacts of slow variables is difficult, and overcoming the problems associated with the process poses a major challenge for the CGIAR in its efforts to develop better methods of assessment. One problem arises from attempts to use methods suitable for reductionist research to understand and manipulate complex ecosystems. As the complexity of an ecosystem increases, the ability to predict its behaviour decreases. This raises the question of how broadly to extend research agendas by assessing marginal costs versus marginal benefits. Modelling has both advantages and constraints as a means to better understand complex issues of scale and resolution. Indeed, folk wisdom is often based on complex models developed through experience.

Addressing these challenges offers an opportunity for the CGIAR to demonstrate that it is not, as some stakeholders have cautioned, drifting into areas of ill-defined research that do not contribute to the well-being of poor people and are difficult to assess for impact.

4. Fundamentals of Natural Ecosystems and Agroecosystems

The CBD defines an ecosystem as 'a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit'.

Ecosystems can be delineated by several variables, including geography, function, use and time. They cannot always be defined by boundaries alone; scale and focus must also be considered. Ecologists measure ecosystem diversity in a variety of ways. One commonly used method is counting the number of species in an ecosystem; others are based on measuring the relative abundances of species or various trophic groups. The relationship between these species and their environment and among each other is the most important factor in attempts to prevent declines in diversity and enhance ecosystem resilience. The components and attributes of an ecosystem — biological and physical factors and conditions associated with processes and flows — are subject to varying degrees of human intervention and may vary in time and space according to the degree of entropy and the source of energy (Figure 1). Definitions of an ecosystem are sometimes based subjectively on a particular scale, level or purpose (the goods and services it provides, for example), and how broadly an ecosystem extends also may be defined by its purpose or on events that occur at temporal and spatial scales.

Ecosystems vary along a continuum depending on their degree of human intervention and the scale at which they are sustainable. Differences between natural ecosystems and agroecosystems offer a useful illustration of how ecosystems operate (Table 1). Natural ecosystems and agroecosystems — representing opposite ends of a continuum — have similar biotic and abiotic components, which are linked by similar processes and flows (energy, nutrients, water). However, the two systems differ in the magnitude of their energy flow and species composition. Natural ecosystems are usually closed systems that are self-sustaining and self-regulating. By definition, they are relatively undisturbed by humans and have intact components that provide goods and services to other components in the ecosystems. In contrast, agroecosystems are open systems that are manipulated to some extent by humans to provide food or other products; they change relatively rapidly and often receive water and nutrients to increase production. As a result, agroecosystems have higher rates of degradation, but also higher levels of productivity per unit area than natural ecosystems.

Table 1. Differences between natural ecosystems and agroecosystems

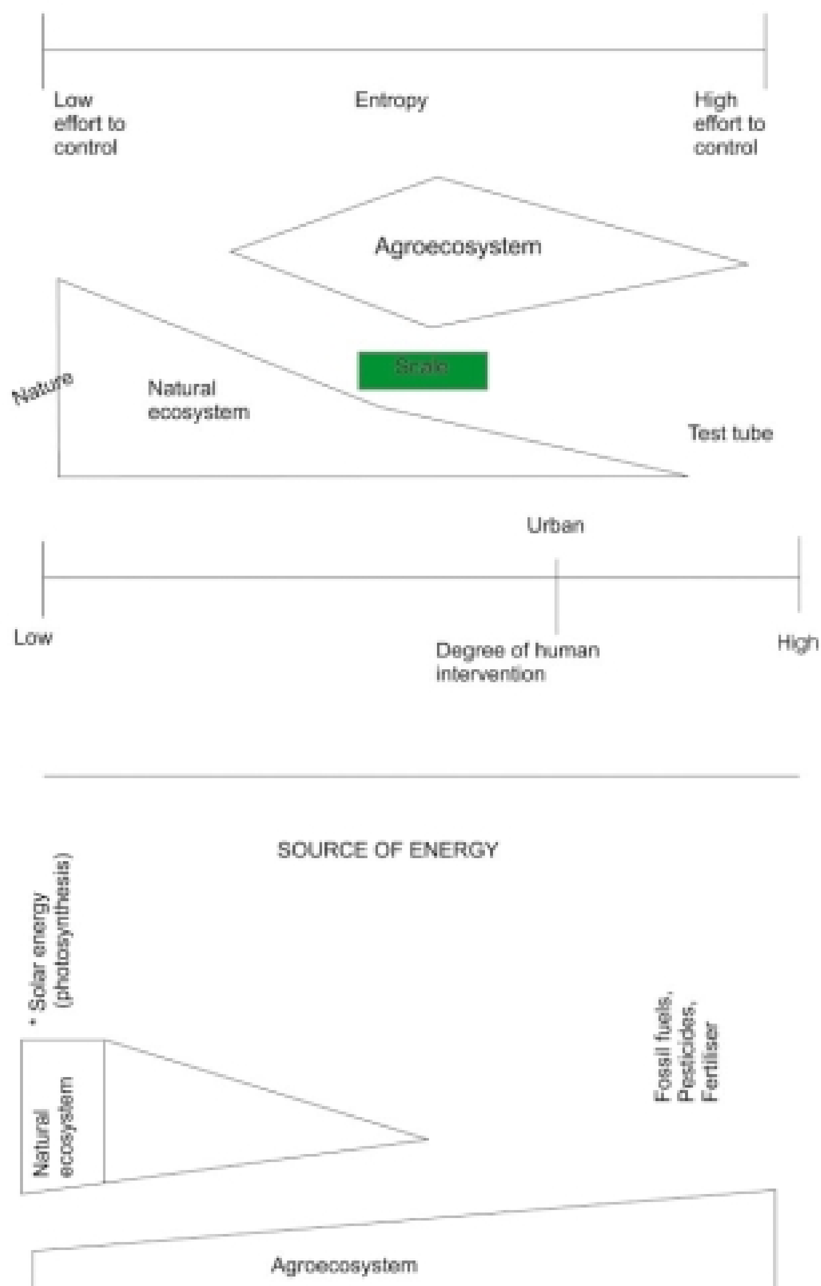
Item	Natural ecosystems	Agroecosystems
Type of system	+/- Closed	Open
Nutrient cycle	Closed	Open
Carbon cycle	Closed	Open
Water cycle	Closed	Open
Among species diversity	High	Low
Within species diversity	High	Low
Human management	Low	High
Individual species density	Low	High
Ease of economic valuation	Hard	Easy
Genetic improvement (domestication)	Low	High

The degree of human modification to an ecosystem is not always correlated with the level of degradation and loss of functional biodiversity. Whether natural ecosystems are 'better' than agroecosystems for achieving conservation depends on the exact nature of the systems and the particular species being addressed. Factors that come into play include the extent of human modification (which may be related to social attitudes), the existence or development of markets, population density, infrastructure and technology features, and the kinds of resources that are harvested and their intended use.

An agroecosystem may be of low value for conservation at a local scale but of high value on a larger scale when tradeoffs between local and regional conservation are considered. For example, an agroecosystem may be good for conservation when it diverts use and disturbance of resources from other areas that can be used as reserves.

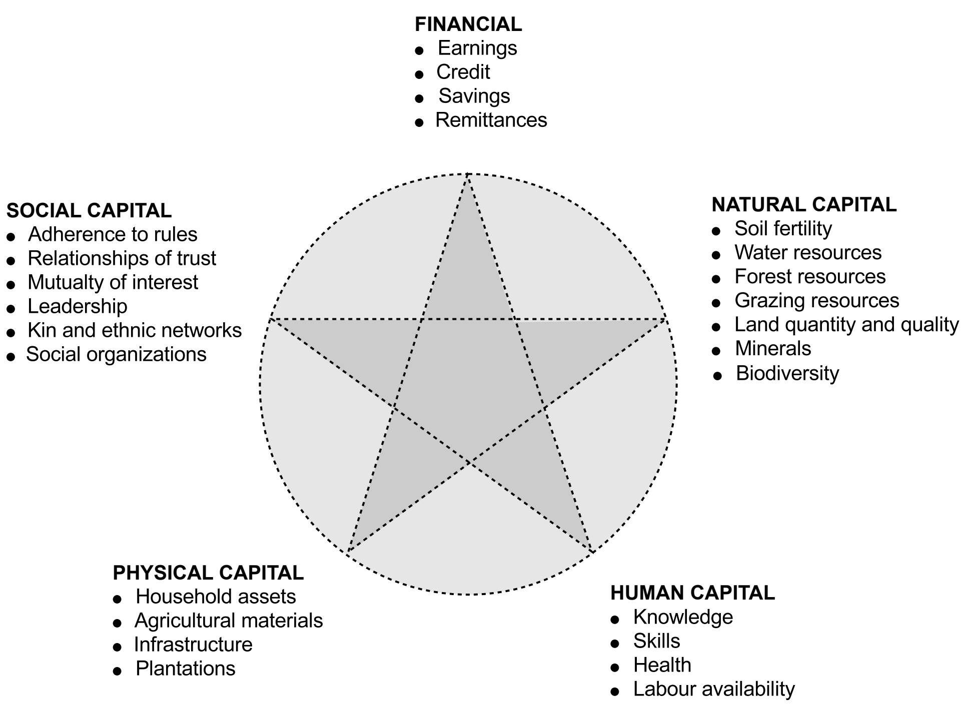
The work of the CGIAR centres spans the natural ecosystem-agrosystem continuum, ranging from diverse forest ecosystems with little human intervention to intensely cultivated and less diverse agricultural and peri-urban ecosystems. Energy sources and flows in these systems differ in form and intensity (Figure 1). The report 'Integrated Natural Resource Management in the CGIAR', which summarises results of a workshop on INRM held in August 2000 in Penang, Malaysia, noted that 'INRM is centred on the interactions that occur between elements of natural capital and the four other realms of capital, especially social capital (Figure 2). The CGIAR, in working to meet its mission, originally concentrated on building physical and human

Figure 1. The ecosystem continuum (see text for further description)



capital (through developing improved agricultural materials and methods, and in developing national agricultural research systems and in training NARS scientists). In the last decade or so, the CGIAR system broadened that focus to also include building of natural capital (through INRM research) and social capital (through participatory research approaches with farmers, foresters and fishers, and collaboration with NGO's).

Figure 2. The five capital assets (modified from Bebbington 1999 and Carney 1998)



RECOMMENDATIONS

- Research should be done at various scales, preferably including one above and one below the level at which the problem is identified and defined.
- Agroecosystems should mimic natural ecosystems in terms of process, succession and mosaic, and major research is needed to work toward this.
- Some systems (such as agricultural production systems) may have hard boundaries, and good management of them reduces 'edge' effects. Research in this area is also critically needed.
- Research should be based on efforts to achieve and maintain a balance between the five capitals (human, social, natural, physical and financial) (Figure 2).

5. Clarification of Terms

One goal of the workshop was to develop a shared understanding of genetic resource management (GRM) and natural resource management (NRM). There are many similarities and differences between (a) ecosystem and *in situ* approaches to conservation and use of genetic resources; (b) NRM and INRM; and (c) an ecosystems approach versus INRM Inevitably, value judgments colour any effort to compare these approaches.

Ecosystem versus *In Situ* Approaches to Conservation

Similarities

Both approaches aim toward:

- Achieving conservation in the original environment.
- Allowing natural selection and evolution to continue.
- Conserving representative ecotypes for targeted ecosystems.
- Taking a holistic approach to conservation.

Differences

The two approaches may differ in:

- Degree of human intervention — ecosystem approaches entail fewer interventions than *in situ* approaches to conservation.
- Relative focus on processes and function — ecosystem-based approaches are more process-and function-oriented than *in situ* approaches.
- Relative focus on species — *in situ* conservation may be more species-specific and species-centred than ecosystem approaches, which usually involve multiple species.
- Geographical scales of conservation — *in situ* approaches are geographically more restricted than ecosystem-based approaches.
- Targeted components — ecosystem approaches primarily conserve habitats, often with little accurate knowledge of the genetic resources of these habitats, whereas *in situ* approaches target specific genetic resources.

Natural Resource Management versus Integrated Natural Resource Management

Similarities

- Both NRM and INRM are concerned with genetic diversity and natural capital, and aim toward conservation of natural resources, including genetic resources.
- Both approaches can be used in the management of wild and cultivated species.

Differences

- INRM involves a more holistic approach, whereas NRM may consider only environmental factors (such as soil, water and biophysical components).
- An INRM approach works from a broader set of objectives, including social aspects, than an NRM approach.
- An NRM approach seeks to maximise yield at the expense of risk, whereas INRM seeks to optimise yield but also minimise risk.
- NRM involves a more reductionist approach than the more holistic INRM approach.

Ecosystem Approach versus Integrated Natural Resource Management

Participants at the workshop concurred that INRM and ecosystem approaches to management of agroecosystems are synonymous. However, INRM usually differs in approach in regard to agroecosystems and natural ecosystems because in agroecosystems, reproduction and population dynamics are artificially controlled and there are generally few species.

Similarities

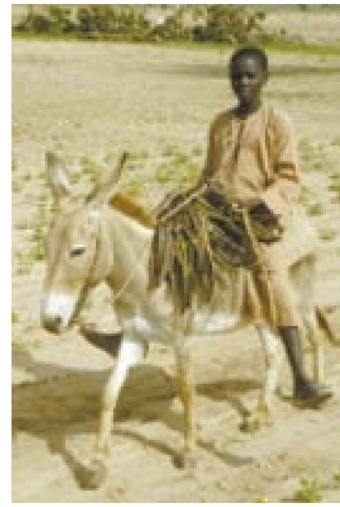
Both approaches:

- Are based on the same scientific and biological principles.
- Aim toward conserving and maintaining biodiversity, including genetic diversity.

Differences

- Ecosystem approaches focus on processes and interactions.
- INRM focuses on outputs and production, and may be more site-specific than ecosystem approaches.

6. Issues in GRM-NRM



In working to define genetic resources issues within natural resource management, the workshop participants ranked by importance the following six subject areas:

- The relationship between GRM and NRM.
- The scope and role of the CGIAR in genetic resource management and natural resource management.
- The value of genetic resources.
- Appropriate methodologies and identification of gaps in methodological approaches.
- Scale and complexity.
- The role of biodiversity.

6.1 Relationship Between GRM and NRM

In exploring the relationship between GRM and NRM, the following important issues were identified and illustrated with examples.

Synergies Between GRM and NRM

A number of examples, drawn primarily from CGIAR projects, serve to illustrate the potential for synergies between GRM and NRM:

- Water harvesting and improved water-efficient germplasm.
- *Striga* control and improved soil fertility technologies based on improved cultivars.
- Use of improved germplasm to 'sell' improved NRM technologies.
- Promotion of greater awareness about factors that limit production (e.g., soil micronutrient deficiencies or toxicities).
- Reduction of deforestation rates through improved plantations and NRM.
- Revitalisation of GRM leading to habitat and ecosystem conservation.
- Identification and management of wild *Oryza* populations.
- Landscape modelling and *in situ* conservation.
- Identification and sustainable management of wild fish populations.
- Fish and shellfish stock enhancement and reseeding.

Important issues common to all or most of these examples follow.

1. The main implications of NRM approaches for GRM are in the areas of:
    - Germplasm evaluation.
    - Geographic Information Systems and *in situ* conservation.
    - Unknown and unevaluated landraces developed as exploitable GRM.

2. GRM is relevant to NRM in the areas of:
   - Germplasm evaluation.
   - Crop domestication.

RECOMMENDATION

- Because evaluation of germplasm is important, it would be strategically helpful to develop an integrated strategy for evaluating germplasm in the context of GRM/NRM.

6.2 The Scope and Role of the CGIAR in GRM and NRM

The workshop discussions centred heavily on integrated natural resource management (INRM) in the context of the CGIAR. A key question was how the CGIAR and its centres could create better synergy within and among the centres and their partners, thereby leading the CGIAR toward a more cohesive and integrated approach to genetic resources management.

Scope and Role of CGIAR Centres

- What is the role of the CGIAR in regard to INRM and ecosystem management?
- A strong case should be made for inclusion of GRM conservation in ecosystem management and INRM.
- Ecosystem management should be viewed as an integrated approach for conservation of GRM.
- How should an appropriate research agenda for the CGIAR be defined?
- The need to achieve a balance between biological and social considerations should be emphasised.
- Genetic resource conservation should be regarded as an integral part of natural resources management.
- The role of genetic resources in maintaining ecological processes and functions needs to be clarified.
- The research should focus on achieving benefits for poor farmers, fishers and forest-dependent people.

6.2.1 Conceptual Framework

Workshop participants considered the relationship between the aims of genetic resource management and how they relate to the biophysical environment (e.g., soils, nutrients and water). Participants also identified the scales at which GRM issues should be considered.

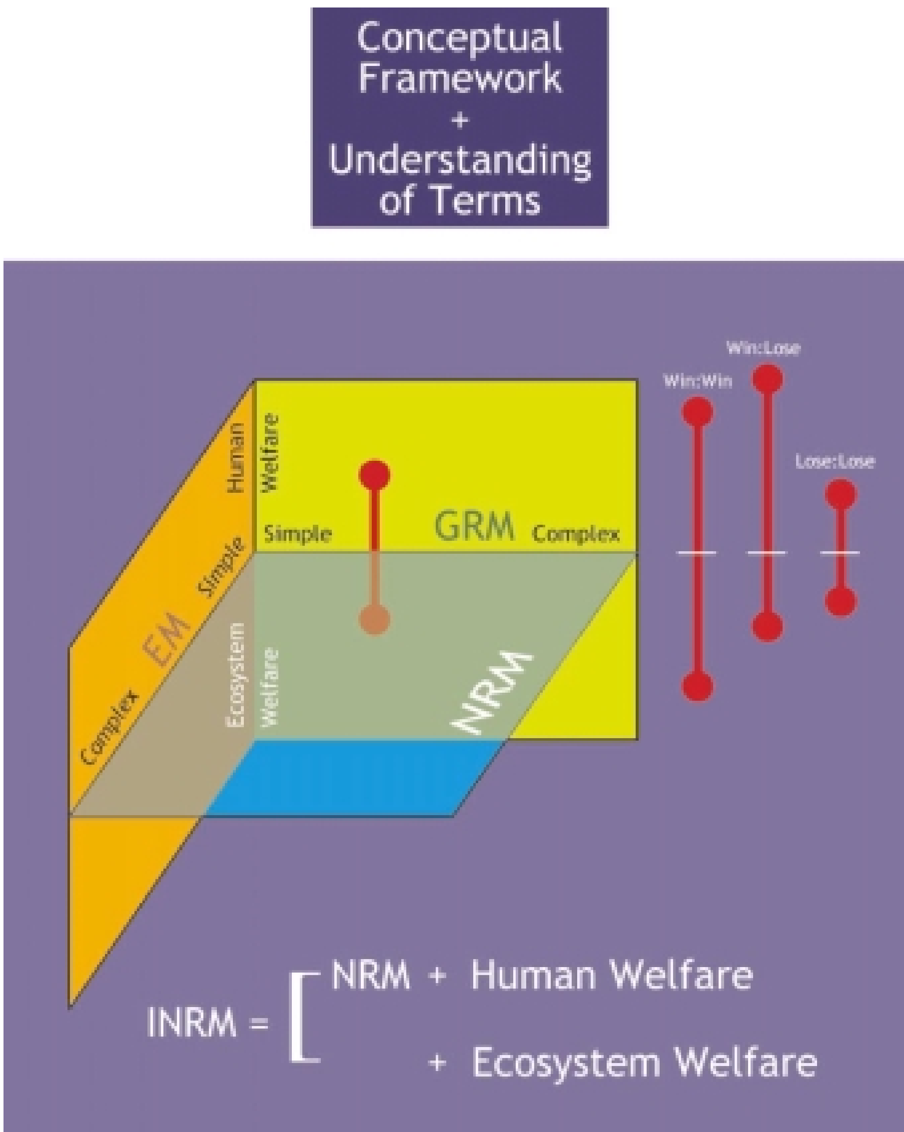
In keeping with the definition of agrobiodiversity in the Convention on Biological Diversity (CBD), the term 'biodiversity' in this document encompasses not only species of actual or potential value for agriculture but also guilds of species (such as pollinators, pests, pathogens and symbionts) that influence the abundance of, and induce genetic changes in, agricultural or harvested species. The scope of attention may range from that of individuals to populations and species, and from interactions between individuals to events across a landscape or an entire ecosystem. A functional and synergistic relationship exists between the management of a genetic resource and the biophysical environment. Although it may be convenient to view the components and processes separately, such a division is artificial. Genetic resources are an integral component of ecosystems and thus of natural resources. The additive and interactive effects of within- and between-species genetic diversity determine both the resilience of agro-ecosystems and the evolutionary potential of species.

To illustrate the relationship between GRM and NRM/INRM, the workshop participants formulated a conceptual framework (Figure 3). It is based on the recognition that the CGIAR's goal is to promote food security and reduce poverty. Therefore, the sustainable use of natural resources must be the foundation on which to develop a positive relationship between human well-being and environmental health. The conceptual framework views NRM in terms of GRM (x axis) and environmental management (EM) (y axis). Interactions between these variables create the surface representing the NRM response. Points above the NRM plane signify human well-being and those below, ecosystem well-being. Activities and goals of the CGIAR centres are represented by the z axis, thus conveying the overall integration of INRM.

The scale on the GRM axis can range from that of genes (DNA) to individuals to populations to ecosystems, while the scale on the EM axis can range from that of soil particles to landscape. The response surface may vary in time and space, and can reflect 'win-win', 'win-lose' or 'lose-lose' outcomes in relation to human and environmental well-being. For example, the long-term rehabilitation of a degraded desert margin with crops that provide food security is a win-win situation for both human well-being and the ecosystem. However, the degradation of a coastal ecosystem as a result of pollution and the loss of fisheries production is a lose-lose outcome.

The conceptual framework attempts to clarify the definitions of NRM and INRM. It expresses the requirement that genetic resources be an integral component of INRM. The framework also lends itself to analysis of other factors associated with resource management. For example, research directions could be assessed by replacing the axes

Figure 3. Response surface of human and ecosystem well-being as a function of genetic resource management and environmental management; together these constitute NRM. Integrating human and ecosystem well-being with NRM constitutes INRM.



representing human and ecosystem well-being with axes quantifying the state of knowledge about a particular topic. It also could be useful as a tool to help set INRM research priorities. Individual CGIAR centres might use it to help assess their comparative advantage vis-à-vis other research centres within and outside the CGIAR system.

6.2.2 Balance Between Conservation and Sustainable Use of Genetic Resources in an Ecosystem [2]

Given the CGIAR's mandate and mission, balancing conservation and sustainable use of genetic resources is an important issue for the CGIAR. Whether the emphasis should be on conservation or use depends on individual cases. A key question is who will determine what management strategy for conservation and use is adopted, and how the decision will be made. Because it will be important to involve different groups of shareholders, negotiation and conflict resolution will be highly relevant to the CGIAR's agenda for genetic resource management.

Spatial and temporal variables are also important considerations in efforts to balance conservation and use. A broad geographical perspective, for example, might entail intensive use of lowlands for cultivation so that upland areas can be conserved. In working to develop appropriate management strategies, a large body of reliable information is needed, as well as measures of assessment such as sets of indicators that would convey how well a balance between conservation and sustainable use is being achieved. Decisions would be made on the basis of criteria that indicate conditions and influences with respect to:

- Knowledge of population structure of affected species.
- Identification and conservation of local adaptive traits and adaptation.
- Social well-being.
- Economic considerations.
- Environmental conservation.
- Conservation of biodiversity.

[2] The discussions were based on general experience and the following specific examples of the use of genetics in conservation:

- Use of genetics in harvest management: Barramundi along the north coast of Australia (natural systems, fish populations).
- Conservation of natural genetic diversity in rangelands: Effect of livestock grazing on rangeland species.
- Conserving fragile lands: Crop system intensification in productive areas.
- Landraces as natural resources: On-farm conservation.

RECOMMENDATIONS

- Develop integrated criteria for identifying target and strategically selected non-target species.
- Develop performance indicators for ecosystems and their sub-systems.

Efforts to develop integrated management of agroecosystems or other landscapes for a balance between conservation and sustainable use of genetic resources and biodiversity are the basis of various projects already being implemented by the CGIAR centres. Overgrazing by livestock, vegetation changes and impacts on within-species diversity is the focus of an integrated resource management project in the Sahel. The research involves the use of molecular genetic methods to detect any differences between molecular genotypes in surviving plants in overgrazed and non-grazed areas. In Tanzania, a balance is being sought between livestock grazing in the highlands and protection of habitats. In an area of Zimbabwe where poor soil has led to reduced fertility and constrained production, a two-fold approach to the problem requires restoring soil to productivity and working to develop better germplasm.

6.3 The Value of Genetic Resources

Much of the considerable attention that has been given to genetic resources recently centres on the issue of their economic value. Access and benefit-sharing provisions of the Convention on Biological Diversity have contributed to the widespread interest and debate on this issue. Yet the benefits of maintaining genetic resources are considerably broader than economic interests; biological diversity has considerable value to people for social and cultural concerns, and it is important to sound functioning of ecosystems. On one hand, the conservation of genetic resources is founded on the assumption that genetic diversity has value in and of itself — as a basis for ecosystem health and enhanced human existence. On the other hand, human population growth and the escalating need for food security requires the direct use and development of genetic resources in ways that often interfere with ecosystem functioning. The numerous strategies for conserving genetic diversity range from preservation of germplasm in gene banks to *in situ* conservation or conservation through sustainable use. Determining which of these strategies is most appropriate in various situations requires a realistic view of the costs and benefits of conservation or a lack of it.

It may be useful to define genetic resources more broadly to include all biodiversity in a farming system, as well as the interactions between species that potentially influence evolutionary change. Although sound integrated natural resource management requires a long-term perspective, the CGIAR centres face the question of what can be done in the short term. Nevertheless, long-term vision is needed as the basis for prioritising activities and target species.

For the most part, the value of genetic resources as a global benefit to society has not been sufficiently acknowledged and taken into account in natural resource management. How should genetic resources that are not being used directly be valued? What is the cost of forgoing possible future use of fallow resources, or of resources that have not yet been identified? An important area of research is quantifying genetic resources and developing methodologies to evaluate unused resources. Also needed are methods that can be used in management planning and decision-making to demonstrate the value of genetic diversity.

A number of case examples illustrate the benefits of integrating GRM and NRM, as well as the benefits of inter-centre and sectoral collaboration[3]. In these cases, genetic resources are an integral part of the natural resource being addressed, and genetic and natural resource management are closely linked. While genetic resources are of direct value in promoting food security in many of these cases, genetic diversity also is important for ecosystem services and cultural and social concerns.

Views of how to value genetic resources — whether as individual components of an ecosystem or part of ecosystem functions — often conflict. Research within the CGIAR system covers a wide range in regard to how genetic resources are valued. Some projects emphasise specific components of an ecosystem as commodities for food security; others value genetic diversity in the form of landraces or unused but supportive components of an ecosystem. In the first instance, genetic resources are viewed as separate from the ecosystem, while in the latter case biological resources are regarded as an integral part of an ecosystem. Landraces of plants, for example, could be seen as stores of genetic variability to be exploited for crop improvement, or as important components of a functioning agroecosystem. Emphasising genetic diversity as a commodity places high value on genes and the creation of highly productive genotypes (through selective breeding or genetic engineering). In an ecosystem context, the value of genetic variability within a species is defined by its role in supporting complex interactions with other species.

[3] The following case examples were discussed:

- Millet tree-livestock mixed system in the Sahel region in West Africa (an ICRAF/ICRISAT/ILRI collaborative project).
- Cowpea-sorghum-livestock mixed farming system in the savanna in West Africa (an IITA/ILRI/ICRISAT collaborative project).
- Yellow mottle virus-resistant rice varieties in upland ecologies of West Africa (WARDA).
- Benchmark site in the humid zone in Cameroon (IITA/ICRAF/CIFOR and others).

The development of new genetic resources is a high priority in many areas because the crop options available to many farmers are limited. Having a wide range of crops is important in maintaining sustainability. When new crops become available, however, farmers may reject traditional ones in favour of more productive and less diverse species. Although mechanised agriculture can increase food production, it often leads to a reduction in crop diversity and a gradual shift in the nature a landscape or ecosystem. Maintaining diversity is especially important in forest systems with long-lived trees that cannot be easily replaced. While croplands can sometimes be restored, the intensification of western-style agriculture tends to result in less diversity. The challenge is to strike a balance between increasing productivity and maintaining diversity.

In many farm communities, the value of genetic resources and their diversity is rooted in their role in social and cultural systems, apart from their economic value as commodities to promote food security. Understanding what genetic resources mean to a community in terms of perceived values and benefits will improve the process of assessing their importance and determining how to manage them. In other farm systems, commodity crops are important more for their integral role in ecosystem functioning, and an understanding of wider ecosystem dynamics is vital to sustainable use of resources.

In the savannas of West Africa, for example, a mixed crop-livestock system includes sorghum, cowpea, trees, zero-grazed livestock and grazing range. Soils in the area are poorly developed, so interactions between key components of the ecosystem are crucial in providing nutrients to other components in the system. The greatest challenge in this system is to maintain or enhance soil fertility and simultaneously maintain a balance in inter- and intra-specific diversity. Additionally, the system should be managed with regard to local social and cultural values, which include land use rights, traditional preferences for species, market options and attitudes toward risk. Successful management of a system like this requires focusing on the entire system and not just its components. To achieve that, research and management strategies must build on traditional knowledge of the system and on social and cultural practices and economic expectations among farmers, community leaders, development agencies, policy makers, economists and biologists. Successful management must consider such variables as soil fertility, inter-and intra-specific diversity, productivity, and human welfare.

The use of organisms in coral reefs is another illustration of the need to view an ecosystem holistically. In many marine (and forest) ecosystems where harvested species are part of a complex ecological web, productivity depends on sound maintenance of the ecosystem's services. Along with rainforests, coral reefs are amongst the most diverse ecosystems on earth and are often located along the coasts of developing countries. Among the wide variety of animals in coral reefs are numerous species of fish and invertebrates that are harvested in fisheries for both subsistence and commercial purposes. There are many examples in which the maintenance of high levels of biodiversity is essential to sustainable use. In the South China Sea, for example, the establishment of 'no-take' reserves has spurred support for sustainable use of the reefs outside the reserves as well.

RECOMMENDATIONS

Research should devote attention to priority areas such as these:

- Developing ways of valuing a system's goods and services, including water conservation, carbon sequestration, productivity, poverty alleviation and improvements in the quality of life. Wherever possible, the CGIAR centres should emphasise the preservation of diversity as well as production.
- Investigating policy and marketing implications of the scientific research agenda.

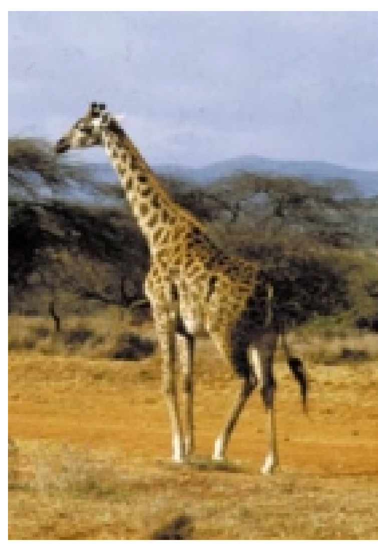
Action should be taken to:

- Achieve greater collaboration among the CGIAR centres and develop broad guidelines for them.
- Develop a research agenda for integrating genetic resources into INRM.
- Study policy issues and evaluate the impact of genetic and natural resource management.

6.4 Methodologies

The foregoing discussions have highlighted several methodological issues that need to be addressed before conservation and utilisation plans can be formulated. At the same time, it will be important to define what role the CGIAR centres should play in both the short and long term with regard to the development and conservation of genetic resources. For now, several questions may be helpful to suggest possible research directions:

- How should genetic resources targeted for conservation be chosen?
- How can widespread wild species be adequately conserved?
- How should sites be chosen for *in situ* conservation?
- How can ecosystems be rehabilitated (with the help of NARS and the CGIAR)?
- How can needed technology best be developed and disseminated?
- What policies should be formulated to conserve and maximise benefits from genetic resources?



The following cross-cutting issues also must be addressed in developing appropriate methodologies and identifying gaps in current methodological approaches:

- Valuation of potential genetic resources.
- Management of INRM sites.
- Quantification of how genetic resources contribute to natural resource functioning.

- Integration of genetic resources and natural resource management.
- Conservation of genetic resources through sustainable use of natural resources
- Definition of scale and integration of research at various levels.
- Identification of constraints to sustainable use of genetic resources.

In the development of practical methodologies, adequate consideration must be given to the needs and abilities of farmers. Most methodologies are specific to particular problems, such as conservation, policy research, and technology development, dissemination and transfer. The development and assessment of technologies will be iterative, and should involve these steps: 1) generation of novelty, 2) selection, 3) promulgation, and 4) motivation or evolutionary drive. Efforts to develop integrated projects for conservation and sustainable use of genetic resources often face problems of a general nature, so broad guidelines on how to overcome such problems may be helpful.

RECOMMENDATIONS

- Develop a framework for understanding ecosystem dynamics. (How can the collapse of an ecosystem be prevented? What needs to be done to restore disturbed ecosystems?).
- Develop benchmark indicators to monitor the health of ecosystems.
- Develop possible environmental policies.

6.5 Scale and Complexity: Appropriate Scale of Management

NRM is far more complex in application than GRM because of NRM's broader scope. Therefore, management actions must be taken at scales of complexity that are likely to achieve the greatest impact. NRM activities tend to focus on species or communities, in contrast to GRM's focus on individuals and populations. The objective of selective breeding, for example, is to improve individual performance, while managing a species in the wild aims to maintain the integrity of its populations. Populations, which consist of interbreeding individuals, represent the fundamental components of an ecosystem. Therefore, the cumulative effect of GRM at the population and species level influences the overall well-being of an ecosystem. The challenge of successful management is determining the appropriate scales at which to focus, because natural and human-induced processes occur on different temporal and spatial scales and at different levels of complexity.

The prevailing view in ecology is that ecosystems with much diversity of viable components are more resilient than ecosystems with few species. The presence of large numbers of species in an ecosystem allows for alternative trophic webs and different ways of providing ecosystem services. The loss of a few key species in a low-diversity ecosystem may lead to the collapse of the system because of the lack of alternative trophic or nutrient pathways to support higher trophic species. In a production system, however, management to achieve high within-species genetic diversity in crop species or in species harvested from

natural ecosystems does not necessarily ensure resilience of the entire system. Among-species diversity within an ecological community is also not necessarily related to intraspecific diversity of production species.

How important GRM issues are to NRM at a particular level of complexity is likely to differ among ecosystems. A key question would be: At what spatial and temporal scale should management of a particular ecosystem be focused to produce the highest degree of resilience? In INRM, the focus, by definition, is on the ecosystem; the ecosystem boundaries are usually defined by spatial scales or the extent of interactions between groups of species. In contrast, *in situ* management of production species focuses on populations as the primary unit. This discrepancy can lead to different results based on what particular unit is the subject of focus. This must be considered when choosing appropriate spatial and temporal scales for management.

The importance of genetic resources management issues to NRM at each level of complexity or scale (spatial or temporal) will differ for different systems. For example, the management of natural populations of harvested fishes, as well as other natural populations, requires both a narrow focus on factors influencing genetic diversity *within* populations and a focus on genetic diversity *among* populations. At one end of a spatial scale, overharvests can lead to reduced population size and the loss of genetic diversity through random drift. The loss of genetic diversity can reduce a population's ability to adapt to environmental changes. At the other end of the scale, translocations over large distances followed by hybridisation can compromise a population's genetic integrity and its ability to buffet change. The loss of genetic variability over a large landscape may also reduce a species' ability to withstand environmental challenges and its value as a base for development.

The CGIAR centres, by focusing on research designed to increase production and the well-being of poor people, have sought to ensure benefits that are relatively short term. However, the management of a production system involves a number of factors: scales of geography, whether the operations are large or small, and a variety of interests and concerns of families, small businesses, communities, industry and governments. The relative importance of these factors can change in response to shifts in political and economic forces. A continuing challenge in implementing GRM and NRM is to identify the most cost-effective activities at various spatial, temporal and technical scales to provide benefits to humans while ensuring ecosystem health and resilience.

Genetic diversity in natural and cultivated populations must be regarded as an integral part of the CGIAR's work on genetic resources. This is particularly relevant because of fragmentation of populations as a result of human activities. A rich body of information on the dynamics of metapopulations is available in the literature. In as much as management of genetic diversity in natural systems is presently outside the scope of most of the CGIAR centres' work, policy recommendations alone might be considered direct benefits of research. This is outside the actual maintenance of genetic diversity *ex situ* on which many CGIAR centres are expected to concentrate.

RECOMMENDATION

- The research agendas of the CGIAR centres should focus on the interactions among livestock and crop species and physical variables such as water, soils and atmosphere, as well as the interactions among these variables. Some CGIAR centres have a mandate to focus on biomass harvested from natural populations. It is essential in integrated natural resource management to recognise potential off-site impacts of activities and interventions that occur within managed areas. Managed areas are embedded in larger landscapes that involve hierarchical processes, and the challenge for GRM is to determine the appropriate scale and level of biological and physical complexity at which to focus.

6.6 The Role of Biodiversity

Several phenomena are included under the banner of biodiversity. These can be roughly classified in three broad areas, each of which is governed by perspectives that influence the particular kinds of diversity being emphasized and the priorities for conservation and management. To many people, biodiversity is simply a list of species existing in a particular area or taxonomic group. Hence, exploitation and conservation is often concerned with this level of biological structure. For example, numerous conservation agencies are attempting to save the 'panda', 'black rhinoceros' and 'barndoor skate' from extinction. The use of shorthand names for biological entities is useful and perhaps necessary, but this practice often obscures better understanding of the wealth of genetic diversity among and within populations of a species. Only by preserving the mechanisms that maintain this genetic diversity can we conserve species and use them in a sustainable way.

Ecological and genetic approaches to conservation and sustainable use are connected at the level of population. An entire species (unless it has been reduced to a single population)



cannot be treated as an ecological entity, as a species may be widely distributed and may perform different roles in different ecosystems. Species are represented in ecosystems as populations that interact with populations of other species. From a genetic perspective, biological and environmental interactions — such as predation, competition for resources, and decomposition — that influence the flow of energy through a system shape the genetic architecture of the populations in the ecosystem. Genetic processes such as divergence in isolation, loss of gene diversity through population bottlenecks and connectivity through gene flow ultimately shape ecosystems. At high levels of organisation, various components of an ecosystem have properties that do not exist at lower levels. Thus, an understanding of these levels is needed to develop effective management and conservation of biodiversity.
The biological diversity that exists around us today is the result of past diversifications and extinctions of species groups. Cataloging this diversity falls under the discipline of systematics. Ecologists aim to understand the structures of ecosystems by studying trophic and competitive interactions among species as well as interactions between species and the physical environment. Not all species are equal; some play 'keystone' roles and are important to the survival of other species. Without fundamental ecosystem services, the units of biological diversity are unlikely to flourish. Evolutionary biologists work to understand the genetic and geographical mechanisms that produce diversity, and therefore place a high priority on preserving species or species groups that promise to be progenitors of future biological diversity. The principles on which these three disciplines — systematics, ecology and evolutionary biology — operate are relevant to the sustainable development of genetic resources.

7. Principles, Mechanisms and Indicators in Genetic Resources Management

CGIAR examples considered:

- Fertile Crescent Initiative (ICARDA).
- Arab Peninsula Project (ICARDA).
- Forest Margins Project (IITA).
- Desert Margin Programme (ICRISAT).
- Mixed crop and livestock system in the savanna belt of Africa.
- Coastal marine ecosystems (ICLARM).
- Forest ecosystems (CIFOR).

These examples are a good reflection of activities by CGIAR centres in mixed cropping systems, marine ecosystems, rangeland ecosystems and forest ecosystems. *Mixed cropping systems* are characterised by drought, decreased soil fertility and decreased fallow or forage alternatives that limit the range of crops that can be grown. *Forest ecosystems* focus on the management of fragmented locally adapted populations with little dispersal, while marine ecosystems are concerned with the management of such systems as fragmented coral reef populations. *Rangeland ecosystems* are characterised by overgrazing, resulting in increased biodiversity of unpalatable or toxic pasture species. Management of grazing and land use aims to conserve genetic diversity in adapted populations of forage species.

At the workshop, challenges associated with NRM, GRM and their integration were discussed in relation to each of the systems and cases presented. The participants subsequently proposed principles and mechanisms for addressing these challenges, and identified indicators that might be suitable for assessing impact in various areas of NRM and INRM management.

NRM Challenges

Major NRM challenges that all these systems or ecosystems have in common include:

- How to maintain diversity and the health of an ecosystem while allowing sustainable use of the resource(s).
- How to achieve sustainable land use or to maintain or enhance soil fertility while avoiding habitat loss or degradation (resulting in erosion of genetic resources and soil).
- How to ensure an appropriate balance between multiple uses, goals and ecosystem services to enhance productivity.
- How to make the users of an ecosystem understand the need for sustainable use of resources instead of viewing such resources primarily as a source of immediate economic gain.

GRM Challenges

The main challenges associated with genetic resource management are:

- How to maintain or enhance intra- and interspecies diversity.
- How to achieve restoration, reclamation and rehabilitation.
- How to document, understand and deal with intraspecific and population differences and the introduction of exotic genotypes and species to maintain genetic variability in the NRM context.
- How to improve the import of inputs and to use genetic resources to increase nutrient flow and cycles and the efficiency of water use.
- How to diversify the genetic base of species to ensure survival during revegetation, reforestation and restocking of degraded areas to restore viable populations for NRM.
- How to reconcile genetic issues with larger issues such as politics, institutional frameworks, policies and food security in NRM.
- How to identify management techniques developed for natural ecosystems that could be used to aid conservation of genetic diversity.
- How to make users understand the need for sustainable use of ecosystem resources rather than viewing them primarily as a source of immediate economic gain.

Additional challenges are posed by factors such as cultural values, institutional issues, land tenancy, property rights, traditional use of and preferences for species, market options and acceptable levels of risk.

Operating principles and elements of NRM/GRM approaches

- Adopt an adaptive management approach that acknowledges imperfect understanding of the system and allows for learning and adjustment by all stakeholders.
- Focus on the overall system rather than individual components (e.g., millet + trees + livestock).
- Empower farmers with the ability to innovate (to pursue development of new crops or other resources, for example).
- Create alternative sources of food and cash to broaden the options of small farmers (providing incentives).
- Help guide the development of policies that are based on a holistic view of NRM
- Consider the need for integration or extrapolation of scales in the design.
- Adopt a 'benchmark' approach as a way of bringing stakeholders together.
- Provide knowledge about a system and not just its components.
- Pursue scientific methods that address ecosystem interactions and not just components.
- Acknowledge farmers' existing management ability and build on it.
- Make farmers active partners in the research and development process.
- Match genetic and natural resources needs with system needs.
- Understand that NRM focuses on functional units while genetic resources focuses on individuals and populations.
- Identify intra-specific genetic resources units in an ecosystem that should be targeted for sustainable management.
- Recognise that there is often a lack of precise knowledge about what exists at species and intra-species levels in natural ecosystems.

Mechanisms for addressing the challenges

- Advocate community-based action within a broader institutional structure.
- Establish appropriate partnerships (with farmers, community leaders, development agencies, policy makers, policy developers, social scientists, economists, biophysical scientists) and work with the users immediately as partners to develop management options.
- Incorporate multidisciplinary cooperation and the use of GIS and databases in management planning (contribute new information to databases as well as tapping them, use GIS and databases to identify adapted genotypes or genotypes from the area for restoration).
- Work through local organisations.
- Create problem-solving task forces.
- Take a multi-species approach and investigate changes in community structure

- Pursue studies to collect information on the genetics of target populations of key species.
- Choose sites, scope (scale), areas of focus (species) and partners that are likely to maximise impact.
- Make consideration of larger issues (policy, institutional) part of the agenda.
- Provide for *ex situ* conservation, corridors or refuges in sustainable use planning to ensure sources of genetic resources in the event of unforeseen problems.
- Incorporate genetic resources issues into new management options.
- Promote education and public awareness.
- Study social factors and human decision-making in areas of target species and systems.
- Develop agroecologically well defined 'benchmark' research sites with the potential for wide extrapolation.
- Promote a conducive policy and cultural environment (integrate incentives and influences into management planning).

Indicators for impact assessment

There is no standard way to assess whether an ecosystem is sustainable, and there is disagreement about what criteria should be considered. Yet general indicators can be suggested. The workshop participants proposed that biological indicators could be based on assessment of conditions and factors such as the following:

- Soil fertility.
- Intra- and inter-species diversity.
- System productivity.
- Human welfare.
- Livestock performance.
- Ecosystem carrying capacity of target (and selected non-target) species.
- NARS capacity and commitment.
- Management options implemented by users.
- Available databases.
- Viable populations in a sustainable ecosystem over time.
- Reforestation.
- Restocked marine systems.
- Restored rangelands.
- Degree of inclusion of genetics into management recommendations.
- Survival in critical situations.
- Use of management practises for key species.
- Existence and effectiveness of community action groups, school or radio programmes, public meetings and relevant informational materials such as leaflets.
- How fully the research results are used in developing management options.

8. Conclusions

In a world with a rapidly growing human population, integrated natural resource management is clearly a necessary strategy for conserving biological diversity. A high level of biodiversity in both manipulated and natural ecosystems contributes significantly to human well-being. Healthy ecosystems depend on the vitality of their component species, and diversity ensures that both species and the overall system have flexibility and the ability to adapt. Genetic processes are essential to this adaptive capacity. Thus, they should be regarded as natural resources in and of themselves, and must be integrated into any conceptual basis for natural resource management. Managing genetic resources in an integrated manner, in their natural resources context, requires an ecosystems approach — that is, a holistic and systems-oriented approach.

The CGIAR has identified integrated management of ecosystems and genetic resources as an important issue for the system to pursue. This will require intersectoral approaches and inter-centre cooperation. The CGIAR centres must assess the comparative advantages of themselves and their partner institutions and identify opportunities for enhanced cooperation on NRM and GRM issues.

In regard to biodiversity conservation and GRM, the CGIAR must shift from its traditional commodity-based focus (in which productivity is the main concern) toward a perspective that recognises the combined commodity and service functions of biodiversity. Finding ways of achieving balance between conservation and sustainable use is critical and merits particular attention. The CGIAR needs urgently to devise a strategy that will move the system in that direction. Such a strategy should incorporate understanding of ecosystem functions and components down to the physiological and molecular levels for both genetic and natural resources. Besides practical experience, policy research is needed to address critical issues related to the interface of GRM, NRM and INRM. Of particular relevance are macroeconomic and both sectoral and cross-sectoral policies, which have the potential to either promote or hinder conservation and use of genetic resources.

The focus of the CGIAR centres' current research on GRM and NRM ranges from natural to intensively managed systems involving many commodities and sectors (water/aquatics, crops, trees/forests and livestock). Therefore, the CGIAR already has a strong comparative advantage for conducting research on genetic resources management in the context of INRM in production systems. While a movement toward *in situ* and ecosystem-based management practices (conservation and use) of genetic resources should be promoted, there is nonetheless a need for CGIAR centres to devise a more coherent agenda for research on genetic resources management, biodiversity conservation and the production of goods and services in the context of NRM and INRM. Doing this will require related work to better define the values of genetic resources and potential methodologies for assessing them. It will also be important to emphasise the implications that integrated approaches to genetic and resource management have for long term sustainability of ecosystems.

9. Issues Requiring Further Discussion

The workshop participants identified several issues and topics that were not addressed but are seen as needing further discussion.

Mechanisms and strategies for programmes and inter-sector collaboration

- Develop mechanisms and strategies to promote GRM in INRM within and among the CGIAR centres and to identify opportunities for new or enhanced inter-sectoral INRM research.
- Devise a plan for collaboration at regional levels.
- Identify NRM programmes and projects within which to promote GRM, and determine specific areas in which the CGIAR can expand its involvement.
- Form a follow-up action group to monitor and guide developments.
- Identify proposed task forces to develop integrated projects for key ecosystems.
- Identify agents of change within the CGIAR and how to increase their understanding of and support for these issues and directions.
- Determine strategies for encouraging support of 'new' holistic views of resource management among colleagues to develop institutional strength.
- Identify opportunities for inter-center collaboration on policy research vis-a-vis GR within regions.
- Identify opportunities for inter-center collaboration on on–farm conservation of genetic resources within different ecoregions.
- Establish a working group to review implications of shifting toward more integrated GRM (in terms of issues such as impact assessment, transaction costs, collaboration and site selection).
- Develop a common research agenda for the CGIAR centres and identify priority areas for both research and funding (including inter-centre programmes).
- Modify the CGIAR centres' mandates.
- Articulate strategic objectives for the CGIAR system.
- Elaborate issues of systems research and scale (complexity).

Partnership issues

- Determine what issues partners could lead and how the CGIAR could contribute.
- Develop partnerships with a greater number of organisations (e.g., FAO, NGOs).

Concrete examples

- Review examples presented at the workshop as part of efforts to enhance policy and valuation research.
- Document examples of INRM (including GRM) as reference material.
- Elaborate GRM-NRM relationships more explicitly in the context of case studies (e.g., plants, animals, trees).
- Develop a cross-institute CGIAR project to showcase the benefits of GRM/INRM.
- Address priority issues for discrete genetic resource management challenges in relation to NRM (forest, fish, livestock, crop).
- Help farmers broaden the 'basket of crops', especially cash crops, for income they need to purchase inputs and exploit the genetic potential of domesticated GRM.
- Emphasise the comprehensive nature of INRM that encompasses within-species genetic diversity, species diversity, ecosystem resilience and adaptability of genetic resources.
- Propose policy recommendations to encourage more rapid integration of GRM and NRM.
- Determine impact pathways for policy research.
- Identify possible areas for further action.

Annex 1. Overview of the Workshop Programme

Annex 2. Ecosystem Approach
Decision V/6 of the Conference of the Parties to the Convention on Biological Diversity

1. Endorses the description of the ecosystem approach and operational guidance contained in sections A and C of the annex to the present decision, recommends the application of the principles contained in section B of the annex, as reflecting the present level of common understanding, and encourages further conceptual elaboration, and practical verification.

2. Calls upon Parties, other Governments, and international organizations to apply, as appropriate, the ecosystem approach, giving consideration to the principles and guidance contained in the annex to the present decision, and to develop practical expressions of the approach for national policies and legislation and for appropriate implementation activities, with adaptation to local, national, and, as appropriate, regional conditions, in particular in the context of activities developed within the thematic areas of the Convention.

3. Invites Parties, other Governments and relevant bodies to identify case-studies and implement pilot projects, and to organize, as appropriate, regional, national and local workshops, and consultations aiming to enhance awareness, share experiences, including through the clearing-house mechanism, and strengthen regional, national and local capacities on the ecosystem approach.

4. Requests the Executive Secretary to collect, analyse and compare the case-studies referred to in paragraph 3 above, and prepare a synthesis of case-studies and lessons learned for presentation to the Subsidiary Body on Scientific, Technical and Technological Advice prior to the seventh meeting of the Conference of the Parties.

5. Requests the Subsidiary Body on Scientific, Technical and Technological Advice, at a meeting prior to the seventh meeting of the Conference of the Parties, to review the principles and guidelines of the ecosystem approach, to prepare guidelines for its implementation, on the basis of case-studies and lessons learned, and to review the incorporation of the ecosystem approach into various programmes of work of the Convention.

6. Recognizes the need for support for capacity-building to implement the ecosystem approach, and invites Parties, Governments and relevant organizations to provide technical and financial support for this purpose.

7. Encourages Parties and Governments to promote regional cooperation, for example through the establishment of joint declarations or memoranda of understanding in applying the ecosystem approach across national borders.

A. Description of the ecosystem approach

1. The ecosystem approach is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way. Thus, the application of the ecosystem approach will help to reach a balance of the three objectives of the Convention: conservation; sustainable use; and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources.

2. An ecosystem approach is based on the application of appropriate scientific methodologies focused on levels of biological organization, which encompass the essential structure, processes, functions and interactions among organisms and their environment. It recognizes that humans, with their cultural diversity, are an integral component of many ecosystems.

3. This focus on structure, processes, functions and interactions is consistent with the definition of "ecosystem" provided in Article 2 of the Convention on Biological Diversity: "Ecosystem means a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit." This definition does not specify any particular spatial unit or scale, in contrast to the Convention definition of "habitat". Thus, the term "ecosystem" does not, necessarily, correspond to the terms "biome" or "ecological zone", but can refer to any functioning unit at any scale. Indeed, the scale of analysis and action should be determined by the problem being addressed. It could, for example, be a grain of soil, a pond, a forest, a biome or the entire biosphere.

4. The ecosystem approach requires adaptive management to deal with the complex and dynamic nature of ecosystems and the absence of complete knowledge or understanding of their functioning. Ecosystem processes are often non-linear, and the outcome of such processes often shows time-lags. The result is discontinuities, leading to surprise and uncertainty. Management must be adaptive in order to be able to respond to such uncertainties and contain elements of "learning-by-doing" or research feedback. Measures may need to be taken even when some cause-and-effect relationships are not yet fully established scientifically.

5. The ecosystem approach does not preclude other management and conservation approaches, such as biosphere reserves, protected areas, and single-species conservation programmes, as well as other approaches carried out under existing national policy and legislative frameworks, but could, rather, integrate all these approaches and other methodologies to deal with complex situations. There is no single way to implement the ecosystem approach, as it depends on local, provincial, national, regional or global conditions. Indeed, there are many ways in

which ecosystem approaches may be used as the framework for delivering the objectives of the Convention in practice.

B. Principles of the ecosystem approach

6. The following 12 principles are complementary and interlinked:

Principle 1: The objectives of management of land, water and living resources are a matter of societal choice.

Rationale: Different sectors of society view ecosystems in terms of their own economic, cultural and societal needs. Indigenous peoples and other local communities living on the land are important stakeholders and their rights and interests should be recognized. Both cultural and biological diversity are central components of the ecosystem approach, and management should take this into account. Societal choices should be expressed as clearly as possible. Ecosystems should be managed for their intrinsic values and for the tangible or intangible benefits for humans, in a fair and equitable way.

Principle 2: Management should be decentralized to the lowest appropriate level.

Rationale: Decentralized systems may lead to greater efficiency, effectiveness and equity. Management should involve all stakeholders and balance local interests with the wider public interest. The closer management is to the ecosystem, the greater the responsibility, ownership, accountability, participation, and use of local knowledge.

Principle 3: Ecosystem managers should consider the effects (actual or potential) of their activities on adjacent and other ecosystems.

Rationale: Management interventions in ecosystems often have unknown or unpredictable effects on other ecosystems; therefore, possible impacts need careful consideration and analysis. This may require new arrangements or ways of organization for institutions involved in decision-making to make, if necessary, appropriate compromises.

Principle 4: Recognizing potential gains from management, there is usually a need to understand and manage the ecosystem in an economic context. Any such ecosystem-management programme should:

(a) Reduce those market distortions that adversely affect biological diversity;
(b) Align incentives to promote biodiversity conservation and sustainable use;
(c) Internalize costs and benefits in the given ecosystem to the extent feasible.

Rationale: The greatest threat to biological diversity lies in its replacement by alternative systems of land use. This often arises through market distortions, which undervalue natural systems and populations and provide perverse incentives and subsidies to favour the conversion of land to less diverse systems. Often those who benefit from conservation do not pay the costs associated with conservation and, similarly, those who generate environmental costs (e.g. pollution) escape responsibility. Alignment of incentives allows those who control the resource to benefit and ensures that those who generate environmental costs will pay.

Principle 5: Conservation of ecosystem structure and functioning, in order to maintain ecosystem services, should be a priority target of the ecosystem approach.

Rationale: Ecosystem functioning and resilience depends on a dynamic relationship within species, among species and between species and their abiotic environment, as well as the physical and chemical interactions within the environment. The conservation and, where appropriate, restoration of these interactions and processes is of greater significance for the long-term maintenance of biological diversity than simply protection of species.

Principle 6: Ecosystems must be managed within the limits of their functioning.

Rationale: In considering the likelihood or ease of attaining the management objectives, attention should be given to the environmental conditions that limit natural productivity, ecosystem structure, functioning and diversity. The limits to ecosystem functioning may be affected to different degrees by temporary, unpredictable or artificially maintained conditions and, accordingly, management should be appropriately cautious.

Principle 7: The ecosystem approach should be undertaken at the appropriate spatial and temporal scales.

Rationale: The approach should be bounded by spatial and temporal scales that are appropriate to the objectives. Boundaries for management will be defined operationally by users, managers, scientists and indigenous and local peoples. Connectivity between areas should be promoted where necessary. The ecosystem approach is based upon the hierarchical nature of biological diversity characterized by the interaction and integration of genes, species and ecosystems.

Principle 8: Recognizing the varying temporal scales and lag-effects that characterize ecosystem processes, objectives for ecosystem management should be set for the long term. Rationale: Ecosystem processes are characterized by varying temporal scales and lag-effects. This inherently conflicts with the tendency of humans to favour short-term gains and immediate benefits over future ones.

Principle 9: Management must recognize that change is inevitable.

Rationale: Ecosystems change, including species composition and population abundance. Hence, management should adapt to the changes. Apart from their inherent dynamics of change, ecosystems are beset by a complex of uncertainties and potential "surprises" in the human, biological and environmental realms. Traditional disturbance regimes may be important for ecosystem structure and functioning, and may need to be maintained or restored. The ecosystem approach must utilize adaptive management in order to anticipate and cater for such changes and events and should be cautious in making any decision that may foreclose options, but, at the same time, consider mitigating actions to cope with long-term changes such as climate change

Principle 10: The ecosystem approach should seek the appropriate balance between, and integration of, conservation and use of biological diversity.

Rationale: Biological diversity is critical both for its intrinsic value and because of the key role it plays in providing the ecosystem and other services upon which we all ultimately depend. There has been a tendency in the past to manage components of biological diversity either as protected or non-protected. There is a need for a shift to more flexible situations, where conservation and use are seen in context and the full range of measures is applied in a continuum from strictly protected to human-made ecosystems.

Principle 11: The ecosystem approach should consider all forms of relevant information, including scientific and indigenous and local knowledge, innovations and practices.

Rationale: Information from all sources is critical to arriving at effective ecosystem management strategies. A much better knowledge of ecosystem functions and the impact of human use is desirable. All relevant information from any concerned area should be shared with all stakeholders and actors, taking into account, inter alia, any decision to be taken under Article 8(j) of the Convention on Biological Diversity. Assumptions behind proposed management decisions should be made explicit and checked against available knowledge and views of stakeholders.

Principle 12: The ecosystem approach should involve all relevant sectors of society and scientific disciplines. Rationale: Most problems of biological-diversity management are complex, with many interactions, side-effects and implications, and therefore should involve the necessary expertise and stakeholders at the local, national, regional and international level, as appropriate.

C. Operational guidance for application of the ecosystem approach

7. In applying the 12 principles of the ecosystem approach, the following five points are proposed as operational guidance.

1. Focus on the functional relationships and processes within ecosystems

8. The many components of biodiversity control the stores and flows of energy, water and nutrients within ecosystems, and provide resistance to major perturbations. A much better knowledge of ecosystem functions and structure, and the roles of the components of biological diversity in ecosystems, is required, especially to understand: (i) ecosystem resilience and the effects of biodiversity loss (species and genetic levels) and habitat fragmentation; (ii) underlying causes of biodiversity loss; and (iii) determinants of local biological diversity in management decisions. Functional biodiversity in ecosystems provides many goods and services of economic and social importance. While there is a need to accelerate efforts to gain new knowledge about functional biodiversity, ecosystem management has to be carried out even in the absence of such knowledge. The ecosystem approach can facilitate practical management by ecosystem managers (whether local communities or national policy makers).

2. Enhance benefit-sharing

9. Benefits that flow from the array of functions provided by biological diversity at the ecosystem level provide the basis of human environmental security and sustainability. The ecosystem approach seeks that the benefits derived from these functions are maintained or restored. In particular, these functions should benefit the stakeholders responsible for their production and management. This requires, inter alia: capacity-building, especially at the level of local communities managing biological diversity in ecosystems; the proper valuation of ecosystem goods and services; the removal of perverse incentives that devalue ecosystem goods and services; and, consistent with the provisions of the Convention on Biological Diversity, where appropriate, their replacement with local incentives for good management practices.

3. Use adaptive management practices

10. Ecosystem processes and functions are complex and variable. Their level of uncertainty is increased by the interaction with social constructs, which need to be better understood. Therefore, ecosystem management must involve a learning process, which helps to adapt methodologies and practices to the ways in which these systems are being managed and monitored. Implementation programmes should be designed to adjust to the unexpected, rather than to act on the basis of a belief in certainties. Ecosystem management needs to recognize the diversity of social and cultural factors affecting natural-resource use. Similarly, there is a need for flexibility in policy-making and implementation. Long-term, inflexible decisions are likely to be inadequate or even destructive. Ecosystem management should be envisaged as a long-term experiment that builds on its results as it progresses. This "learning-by-doing" will also serve as an important source of information to gain knowledge of how best to monitor the results of management and evaluate whether established goals are being attained. In this respect, it would be desirable to establish or strengthen capacities of Parties for monitoring.

4. Carry out management actions at the scale appropriate for the issue being addressed, with decentralization to lowest level, as appropriate

11. As noted in section A above, an ecosystem is a functioning unit that can operate at any scale, depending upon the problem or issue being addressed. This understanding should define the appropriate level for management decisions and actions. Often, this approach will imply decentralization to the level of local communities. Effective decentralization requires proper empowerment, which implies that the stakeholder both has the opportunity to assume responsibility and the capacity to carry out the appropriate action, and needs to be supported by enabling policy and legislative frameworks. Where common property resources are involved, the most appropriate scale for management decisions and actions would necessarily be large enough to encompass the effects of practices by all the relevant stakeholders. Appropriate institutions would be required for such decision-making and, where necessary, for conflict resolution. Some problems and issues may require action at still higher levels, through, for example, transboundary cooperation, or even cooperation at global levels.

5. Ensure intersectoral cooperation

12. As the primary framework of action to be taken under the Convention, the ecosystem approach should be fully taken into account in developing and reviewing national biodiversity strategies and action plans. There is also a need to integrate the ecosystem approach into agriculture, fisheries, forestry and other production systems that have an effect on biodiversity. Management of natural

resources, according to the ecosystem approach, calls for increased intersectoral communication and cooperation at a range of levels (government ministries, management agencies, etc.). This might be promoted through, for example, the formation of inter-ministerial bodies within the Government or the creation of networks for sharing information and experience.

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ISBN 979 8764 63 3