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CONCEPTUAL FRAMEWORKS AND CASE-BASED KNOWLEDGE MANAGEMENT FOR THE ECOSYSTEM APPROACH

Report submitted by the Food and Agriculture Organization of the United Nations

Note by the Executive Secretary

1. At the request of the Food and Agriculture Organization of the United Nations, the Executive Secretary is circulating herewith, for the information of participants in the ninth meeting of the Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA), a document entitled "Conceptual frameworks and case-based knowledge management for the ecosystem approach", prepared by the Food and Agriculture Organization of the United Nations.

2. The document is being circulated in the language and the form in which it was received by the Secretariat of the Convention on Biological Diversity.

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Conceptual Frameworks and Case-based Knowledge Management For the Ecosystem Approach

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INTRODUCTION

The ecosystem concept provides the primary framework for analyzing and acting on the linkages between people and their environment. The Convention on Biological Diversity's (CBD) ecosystem approach is the framework for action, and the Millennium Ecosystem Assessment (MA) provides an assessment structure that can contribute to its implementation. While discussion within the CBD has revolved around its principles and guidelines, recently the MA has taken the lead in designing approaches "to meet the needs of decision-makers for scientific information on the links between ecosystem change and human well-being" ((MA) 2003). Consequently, we attempt to follow the MA's terminology and direction. *We do not continue with the "12 Principles implementation" debate* (e.g., UNEP/CBD/EM-EA July 2003), because from our perspective the CBD principles are effective as an evolving form. We are able to move on from this debate by recognizing that the 12 principles of the ecosystem approach are confined to one of three conceptual frameworks that we will describe. We also believe the MA (2003) has successfully re-articulated the principles and has begun providing operational guidance. To avoid the confusion of multiple acronyms we will use GBCI (global biodiversity-related conventions and initiatives) as an umbrella term for organizations that adhere to the principles and approaches of the CBD and MA.

In this paper, we bring attention to how knowledge is structured and is made available to participants or stakeholders. First we give our own perspective on conceptual frameworks, next we make a plea for integrating information into a federated knowledge management system. We propose case-based reasoning to be the core of this system, because it is one of the most effective means of structuring information and communicating across disciplines and societal sectors. Our example case studies are based on the MA's drivers-of-change framework, demonstrating that valuable insights can be derived from a generalized schema using a wide range of information. We encourage the GBCI, and especially the CBD, to consider developing a case-based knowledge management system for the enormous kinds and amounts of data generated now and in the future. We believe a case-based system could form the hub or "central switchboard" within the CBD's ambitious Clearing-House Mechanism.

The GBCI are committed to a normative shift—an unequivocal ethical stance that is Copernican in the way it reconfigures the historic relationship between humans, nature, and society. Human well-being, poverty reduction, conservation and sustainable use become the central focus for ecosystem science and management. Ecosystem residents are recognized as the decision-makers of primary importance; the ultimate stewards and stakeholders. Consequently, access to appropriate and usable information, for all sectors of society, becomes imperative. This ecosystem approach is bold because the GBCI go beyond noble

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and familiar platitudes by expanding upon the means to achieve their ends. Recurrent and central goals run through the GBCI literature and they can be grouped within these themes:

- Improve interdisciplinary and intersectoral approaches and collaboration
- Increase the use of all knowledge—scientific, practical, local, and traditional
- Appraise reliability of knowledge, particularly uncertainty and irreversible change
- Structure information for sharing, communication, and access by all participants
- Use integrative constructs such as indicators, drivers of change, and metadata
- Evaluate the impacts of decisions as they unfold (adaptive management)
- Achieve the lowest appropriate levels of management.

In the process of achieving these goals, the global community will create diverse kinds of information and enormous amounts of data. To understand how to manage this information we must first recognize that information is gathered, structured, interpreted, and therefore "owned" by many different knowledge (or epistemic) communities. Much of this data acquisition and analysis will take place in the communities, either by the stakeholders or with their active participation. The last 15 years has seen the emergence of a multitude of community-based, participatory education and training efforts, which focus on improved livelihoods through sustainable ecosystem management. When done well, these efforts help uncover local knowledge systems; thus bringing new information to light in the global community. These programs also have the challenge of helping local communities to access global information resources, in a form that is intellectually accessible and appropriate to the needs expressed by the community members. At national, regional and global levels, therefore, decision-makers face the Herculean task of coping with vast amounts of data, information and experience, of many different kinds and qualities, and in a manner that will allow it to be readily identified, interpreted and transformed into useable knowledge by participants and stakeholders.

The "conceptual framework" of the first MA report (2003) describes the approach and assumptions that will underlie analysis conducted in the MA. We begin by partitioning this overarching framework into three overlapping frameworks for illuminating the central role of stakeholders and how we collectively make knowledge available for learning and discourse. We believe our conceptual divisions emerge as the most salient features of the GBCI perspectives, particularly the ecosystem approach.

CONCEPTUAL FRAMEWORKS

We characterize three conceptual frameworks—normative, mechanistic, and operational—that guide and direct the acquisition and documentation of information and experience, as well as the actions taken based upon that knowledge. Here we take the risk of oversimplifying the complex and stating what might seem obvious. Our purpose is simply to highlight *where* this knowledge eventually must reside—in a knowledge management system—if it is to be eventually accessible and usable by global stakeholders. In this way, we are responding to the GBCI's *normative* radical shift, by recognizing that the implications and outcomes necessitate an *epistemological* reconfiguration. This epistemological shift is far more fundamental than "just" bringing down disciplinary barriers or interpreting specialized models for professional policy makers. The end result can be stated most simply in this way: *knowledge can take many relevant forms, but at least one of those must be useable by, and thus ultimately communicable to, participants of all cultures.*

Normative Framework

Normative implies what should be or ought to be, and the CBD has established principles and guidelines that attempt to be global and so attempt to be universal for most cultures. The stress is on universal human rights and intergenerational equity. The MA elaborates this further by underscoring how the constituents of "human well-being" are "freedoms and choice", which are determined by human security, livelihood, health, and social relations. The GBCI agree that ecosystem services must be equitably shared and maintained by conservation and sustainable use. Whether we label these aspirations and ideals as principles, guidelines, or goals is of little consequence. What matters is that we recognize any normative framework as evaluative rather than descriptive in the following senses:

- Regulative (ideals, norms, and standards)
- Preferential (values)
- Prescriptive (obligations)

The Normative framework is inherently ethical as opposed to epistemic (knowledge) or practical (operational). To be sure, freely choosing citizens make value judgments daily, and any human organization is value-laden to some degree. However, we are referring to it as a concept that embraces culture, religion, humanism, and public policy.

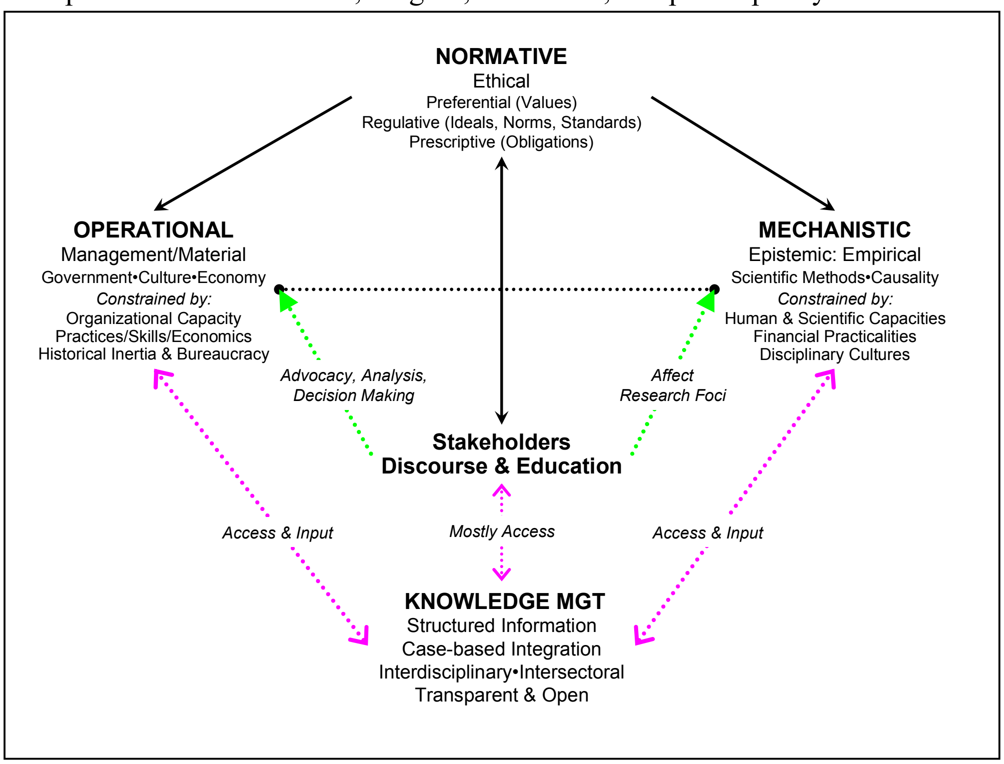

Figure 1. Three conceptual frameworks (Normative, Mechanistic, Operational) are represented in relation to Stakeholders (participants and drivers of policy change) and a proposed Knowledge Management System (KMS). Black arrows depict influence or guidance. Green arrows depict "information to and feedback from" the KMS. Pink arrows depict the influence, direct and indirect, that Stakeholders have on Operational and Mechanistic processes and enterprises. The dotted black line symbolizes the varying alliances and overlaps between Operational and Mechanistic members.

Mechanistic Framework

The Mechanistic framework represents the cluster of epistemic communities (disciplines) for which the key identifiers are empiricism, scientific method, experimental design, models, causal theory, and technology. This framework is often identified with the physical and life sciences, but it includes many of the social sciences. These disciplines have their own internal value-laden cultures, but share a common undertaking as a whole. We agree with Herbert Simon (Simon 2000) at his tersest:

> At the outset, I will accept, without discussion or debate, the view commonly held by scientists and philosophers alike that the goal of science is to discover real-world phenomena by observation and experiment, to describe them, and then to provide explanations (i.e., theories) of these phenomena. It does not matter which comes first—phenomena or the explanation. As a matter of historical fact, phenomena most often precede explanation in the early phases of a science, whereas explanations often lead to predictions, verified by experiment or observation, in the later phases.

The ecosystem concept and typologies emerged from the Mechanistic framework, along with all the data and models that underpin our belief in the reliable knowledge of "accounts and assessments" (MA 2003; however, we will use "assessments and indicators"). Theory, synthesis, and speculation form the frontier that is currently characterized by terms such as informatics, network science, ecological stoichiometry, reconciliation ecology, and panarchy.

Knowledge production within this framework is constrained by our human and scientific capacities, such as:

- Limitations of techniques and methods
- Physical limitations
- Funding and other practicalities
- Disciplinary cultures that impede collaboration

Operational Framework

Operational refers to all practices and skills applied to management, particularly how human organizations implement policy and deploy resources. Organizations range from local to global and may be institutions, governing bodies, societal sectors, or cultures. We most often say that institutions make policy and their agencies implement it. In doing so, the Operational framework produces data and knowledge, frequently in collaboration with Mechanistic counterparts who provide methods and technology.

The key identifiers of this framework are synonymous with how an organization's effectiveness is constrained: legal, regulatory, political, socioeconomic, and corporate/commercial. Consequently, Operational actions strive to be the most feasible under all restraints, such as financial, organizational capacity, and conflicting societal demands. Inertia is a feature of organizations that refers to their ability to change (e.g., policy), due to their structure or history. For example, high-inertia constitutions purposefully protect a state against rapid change while high-inertia bureaucracies preserve a status quo, inadvertently and sometimes pathologically.

Stakeholders – Participatory Learning, Discourse, and Advocacy

At the heart of these frameworks are the global citizens who occupy ecosystems, the participants who make choices and advocate change. Frequently they are the residents of, and therefore lowest-level managers of, ecosystems. The Normative shift towards an ecosystem approach has cast stakeholders as the center and purpose of the frameworks. In the policy process, they may form temporary or permanent groups—communities that share similar knowledge, beliefs, and concerns. A concern or issue becomes identified as a problem through learning and discourse. A problem may evolve into a perceived crisis, thereby increasing the cohesion among stakeholders in identifying themselves as advocates. Academic communities, boundary organizations, and government agencies may join in advocacy or even become proxies for stakeholder interests. Thus begins the policy process with stakeholders driving and participating in decision-making. The question we ask is, "How can participants best educate themselves on issues and where can they consistently find reliable and understandable knowledge?" This topic of systematic and useable information is discussed below in the section titled "Knowledge Management".

Framework Relations

We begin with an oversimplified analogy: If the Normative framework expresses our ethical nature and the Mechanistic represents our rational constructions of nature, then the Operational captures our ability to manipulate energy, resources and labor. The Normative guides the "means and ends," generally referring to freedom of choice and human rights, while specifically guiding the Mechanistic in "What is worth knowing?" and the Operational in "How do we conduct ourselves in implementing effective decisions?" Figure 1 depicts the relations among the three conceptual frameworks, the stakeholders, and a proposed knowledge management system.

In distinguishing these three frameworks, we are not implying a rigid division of interests and activities, particularly among the epistemic communities that comprise the Mechanistic and Operational frameworks. For example, traditional Operational agencies that managed resources typically worked in alliances with Mechanistic academic disciplines. Agencies involved in conservation and development still tend to fall out along lines reflected by the three frameworks, but each involves or participates in the others. For example:

a. **International Conventions**, such as the CBD, IPRI, CCD, etc., are engaged heavily in developing the Normative framework, while seeking to understand and guide the Mechanistic and Operational frameworks.
b. **Academic institutions, including international research organizations (e.g., CGIAR)** are engaged in scientific inquiry (Mechanistic), and in exploring and translating the Normative (e.g., policy studies). Yet, increasingly driven by concern and frustration with the state of affairs in the world, they often look to be engaged as Operational actors.
c. **National governments and development agencies** tend to focus on implementation (Operational). The policy process is strongly influenced by the Normative, with guidance and collaboration from Mechanistic members. Frequently, members can be categorized as both Mechanistic and Operational.
d. **UN special agencies**, such as FAO, have historically been heavily involved in both Operational and Normative roles, with a lesser emphasis on direct, Mechanistic work.
e. **Non-Governmental Organizations (NGOs)** are well known for merging the three frameworks because so many NGOs are "boundary" or "parallel" organizations. There is, however, great variation; for example, some NGOs specialize in advocacy and others in scientific research.

KNOWLEDGE MANAGEMENT

The CBD and MA express an emphatic commitment: only *informed* participants make wise choices, drive decision making effectively, and eventually become whole-hearted participants in ecosystem stewardship. With this emphasis, the focal interest becomes getting usable knowledge to stakeholders and inclusion of a Knowledge Management System (KMS) as the structure for information.

We hesitate to predict how much information science and technology will revolutionize learning and discourse for the GBCI ecosystem approach and global assessments (during the last century, television was predicted to revolutionize education). However, many world leaders are insisting on a breakthrough. For example, in a recent *Science* editorial Lubchenco and Iwata (Lubchenco and Iwata 2003) quote Kofi Annan's challenge to the world's scientists: "Recent advances in information technology, genetics, and biotechnology hold extraordinary prospects for individual well-being and that of humankind as a whole." Again quoting Koki Annan, Lubchenco and Iwata state the real challenge he puts to the scientific community is this: "[Y]our advocacy can help bring about a breakthrough in access to scientific knowledge . . ." The authors assert this challenge is one to which the international science community needs to respond forcefully and thereby demonstrate that scientists are indeed an indispensable partner of the United Nations. The World Summit on the Information Society (WSIS), in conjunction with the International Council for Science (ICSU), provides an unprecedented opportunity for the scientific community to promote the importance of open access to scientific knowledge. Scientists must work together to eliminate, not widen, the "digital divide": the division between rich and poor, North and South. It is crucial that the scientific community continue to promote the societal benefit of widely shared scientific knowledge by championing universal and equitable access to it (Lubchenco and Iwata 2003).

Knowledge Management Systems

An idealized future will have a continuously evolving structure for knowledge, accessible to all and understandable by any participant or stakeholder group. This KMS will be a highly structured information and learning system for the GBCI enterprise (see Box 1). All manner of constraints exist for our idealized KMS. Realistically it cannot contain all appropriate data, even if available, because much of it is owned and proprietary. Additionally, most data is useless until it is interpreted and transformed into information by its collectors, and this interpretation involves disciplinary differences in technical languages, histories of concepts, purposes and, as well, cultural differences. Operational constraints will translate into differences in quality and comprehensiveness of information. Altogether, such information will take a great many forms. However, if the GBCI goals are adopted in the future, then a major task and service of all disciplines will be the distillation and rendering of information into a communicable form—not just for other disciplines, but also for stakeholders and policy makers from all sectors. The forms of information will be diverse by nature and there are many cultural "ways of knowing". Therefore, the input and access will be shaped by several key forms of human reasoning and learning, which we describe in the next section.

Currently we are faced with legions of variously connected databases, archives, and other repositories of information. Some are actually portals whose purpose is to consolidate and point to myriad information types, including KMSs. Some portals are global in purpose but specialized in type of content. For example, GBCI members collate interpretative documents aimed at stakeholders and members of the Operational and Mechanistic frameworks. Organizations, such as WRI, also make available intermediate data for mapping and analysis. Some government agencies, such as Agriculture and Census in the U.S., are outstanding national examples of database systems exhibiting thorough access and openness.

BOX 1. Basics of Knowledge Management Systems and Administration

Knowledge management caters to the critical issues of organizational adaptation, survival, and competence in face of increasingly discontinuous environmental change. A Knowledge Management System (KMS) captures information *plus* experience so that it is easily accessible; it embodies organizational processes that seek synergistic combination of data and information, and the creative and innovative capacity of humans. Because KMS references all kinds of knowledge from all parts of an organization, it is frequently identified with technological terms such as 'hypermedia', 'portal', and 'warehouse'.

We use KMS generically to mean either a single database management system or a distributed (or networked) system, but one designed for the primary purpose of *decision support* by diverse stakeholders. Typically, a portal points to or loosely integrates diverse types of independent systems, and therefore does not constitute a KMS by our definition, although a portal is an evolutionary step in integrating unstructured and structured data conjoined with a search engine.

A KMS is a form of database management system, which is a computer-based system used to define, create, and maintain automated data. It is far more than data records organized into a set of files. A layer of software is constructed between the files and the application programs that provides a uniform conceptual view of the data, independent of the underlying physical structures and file organization, and that mediates between the conceptual access requests of the program and the file access methods. Such a layer of software and the files it manages is a database that has two principal components. First, the *data* stored in it, organized logically in terms of an appropriate conceptual data model, and physically in terms of storage and access techniques. Second, the *metadata* defines the logical organization of the data, and maps it to the physical structure. What distinguishes a database from mere files is the stored metadata (database catalog), the data dictionary (database schema), along with the software that uses the metadata to provide high-level data manipulation. A database management system is the software that manages both the metadata and the data under the rules of an appropriate data model and complimentary storage and access techniques. The user accesses databases through a simplified, nonprocedural query language.

The success or failure of a database management system depends on database administration. The database administrator must have a unified, logical view of the organization's data. This logical data model is the "glue" that holds the database together. The model includes the "user's view" of that data, that is, the ways in which different groups of users view and manipulate data that is of interest to them. The objectives of database technology are: data independence, ability to share data, non-redundancy of data stored, ability to inter-relate data, integrity and accuracy, access flexibility, security, performance and efficiency, and control (auditability and consistency). The building and maintenance of data dictionaries, database catalogues and directories, is crucial to a system. There must be an administrative unit responsible for meeting these objectives and accountable for database policies and practices. The database administrator is a key functional construct—not necessarily a single person. It is paramount that data veracity and relations must be agreed upon by managerial and technical database administrators; there can be no contention as to the authenticity of a jointly used and widely distributed system.

For reviews and basics of KMS, see Maier (2002), Liao (2003), Floridi (2003), and begin with this website: kmnetwork.com. For distributed database systems see Ozsu and Valduriez (1999) and Date (2003). For Case-based Reasoning (CBR), see Leake (1996), Watson (1997), Gilboa and Schmeidler (2001), and begin with these: ai-cbr.org, cbr-web.org, aaai.org/AITopics, aic.nrl.navy.mil/~aha/research/case-based-reasoning.html.

In our increasingly networked world, the aggregation of portals and databases resembles a very diffuse, distributed knowledge management system. A typical end user sees chaos in this complexity, whereas the objective of a KMS is to make complex data and relations transparent to the end user (see Box 1). At the international level, the CBD fully recognizes its unique position for developing and administering a unified KMS. It has already begun this arduous task by establishing its Clearing-House Mechanism. While a good start, the current document delivery system is fundamentally different from a KMS.

Ways of Knowing

Widespread and equitable access to a KMS should be possible by structuring, summarizing, and communicating information in a knowledge-based approach such that the widest diversity of end users will find one form or another intelligible and usable. Scientists are natural data experts and collaborators, and if there is one 'sector' that is interdisciplinary and collaborative by nature, it is the pool of enormous talent in the field of information science and management, which spans the cognitive and computer sciences among others. The expertise exists and efforts are widespread and growing in knowledge-based decision support: integrated systems can simultaneously reference data, interpretive summaries, rule-based models, narratives, and case studies. *These different forms of information correspond to different kinds of human reasoning and understanding.* Indeed, much of human cognition is based on heuristics and case-based reasoning rather than rule-based.

Heuristics

The simplest heuristics are intelligent guesswork or rules-of-thumb gained by experience that provides a provisional strategy for decision-making under uncertainty. Gigerenzer and colleagues (Gigerenzer and Selten 2001, Gigerenzer 2002) have described our heuristic repertoire as an "adaptive toolbox". The premise is that people make decisions under constraints of limited time, knowledge, and computational capacities. Heuristics can be fast, frugal, and computationally cheap (rather than consistent, coherent, and general) because they are adapted to particular environments and ecological constraints. That is, they exploit the structure of information in natural environments. These heuristics consist of three building blocks: simple rules for guiding search, for stopping search, and for decision-making. The use of heuristics is sometimes efficient in that they facilitate judgments without tremendous information-processing costs. It has been argued that the primary utility of models is heuristic.

Heuristics are widely used in education, mathematics, operations research, computer science, artificial intelligence, and engineering. Koen (Koen 2003) champions their universal use, since, according to him, to be human is to be an "engineer": "the engineering method is the strategy for causing the best change in a poorly understood situation within the available resources." Although simplicity leads to robustness, some judgmental heuristics can lead to inefficient or suboptimal outcomes that people would reject if confronted with a detailed analysis utilizing statistical arguments. Gigerenzer cautions us that when judgmental heuristics lead to suboptimal outcomes, they are termed biases. Therefore, it is because of their universal appeal and their pitfalls that heuristics should be addressed case-by-case in any KMS. We highlight the difficulties involved in counteracting false heuristics with the tropical rice case study in a subsequent section.

Case-based Reasoning

Of the knowledge-based approaches to decision support, case-based reasoning (CBR) has emerged as one of the most promising approaches for complex data rich domains. Case-based reasoning is often used where experts find it hard to articulate their thought processes when solving problems or when confronted with ill-structured problems, poorly understood models, uncertainty, ambiguity, and missing data. CBR is widely used in medicine, law, business, economics, sociology, public administration, and the political and policy sciences.

In the ecological sciences, the philosophy of case studies has been discussed for explanation, problem solving, planning, and decision-making (Shrader-Frechette and McCoy 1993, 1994, Sagoff 2003). Bosch et al. (Bosch et al. 2003) advance case studies as the basis for sustainable land use, adaptive management, and learning. CBR systems have been developed for supporting rangeland management decisions (Hastings et al. 1996, Bosch et al. 1997, Hastings et al. 2002), wastewater management (Verdenius and Broeze 1999), land development control (Wang 2002), and estuarine model matching (Passone et al. 2002). We know of no CBR approaches to information from multiple ecosystems.

In essence, instead of relying solely on general knowledge of a problem domain, or making associations along generalized relationships between problem descriptors and conclusions, *CBR is able to utilize the specific knowledge of previously experienced, concrete problem situations (cases)*. A new problem is solved by finding a similar past case, and reusing it in the new problem situation. A crucial aspect is that successful new cases, but also important failures are added to the case-base. CBR systems rely on the knowledge contained in multiple knowledge containers, including the case-base, case adaptation knowledge, and similarity criteria. Cases can be decomposed into those features that are important for similarity matching. A case-base is incrementally built with cases (or episodes), but can be initially seeded with the richest cases (prototypes, exemplars, or precedents).

As a natural byproduct of problem solving, CBR also is an approach to incremental, sustained learning, since a new experience is retained each time a problem has been solved, making it immediately available for future problems. CBR favors learning since it is usually easier to learn by retaining a concrete problem solving experience than to generalize from it. People are adept at adapting a contextually rich, concrete experience from the past. A case-based reasoner becomes more competent over time, can avoid previously made mistakes, and can focus on the most important parts of a problem first (e.g., heuristic probing). Still, effective learning in CBR requires a well worked out set of methods in order to extract relevant knowledge from the experience, integrate a case into an existing knowledge structure, and index the case for later matching with similar cases. We will give one example of a basis for similarity matching among cases—the MA's drivers of change framework, which provides a uniform and systematic set of categories, and a flexible set of components.

CBR allows the case-base to be developed incrementally, while maintenance of the case-base is carried out by domain experts. Incremental building of cases is essential when they involve adaptive management, which regularly elicits results from "learning by doing" among stakeholders. In addition, when possible, the backlog of ecosystem case knowledge can be gradually converted into cases of appropriate detail.

Nickles (Nickles 1998, 2000, 2003) reinterprets Thomas Kuhn's account of problem solving as a theory of case-based and model-based reasoning in normal science. In doing so, Nickles gives an eloquent and concise summary of CBR advantages, particularly compared to rule-based and expert systems. Fundamental is that knowledge of concrete cases is more easily elicited from experts, taught, and learned (e.g., sets of problems in textbooks are precisely repositories of such cases). In addition, CBR:

- Readily accepts new cases and corrections from experts or "outside authorities" when new cases conflict with old
- Is closer to how human beings go about solving problems, especially solving novel problems, and developing innovative practices
- Provides a surrogate for logic of discovery
- Helps bridge the gap between "knowledge-that" and "knowledge-how"
- Does not necessarily require linguistic ability on the part of the agent
- Is more useful in theoretically "weak" domains, including the frontiers of research

It is important to note that CBR does not replace other knowledge systems. CBR systems can be generalized to include similar approaches (exemplar-, instance-, memory-, model-, and analogy-based) and it can be integrated with or draw from other systems and approaches: rule-based, expert, GIS, genetic algorithms, fuzzy logic, data mining, and scenario planning. In addition, CBR is flexible enough to incorporate information such as heuristic devices, narratives, and diverse forms of local and indigenous knowledge that the MA has highlighted as too frequently overlooked.

DECISION MAKING

We contend the most promising knowledge-based approach would be based on a CBR system. How would this KMS fit in with our conceptual frameworks and the key elements of the previously described CBD-MA approach? It can best be illustrated in conjunction with the MA's capstone figure, which depicts the culminating role of information and participation in the decision-making cycle ((MA) 2003).

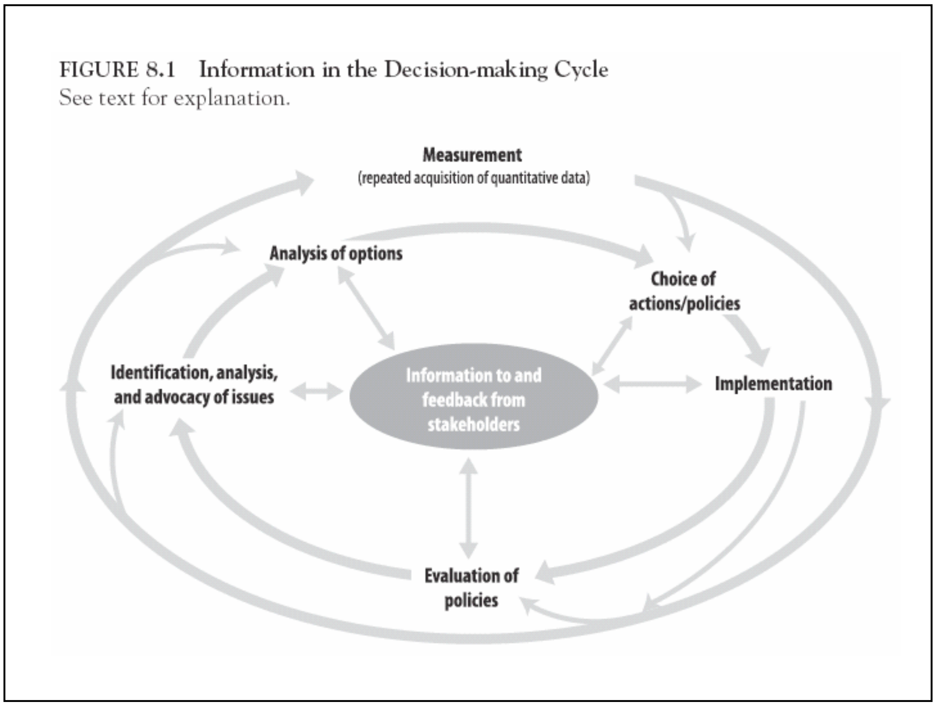

Figure 2. This synthetic figure is from the recent Millennium Ecosystem Assessment book (2003:188), online at wri.org. It portrays three interacting processes: monitoring (Measurement), the decision-making cycle, and the flow of information revolving around stakeholders.

We reproduce their Figure 8.1 here as our Figure 2. It portrays three interacting processes: monitoring (measurement), the decision-making cycle, and the flow of information to and from stakeholders. Policy making starts by identifying a problem, then it defines policy options and their choice, formulation, implementation, and ideally, it finishes with monitoring and evaluation of the results of executed actions. The process is interactive and iterative, takes place within a specific institutional structure, and engages all stakeholders. Measurement assembles information from regular monitoring (the outer cycle) and other sources. These sources are summarized as "assessments and indicators": assemblages of numerical data (accounts), spatial data, indicator variables, and sometimes issue-specific assessments. Policies are implemented through institutions. For simplicity, Figure 2 does not portray where information flows from and to, nor how stakeholders get information and how they give feedback. Although the MA does refer to "information providers", we will add the KMS for that foundational role of providing information.

In Figure 3, we have injected the KMS into the decision-making cycle by having unwrapped and straightened the concentric circles of Figure 2. The policy cycle is now simplified as a segmented process, starting with an issue (identification, etc.) and terminating in the ideal finish (a successful endpoint), else, the cycle will continue. We must be mindful that all policies are experiments, just as all measurement is best conducted as an experiment—in the spirit of adaptive management.

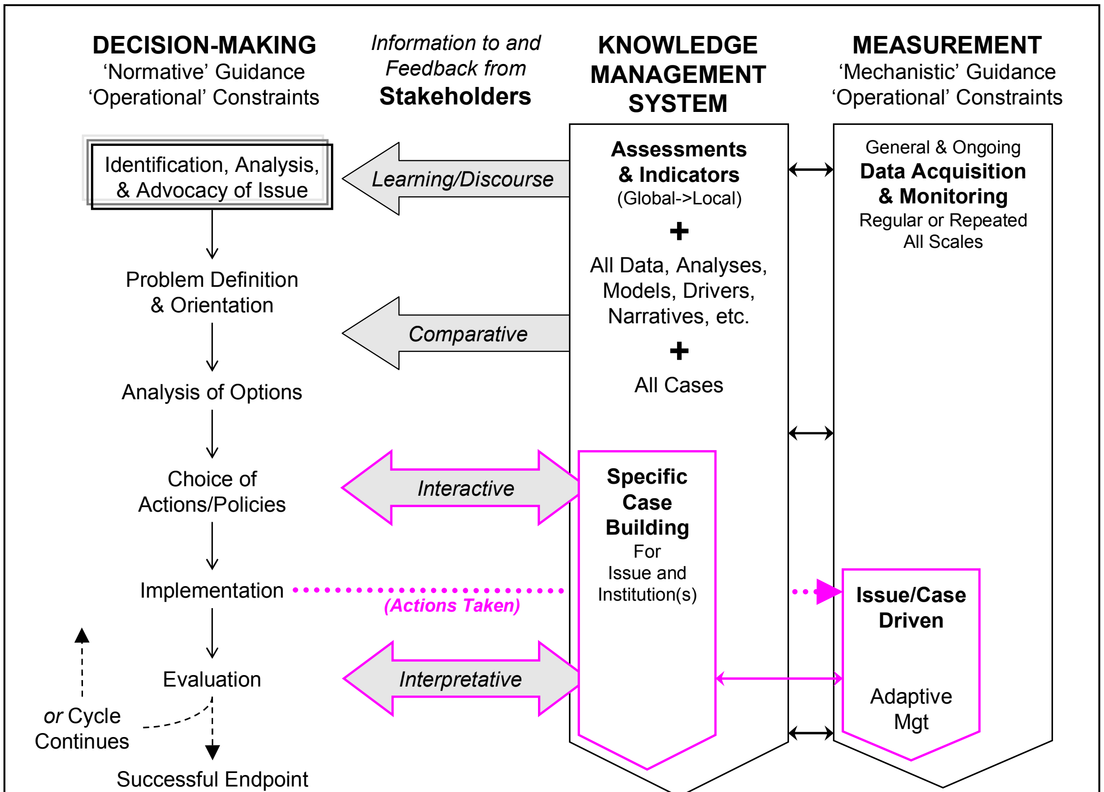

Figure 3. Another depiction of the decision-making cycle (Figure 2), incorporating the concept of a Knowledge Management System. No longer a cycle, but a sequence of events and actions, we can better illustrate how a case study can be central to the policy process, use and construction of agreed-upon knowledge, and directing measurement (monitoring) in the form of adaptive management. The colored portions highlight case specifics. Arrows represent flow of knowledge (input to and feedback from): block arrows are specific to stakeholders, but also policy professionals

With this arrangement we can better see how events unfold in time, particularly how a case is added to the KMS and built over time, and at each stage interacting with participants and improving measurement strategies. Although experimental designs from the Mechanistic framework may guide monitoring, the realization of a particular monitoring scheme will be determined by its Operational feasibility. General and ongoing measurements accumulate in the KMS, which serves as the major source of reliable knowledge agreed upon by participants. Of course, all knowledge is contentious, but at any given time, we have to cede the point of "best available information".

When continual learning and discourse among participants precipitates into a perceived problem or crisis, then participants become stakeholders in an issue. Thus begins the decision-making process. Stakeholders' orientation to the problem begins with problem definition, during which they would access the KMS for comparable cases and lessons, in-depth analysis of data, and analysis of policy options. Defining problems can be very difficult because boundary conditions may be unclear, symptoms vs. root causes unknown, cause-and-effect relationships clouded, consequences unclear, and real opportunities to make improvements uncertain. To some extent, the way a problem is defined is tantamount to prefiguring a solution. Problem definition must take place in policy-making arenas and organizational settings, which range from village meetings to global assemblies. In this context, problems are defined to guide future policy, as well as to make sense out of past actions. Because problem definition and redefinition usually challenge existing organizational myths, prevailing premises, and traditional problem frames, the process is highly political (Clark 2002).

At some point in the decision-making process case building will be initiated. This will surely take place by the time choices are being made for policies and actions, because at this time case knowledge is actually being created, and therefore must become available to stakeholders. Stakeholders, together with Operational professionals, will be building their case within the KMS in a coherent and accessible form for access by all. It does not have to be agreeable to all, because—by definition—the case should represent different options and scenarios. However, verified and consistent knowledge must be understandable and useable to all for productive interaction. Realistically, among stakeholders there will be those who are better at interpreting and communicating specialized knowledge.

The next stage is implementation of the chosen policy, which instigates action that has measurable effects. This would begin a case-driven strategy of monitoring, and ideally adaptive management (see next section). Intermediate results are added to the case history for discourse and interpretation by stakeholders and their Operational and Mechanistic collaborators. This evaluation stage in decision-making may be interpreted as successful (hence, end of process), or the process continues with adjustments or the issue is redefined.

ADAPTIVE MANAGEMENT

In the previous section, we illustrated the interaction between decision-making, the knowledge management system, and measurement, with stakeholders being the focal point of information flow and the drivers of the policy process. *Decision-making culminates in actions that require monitoring, which in turn produces case-based data for analyses and models*. Throughout this process, in the spirit of the Ecosystem Approach, is the dictum, "first do no harm". To this end, an adaptive design is one that considers foremost the role of uncertainty, while safeguarding against irreversible changes. 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.

In this section, we interpret the MA's drivers of change to consist of a unifying framework for the ecosystem approach—because it provides a consistent set of categories and elements that are the targets of intervention (policy actions). *The drivers of change framework is comprehensive in providing a uniform diagnostic chart of ecosystem pathology that views human actions as both the primary stressors and the potential releasers.* The drivers of change are derived and specified from theoretical or explanatory models in the Mechanistic sense, and the causality is interpreted and extended ultimately to human actions. This allows a single-purpose schema for organizing the categories: drivers, sources, stresses, effects, and responses (interventions). Each category contains comparable elements that are shorthand statements of system states, rates, or description. The framework is easy to communicate with a flow diagram and has a long lineage ((MA) 2003).

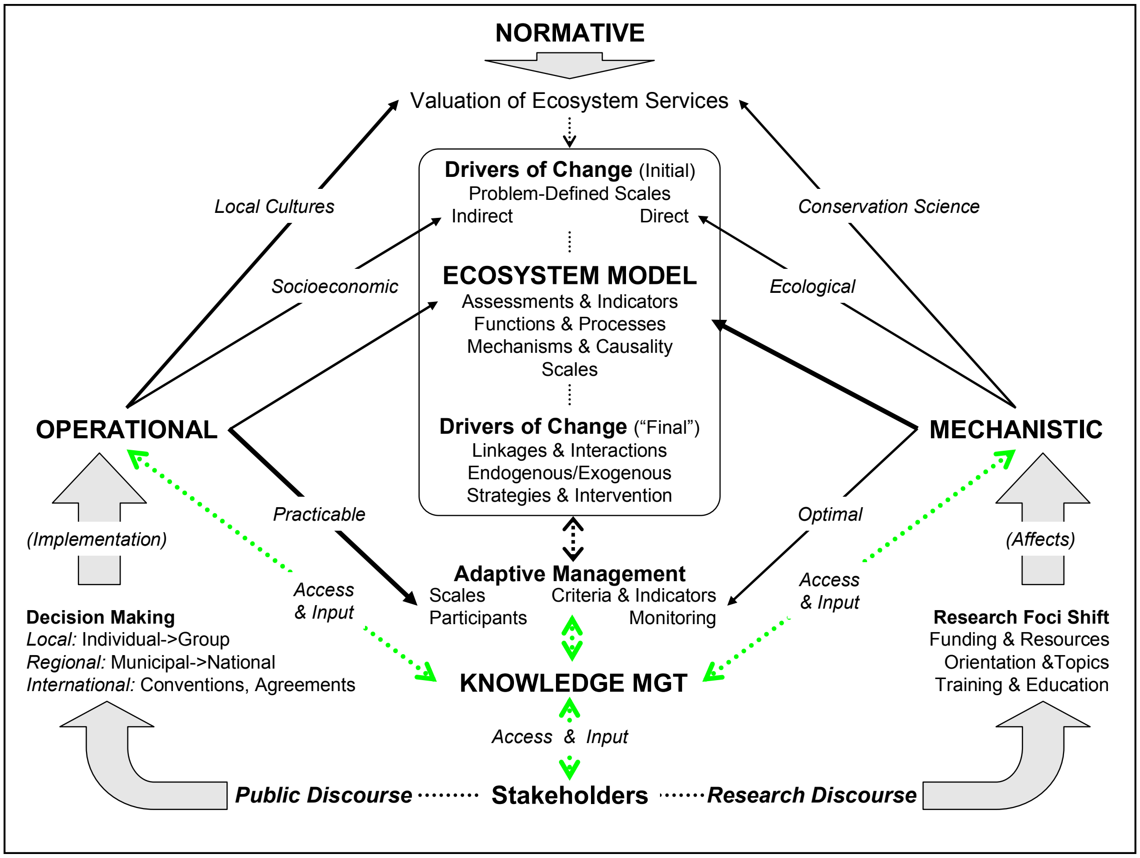

Figure 4. Here we combine the overall structure of Figure 1 with the case-building component of Figure 3. The central focus is the sequence of model development that leads to adaptive management, all of which enters the KMS, which in turn provides continuous access (green arrows). Black arrows depict typical interaction and strength of influences from the conceptual frameworks (Figure 1). Block arrows show other general influences, particularly of how stakeholders affect Operational and Mechanistic frameworks.

We portrayed, as part of Figure 3, how the ongoing results of adaptive management go into case building within the KMS. However, we take another view of this in Figure 4, allowing us to accentuate the different influences on ecosystem modeling of the Normative, Mechanistic, and Operational frameworks. We generalize the "ecosystem model" to be any state of knowledge, ranging from simple descriptive information to the most elaborate model. We strive for a strong, empirically based model, yet incomplete knowledge is the human condition and the basis for adaptive management. From the beginning, adaptive management allows actions to be taken that continuously inform model building and policy evaluation. The implications of the Normative framework for ecosystem modeling are clear: the most useful modeling approaches are relevant to or guided by a valuation of ecosystem services, which is influenced by local cultures and the state of conservation science (Figure 4). However, for any ecosystem model to be relevant, it must be transformed into useable knowledge for a wide range of participants in decision-making. Scientists can begin to accomplish this by translating and rendering the model into drivers of change.

For simplicity, we assume an ecosystem model is inspired by the perception of ecosystem pathology, perhaps from stakeholder advocacy. This motivates a preliminary identification and sketch of the drivers of change (Figure 4). Here begins the initial assessment of variable relations: generally, indirect drivers are more in the realm of Operational while direct drivers fall in the realm of Mechanistic. Most ecosystem modeling is empirical because estimating causal linkages requires scientific methods and experimental design. At some point, when the model is used for decision-making, model results must be translated into drivers of change by fully specifying linkages, interactions, and strategies of intervention. This begins adaptive management, which is guided by Mechanistic concepts (guidance on optimal design), but often conducted by Operational agents (the practicable or feasible design). *The KMS is continuously evolving and providing feedback to and from Mechanistic, Operational, and stakeholder participants.* Public stakeholders, through discourse and advocacy, influence the direction and topics of research (affecting the Mechanistic). At the same time, stakeholders are central to decision-making in conjunction with Operational members mostly, which is then implemented through agents of the Operational framework.

We have stressed the importance of CBR and how drivers of change provide a universal schema for comparing ecosystem cases. In the next section, we present example cases representing a range of ecosystem models, from rudimentary to sophisticated. We apply the drivers of change schema, decomposing each case into comparable elements and linkages. We represent each case with a flowchart that would facilitate communication among stakeholders.

DRIVERS OF CHANGE APPLIED TO CASE STUDIES

The purpose of this section is to illustrate how the MA's drivers of change offer a coherent framework for portraying the salient features of any ecosystem case study (described in the previous section). The categories we use are consistent (drivers, sources, stresses, effects, and responses), and each category's elements follow a common descriptive format, but each case is unique in its exact typology and linkages among elements. Our objective is not to present any case study in great detail, but to demonstrate how a relatively simple graphic can depict drivers of change based on virtually any ecosystem model, whether poorly or richly specified. The resulting flow diagrams, along with narrative details, rapidly and effectively communicate the key cause-and-effect relationships, and thus serve as a basis for discussions and planning with stakeholders. It also provides a starting point for constructing the case for a KMS, which allows comparison of multiple case studies.

The FAO-Netherlands Partnership Program (FNPP) Biodiversity Theme has, for the past two years, supported development of a number of case studies related to Biodiversity, and cutting across a range of FAO Departmental areas. These include Forest Ecosystem Services, Inland Aquatic Biodiversity, Animal Genetic Diversity, Plant Genetic Diversity, Soil Biodiversity, Integrated Pest Management (IPM), pollination ecology, and Globally Invasive Species. Here we present three of the many studies done under this Programme plus a case study on tropical rice, done prior to this programme. See the Appendix brief excerpts from each case study.

CASE-STUDY 1: SEED SYSTEMS AND EMERGENCY PROGRAMS

We start with a simple, yet elegant story related to "seed systems" that, from an Ecosystem Approach perspective, presents relatively few complexities. A "Drivers" framework suffices to capture the essentials of the story with only 10 elements.

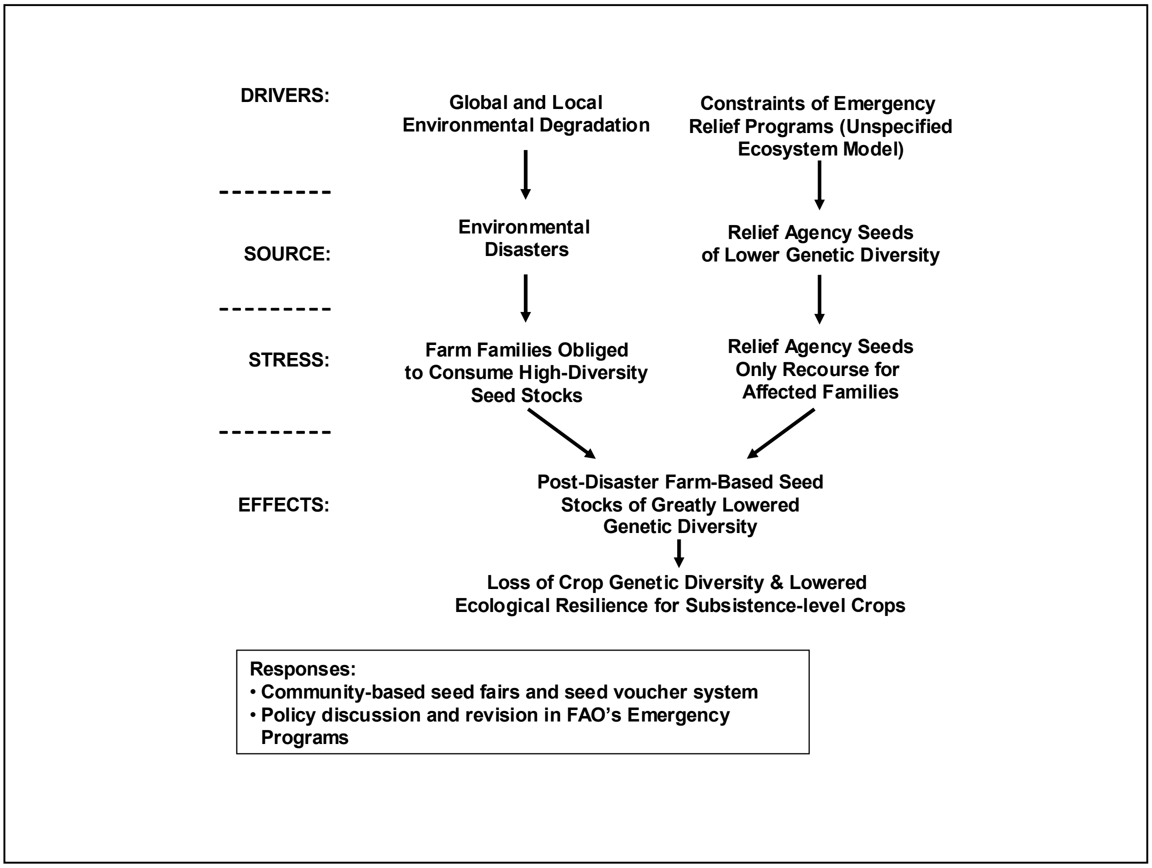

Figure 5. Drivers-of-Change framework: seed-systems, natural disasters and emergency relief agencies cae study

In Mozambique in February 2000 torrential rains, a cyclone and the sudden opening of flood gates of dams in South Africa led to massive flooding. Some 207,000 people were affected, having lost houses, part or all of their crops or having their economic activity disrupted. In some districts, 90% of planted areas were submerged in the flood. This disaster provoked massive relief efforts from the local and international communities, including seed relief.

During the year prior to the floods, the majority of women accessed seed entirely through the conservation of their own seed, while the remainder supplemented conservation with seed purchase or solidarity from friends or relatives, or relied solely on purchasing seed. Just after the floods the majority of these farmers now depended on relief agency seeds either entirely, or with some purchase from markets and solidarity with friends and family. Only 6% of farmers depended on conservation in any form. More than 10 relief agencies and NGOs participated in the effort to distribute seeds, and while there was some diversity in seeds among them, what they distributed tended to be quite homogeneous, leading to a loss of genetic diversity, particularly of the rarer alleles that tend to accumulate only over time.

In other words, resource poor farmers affected by the floods had lost their local genetic resources, had come to rely on less diverse seed stocks from relief agencies, and were then *subsequently recycling these same genetically-depauperate seed stocks*. Although crop genetic diversity has recovered to some extent in the flood affected areas, (most likely from solidarity within and among local communities) it appears that the impact of the flood on the diversity is still evident two and a half years later.

Strategies and Interventions

In response to this problem, the Catholic Relief Service and other NGOs, have suggested that in order to restore food and seed security after a disaster, it is important that diversity is restored in the agricultural system. They further suggest that a relief approach that builds on the traditional coping and recovery strategies of solidarity and purchase from markets will be more effective in restoring diversity than a system based only on 'seeds and tools' in which less diverse 'improved' varieties are distributed. In line with this they have tested a system in which disaster-affected farmers, in lieu of direct disbursement of imported relief seeds, are given 'seed vouchers' with enable purchase seeds of their own choice at regional seed fairs. Farmers from throughout the region come to these seed fairs, and therefore these fairs present a high diversity of locally adapted genetic material, appropriate to the larger geographic locale.

The Mozambique case study, along with a later study done in Ethiopia (FAO 2003) prompted policy reconsideration by FAO's Seed Service, Economic Development Division and Emergency Operations and Rehabilitation Division (TCEO). The Emergency Coordination Group (ECG), which oversees all of FAO's emergency operations, has endorsed a set of guiding principles (see Box 2) and begun making them operational. TCEO will work to pilot the Seed Fair and Voucher approach as an additional approach to improving emergency seed relief programs.

Basic guiding principles for seed relief

1. A needs assessment should underpin any decisions to undertake seed relief and guide the choice among possible interventions. This needs assessment should be holistic, putting seed security in the context of livelihood security.

2. Seed relief interventions have to be clearly matched to the context (for example, a crisis caused by drought may require very different actions from a crisis caused by war). By supporting food production, seed relief should decrease dependence on repeated food aid

3. Seed relief activities should aim to both:

-- be effective with the immediate objective of facilitating access to appropriate planting material and
-- contribute to the restoration, rehabilitation or improvement of agricultural systems in the longer term.

Ideally, considerations of seed system sustainability should be built into seed interventions from the beginning. As a minimum, seed aid should do no harm to farming systems. Thus emergency relief activities should support local seed system development, ideally by integrating long term needs in the design of the project.

4. Seed relief activities should be built upon a solid understanding of all the seed systems farmers use and the role they have in supporting livelihoods. The local system is usually more important in farmers' seed security and has shown to be quite resilient. Depending on the context, the focus in an emergency should normally be on keeping the local seed system operational. One practical problem is that seed systems are often not sufficiently understood, especially in emergency situations.). Hence there is a need for more emphasis on understanding seed systems, and their role in supporting livelihoods, and on needs assessment.

5. Seed relief interventions should facilitate choice by farmers of crops and varieties. Seed relief interventions should aim to improve, or at least maintain seed quality, and aim to facilitate access to varieties that are adapted to environmental conditions and farmers' needs.

6. Monitoring and evaluation should be built into all seed relief interventions, to facilitate learning by doing and thereby to improve interventions.

7. An information system should be put in place to improve institutional learning and as a repository of information gained from cumulative experience. Such information systems should be institutionalized at national levels, to the extent possible.

8 A strategy to move from the acute emergency response to a capacity building or development phase should be included in the design of the intervention.

Box 2:
Note how the guiding principles for seed relief reflect many of the principles outlined in the Primary Framework of the Ecosystem Approach—specifically: societal choice, decentralized management, the need to understand ecosystems in an economic context, conservation of ecosystem services, monitoring and learning-by-doing (adaptive management).

Brief Discussion of the Framework

The linkages of cause-and-effect in this case study are so straight forward that a graphical summary hardly adds to conceptual clarity.

However, it allows immediate comparisons and serves as a “template” for preparing this case study for indexing and entry into a future KMS. This case also offers us an opportunity to introduce the Drivers-of-change graphic in its most simple form. In our subsequent cases we will introduce progressively more complex graphics.

A “seed system” is essentially the economic and social mechanisms by which farmers’ demands for seeds and the various traits they provide are met by various sources of supply. The conservation of genetic variability in seed stocks held by subsistence-level farmers is a “good” to be conserved. This genetic variability helps farmers by providing options related to niche markets and environmental adaptability in space and time (increased system resilience).

The “drivers” in this case are, first off, global and local environmental degradation. Evidence is accumulating to suggest that global warming is likely to lead to more frequent and more violent climatic phenomena world-wide (floods and drought). Locally, changes in vegetation cover due to drought and deforestation lead to a lessened ability of watersheds to be able to absorb and buffer large rainfall events.

The second driver is institutional. Relief agencies, quite naturally, have focused on addressing the urgency of situations—if farmers have eaten their seed stocks the following season’s planting is at risk. Stress occurs in this system when environmental disasters cause farmers to consume, or otherwise lose their seed-stocks, and, the only recourse for them is to accept seeds of much lowered genetic diversity from relief agencies. The consequent effects are a long-term, post-disaster period in which on-farm, genetic diversity has been substantially lowered, with a reduction (non-quantifiable) in long-term resilience for the system.

In focusing on short-term needs, relief agencies have historically overlooked the long-term impacts their actions might be having on biological (crop genetic) diversity, and the consequent indirect effects their actions might have on system resilience. In short, by working with an unspecified ecosystem model, the agencies have been blind to the long-term effects of their actions.

The authors of this case study—within FAO’s economic division—are working on a more detailed (mechanistic) study of seed systems in the region. This study will include measurements of varietal and allelic distributions and flows, over space and time, along with socioeconomic “drivers” behind these patterns. FAO is currently collaborating with CIAT, ICRISAT, CRS and others to profile seed systems targeting the most vulnerable countries, and to evaluate different approaches to developing resilient seed systems. Clearly, some form of manifold analytical framework will need to be developed to enable cross-system comparisons.

CASE-STUDY 2: PALMYRA DESERT

The Palmyra Desert case study provides a look at a system exhibiting a downward trend in productivity and biodiversity. For the actual case study, see the contribution "From Mindfulness to Awareness" presented as additional materials by FAO for this CBD SBSTTA 9 meeting. In this and subsequent case studies, the story and text are sufficiently complex that a graphical analysis, provided by a "drivers-of-change" approach, serves new readers as a rapid and effective introduction to a case study.

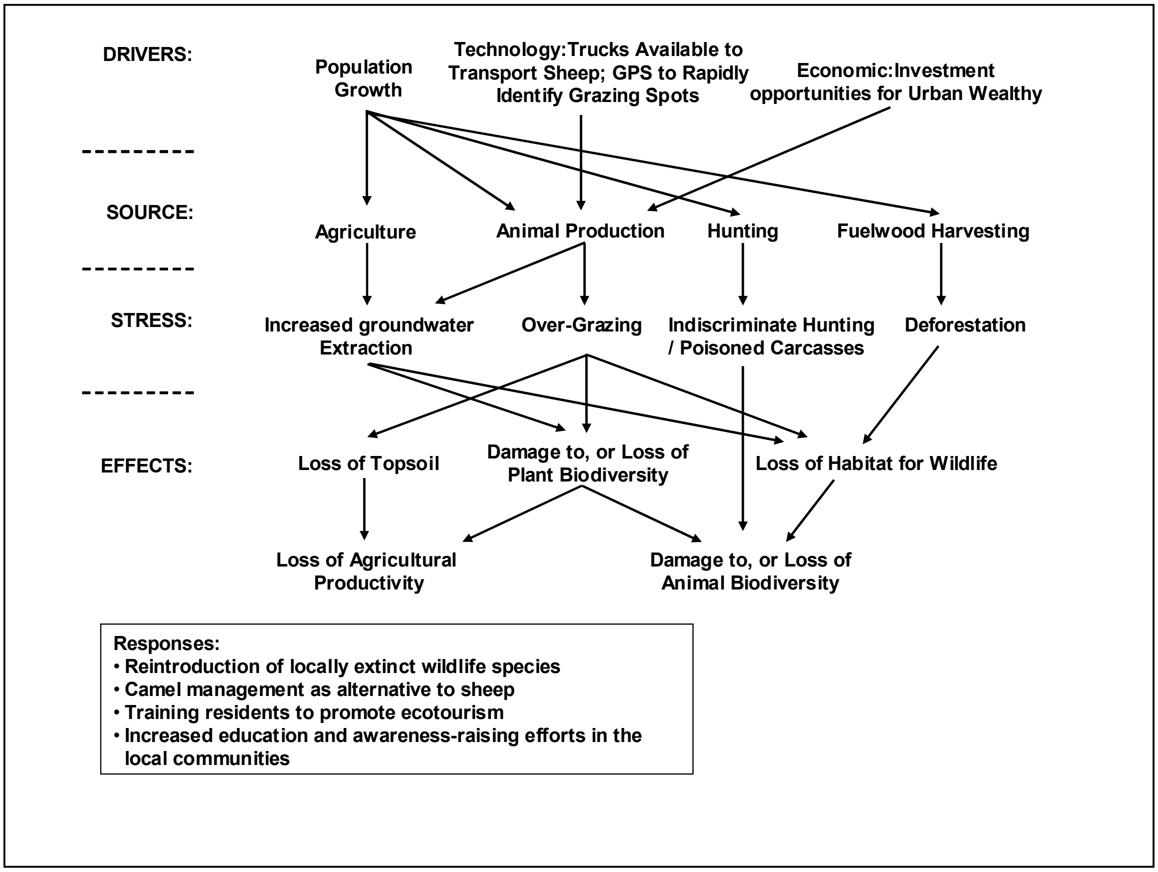

Figure 6. Drivers-of-Change framework: Palmyra Desert, Syria case study

Brief Discussion of the Framework

We infer from the case study that the key drivers of change in the ecosystem are population growth in the region, combined with the existence of a wealthy class of city-dwellers looking for investment opportunities in the region. This leads to increases in the number of sheep being grazed in the fragile desert system. Technological development is another driver, in the form of truck transport, advanced communications, and Global Positioning Systems (GPS). Such greatly increased modern capabilities allow well-financed sheep herders to rapidly identify locations having recently received rain, and to rapidly deploy large numbers of sheep to take advantage of the ephemeral grassland resources. Overall, these advancements have led to the desert system being subjected to far larger populations of sheep than ever before, and likely at levels above the long-term, sustainable carrying capacity for the system.

The human population driver leads to other sources of stress in the region, including irrigated agricultural in the oases, hunting, and fuel-wood harvesting. Together, these activities (sources) lead to specific environmental outcomes (stresses), including a lowering of the water table, overgrazing, indiscriminate hunting with poisoned carcasses, and deforestation. In turn and in a slightly more complex way, these stresses lead to a change in state for a number of environmental variables (effects), related to soil erosion, loss or damage in plant and animal biodiversity, and potential agricultural productivity—all of which are critically related to sustainable human and environmental well-being.

Strategies and Interventions

In 1996 an Italian funded and FAO implemented project began, entitled: "Range rehabilitation and establishment of a wildlife reserve in the Syrian Steppe". This project has as its aim to assist Syrian authorities with promoting conservation and sustainable use of biodiversity in their country, by developing the Al Talila Reserve and rehabilitating the rangelands that surround it.

Management objectives for the reserve include:

- **Reintroduction of locally extinct antelope species** (restoration), provides an important conservation example for other countries in the region, and helps shift the system towards an ecotourism footing.
- **Managed camel grazing** offers a more environmentally suitable alternative to sheep; hence, potentially relieving one of the principal sources of stress. By removing the above ground dry biomass during winter dormancy, camel grazing actually has a beneficial pruning effect on important shrub species. More than 1200 camels graze the reserve annually for a period of seven months with no negative impact on shrublands, even in drought years.
- **Surveying, inventorying and photo-documenting of habitats, flora and fauna**, and other conservation-related activities, provide valuable employment and at the same time creates a resource to be used in local education. For example, training local staff as eco-tourist guides helps to reinforce a shift in values.
- **Increased education and awareness-raising efforts,** related to local conservation issues

CASE-STUDY 3: MT KENYA FOREST ECOSYSTEM AND SURROUNDING FARMS

The Mt. Kenya case study provides a look at another system exhibiting a downward trend in productivity and biodiversity. Although this system is in an upland-tropical forest setting, with quite different climate, population, land-form and land-use characteristics, the drivers-of-change framework helps us see that it shares several key features with the Palmyra Desert case study.

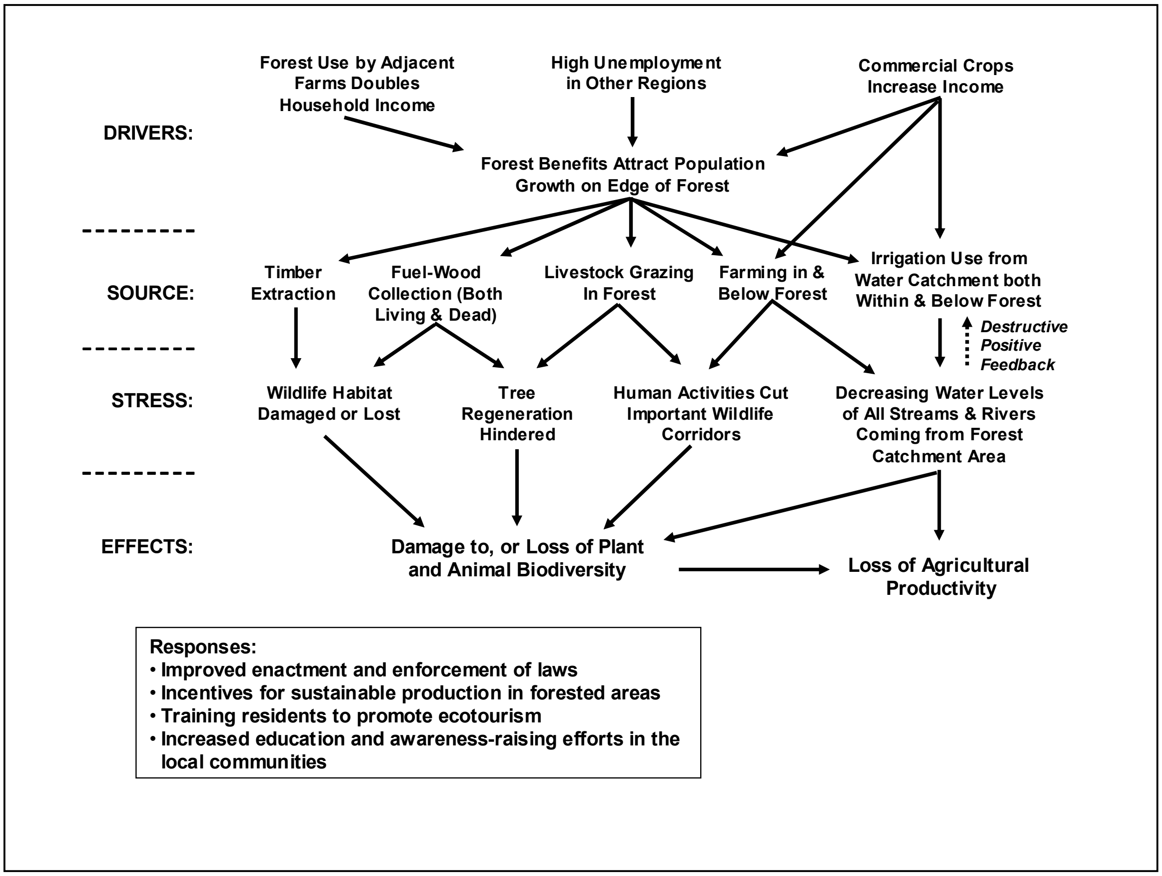

Figure 7. Drivers of change, Mt. Kenya case study

Brief Discussion of the Framework

In the Mt. Kenya case, the principal drivers are related to the access to rich and commonly held forest resources, which dramatically boost income and thereby drive substantial local population growth in the farming communities living on the edge of the forest. Household income is nearly double compared with farms further down the mountain (not adjacent to forest reserve), and population density on the edge of the forest reserve is six times that of areas further down the mountain slope. The easy access to the nationally-owned forest has led to a gradual and continued encroachment and degradation in the watershed. The sources of stress are related to activities affecting timber, fuel-wood, animal grazing, and water resources. Conflicts between humans and wildlife, and the cutting of wildlife corridors have led to substantial negative effects on wildlife. Livestock grazing, fuel-wood collection and farming within the forest reserve have negatively affected vegetative patterns. Competition among farmers for limited water sources for irrigation is measurably seen in decreasing water levels of all streams and rivers. The status and trend of key indicators—

including increasing areas of human encroachment, decreasing forest regeneration, and falling water levels in streams and rivers—all point to a downward trend in overall ecosystem health, that will ultimately affect plant and animal biodiversity and agricultural productivity.

Strategies and Interventions

The details of this case study reveal solutions sought by the Kenyan government are currently restricted to law enactment and law enforcement. Yet, experience in other systems in many parts of the world suggests that a strictly protectionist policy is unlikely to succeed, because the needs and livelihoods of the people living in these areas adjacent to the common resource will not be addressed. Responses suggested in the study are intended to promote important shifts in the social and economic drivers. In addition to improved law enforcement, these include community-based education, and new economic incentives, both of which will promote ecologically sustainable alternatives.

CROSS-SYSTEM COMPARISONS

By comparing drivers-of-change graphics for the Seed System (SS), Palmyra Desert (PD) and Mt. Kenya (MK) case studies, certain points stand out as worth mentioning:

1. The SS case is one in which existing farmer practices (saving, selecting and sharing seeds among extended family, friends, and community) *support* long-term system sustainability through maintaining or increasing genetic diversity. The threats to these systems are external, in the form of natural disasters coupled with an international response based on a previously unspecified ecosystem model. The described strategies and interventions seem on a path to success, and begin with a better-specified ecosystem model, to which national governments and the international community have responded by seeking more appropriate ways to support and maintain the traditional practices of farmers in the face of local and regional disasters.
2. In contrast, both MK and PD cases show socio-economic drivers in which the collective behaviour of local and nearby residents tends to work *against* the long-term environmental health of the system (seeking short-term benefits, but incurring long-term costs). In the long term, the impacts of forest and rangeland exploitation will have negative consequences for the resident stakeholders, due to degradation of ecosystem services. The threats to the system are internal and more difficult to address than in the SS case study. Proposed strategies and interventions include protection through legislation and enforcement. Both case studies suggest that these (external, protectionist) responses will not succeed alone. Also, the studies point to how efforts need to be made for providing economic alternatives (shifting the economic drivers), including ecotourism, as well as a general education for the population to encourage a better sense of long-term ecosystem services.
3. In the MK and PD frameworks, population growth and the promise of short-term economic gain are the important drivers. In both cases the beneficiaries of the system resources do not own the resources, and in most cases do not even reside directly on the land. In this way the two case studies present a profile we might describe as a classic “tragedy of the commons”. This type of ecosystem pathology is undoubtedly widespread across many system types, so an easily recognized label and diagnostic routine needs to be created for indexing in a future KMS.
4. In the MK and PD case studies, negative feedback from environmental degradation is the result of a series of indirect or diffuse economic and ecological pathways, “felt” only on the time course of years or decades; hence, there is usually little inherent

understanding and perception of the causal relationships by the resident actors. We suggest this phenomena (lack of feedback from actions taken on the system, on a time-course appreciable by ecosystem residents, or "delayed feedback") is another distinct ecosystem behaviour worthy of a label that could be used to characterize and index case studies within a KMS.

5. As a result of both points 3&4 combined ("tragedy of the commons" and "delayed feedback"), the *economic status* of the system participants is a poor indicator for the MK and PD systems (e.g., farmers on the edge of the forest have nearly double the household income of those further down the mountain). In essence, the human populations are experiencing economic growth that is *subsidized* by the longer-term cost of the health and sustainability of the systems. Better indicators would be ecological, easily measurable, and probably found at the "stress" and "effects" layers of the flowcharts. Again, an important system attribute is portrayed here, call it "ecological subsidies", and we need a useful index label (as we will see in the rice example below, however, not all "ecological subsidies" are "bad" for long-term human or ecosystem health and well-being).
6. In the MK system, one observation is that as resources continue to erode, competition for those resources—especially for water— is intensifying, leading farmers to attempt exploiting resources higher up into the watershed, employing long pipes, thus further undermining the capacity of the watershed to provide water. In this way a "destructive positive feedback loop" has emerged—a commonly found and important emergent behaviour of ecosystems. An analogous type of positive feedback loop does not clearly show up in the PD case, but it begs us to double-check if any such feedback loop exists, as they are important factors to consider in examining response scenarios.

CASE-STUDY 4: TROPICAL IRRIGATED RICE

This case study represents a more complicated drivers-of-change framework. The case study is based on work done by FAO's various regional Integrated Pest Management Projects, working for more than 15 years in tropical rice systems. It represents the process of ecosystem model building depicted in Figure 4. Data collection, model specification, and a participatory form of adaptive management were developed, in this case in response to an international crisis in crop protection. The crisis first drove the development of an adaptive management response through the joint effort of scientists, agency personnel, and farmers. Over the course of two decades an ecosystem model evolved, revealing *how* ecosystem services had been disrupted by several decades of "Green Revolution" management. In essence, the interactions of spatial processes with timing of events at different scales are what lead to counterintuitive linkages in the rice-system food web. Note that this case study is generalized across a "class" of ecosystem, and not location-specific.

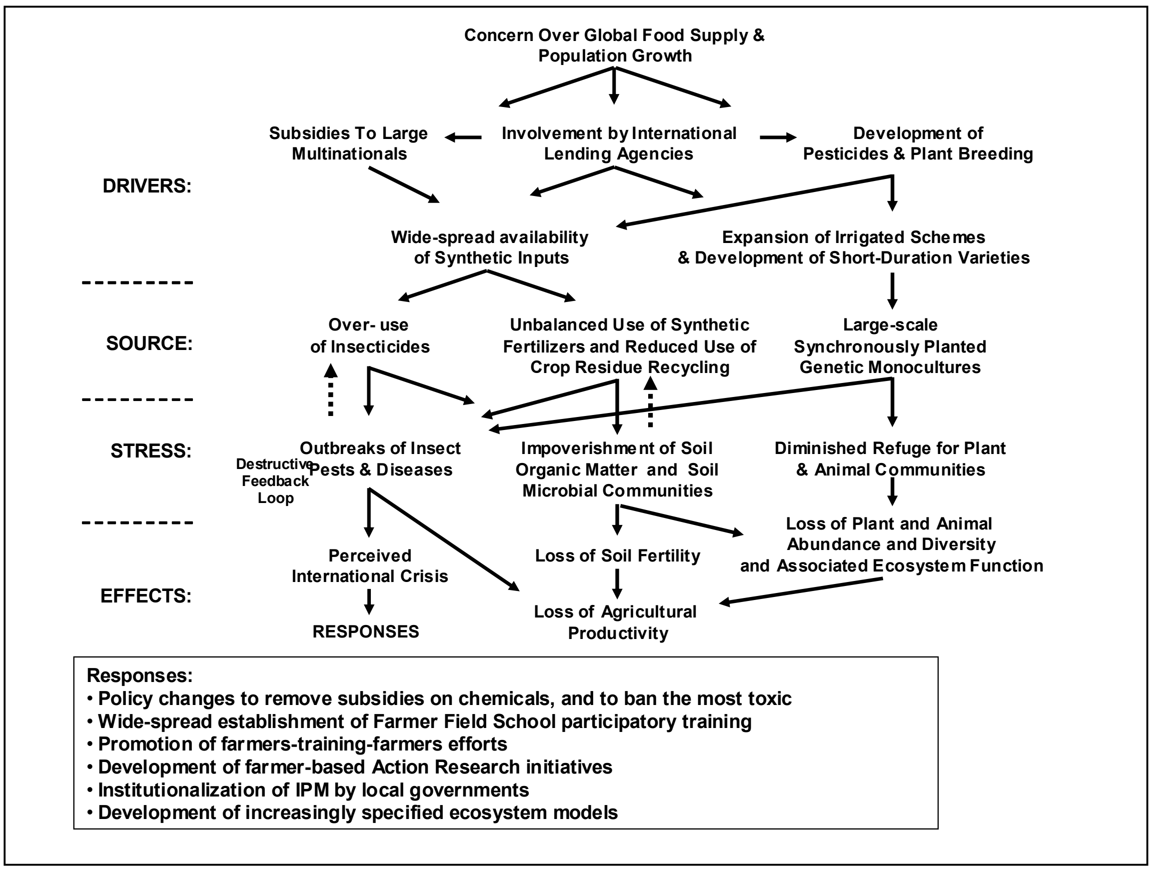

Figure 8. Drivers of change for irrigated tropical rice—Green Revolution era

Beginning in the late 1960s, (early "Green Revolution"), pesticides and synthetic fertilizers were aggressively introduced on a vast scale throughout much of Asia. The primary drivers included a growing concern for future food stocks in light of anticipated population growth. From about the end of WWII, technological drivers included the rapid growth in development of nerve toxins as insecticides. Economic drivers included involvement by international lending agencies (e.g., The World Bank) providing loans to governments for agricultural research, extension, and subsidies for large multi-national chemical firms. The subsidies were used to lower the cost of synthetic inputs to farmers.

From the 1960s through the 1980s, shifts by large numbers of farmers toward the use of synthetic fertilizers tended to be at the cost of recycling crop residues and other organic amendments, over many years, this exclusive dependence on synthetic fertilizers resulted in reduced soil fertility through nutrient mining, loss of soil biodiversity, increased nutrient leaching and volatilization, with concomitant negative local, regional and global consequences. A typical response by farmers, faced with a declining yield from diminished soil fertility, was to increase amounts of synthetic fertilizers used (a destructive positive feedback loop). This has led, in some areas, to detrimental nutrient loads in ground water, streams, rivers and larger bodies of water.

The most widely used insecticides have always tended to be highly toxic, broad-spectrum biocides harm the health of farmers and their families and have a disrupting effect on ecosystem function, in both agricultural and downstream natural systems. Massive and widespread pest outbreaks were generated by the extensive use of these synthetic pesticides, which suppressed the otherwise dominant levels of natural biological control. Due to the counter-intuitive nature of the problem, and a lack of understanding of the mechanisms (a realistic ecosystem model), governments, researchers, and farmers responded to the problem by *increasing* the use of pesticides (a destructive positive feedback loop). During the 1970s, this led to national crises in several Asian countries.

Historical Change of an Ecosystem Model

By the mid 1980s, this crisis in crop protection in tropical rice was motivating some researchers to take a closer look at the structure and function of tropical rice ecosystems. Early work, looking at existing biological control agents of key insect pests, suggested that these natural levels of biological control could potentially be sufficient to control pests, *without recourse to insecticides*.

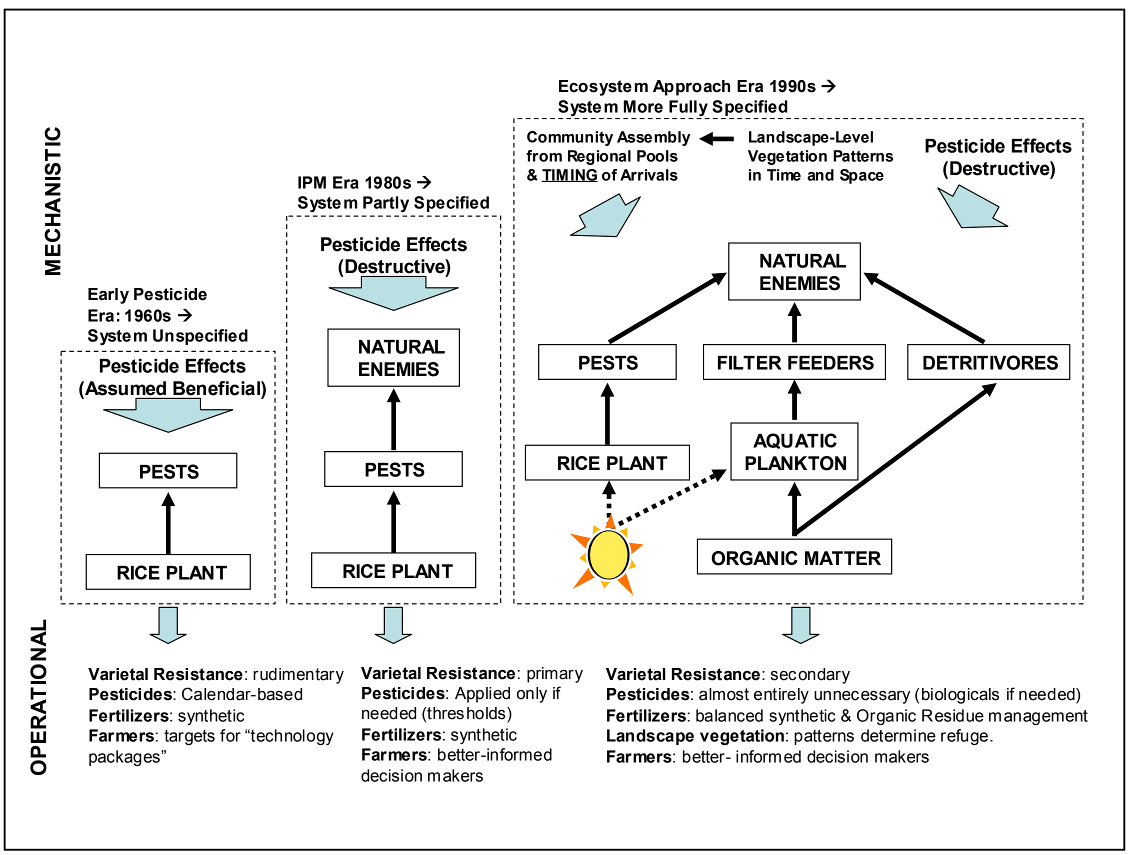

Figure 9. Evolution of *mechanistic*, tropical-irrigated-rice-ecosystem models over four decades, and the implications, or relationships to *operational* strategies (the tactics employed to control pests).

By the mid-1990s, the ecosystem model had become better elaborated (see far right of Figure 9), showing that tropical irrigated rice ecosystems are extraordinarily well suited to support abundant, diverse and well-distributed populations of predatory insects, due to the existence of abundant, alternative food sources coming up from the aquatic fraction of the ecosystem (detritus-eating and semi-aquatic filter-feeders) (Settle et al. 1996). These alternative food sources appear, with a high degree of certainty in any location, very early in the rice-growing cycle; and therefore "prepare" or boost the beneficial (predator) populations *well in advance* of the arrival of many pest organisms.

At the same time, additional factors were articulated that help to determine the strength of the "ecosystem service" of pest suppression. Landscape-level patterns in wetland vegetation were strongly implicated in determining two key elements in the assembly of rice-field communities— relative abundance and species composition (biodiversity), and the *timing of arrival* of arthropod populations to an area, in relation to the crop cycle. These concepts of landscape, metapopulation ecology, and community assembly play a key mechanistic role *with important operational consequences* (Ives and Settle 1997). All of these theoretical developments supported the idea that tropical irrigated rice was inherently a far more robust and pest-suppressive environment than had heretofore been considered—being possibly the most stable annual agroecosystem on the planet.

The mechanisms described above suggests how high levels of natural pest suppression can be brought about in tropical irrigated rice through the early season boosting of predator populations by abundant alternative prey, in turn linked to a highly productive aquatic foodweb. The authors suggest this mechanism can be called a 'general' mechanism (applicable to tropical irrigated rice on any continent), yet the success, or strength of this mechanism, in any locale, will depend on large-scale historical factors in the ecosystem—what we would term the "ecological context" of a locale. This will include landscape characteristics (topography and soil), vegetational and seasonal planting patterns, water availability, overall toxic load (pesticides) and weather.

In brief, experimental results and observations throughout the region, combined with new theoretical developments, suggest several operational conclusions (i.e., 'best practices') regarding these large-scale factors:

1. Organic matter amendments not only are essential for plant nutrition and soil health, *but substantially boost levels of generalist predators in the system*. This result has far-reaching consequences for all types of agricultural systems.
2. The lower elements of the foodweb are ubiquitous—that is, bacteria, aquatic plankton, and various filter-feeding species, can be found in any rice field in the tropics. In contrast, substantial variation can be seen in the upper-level elements of the foodweb (the natural enemies), which are correlated with large-scale, endogenous factors, related to temporal and spatial planting patterns and toxic loads.
3. Specifically relating to #2, large-scale synchronous planting (greater than 500 ha) and long dry fallow periods (greater than 2 months) are correlated with: a) substantial reductions in species richness of predators and parasitoids, and b) delays in the return arrival of predators and parasitoids into the system after the long fallow period, thereby missing the early-season peak in alternative prey, and allowing pest populations to more easily escape control.
4. Early-season applications of insecticides suppress natural enemy populations, causing insecticide-induced pest resurgence (the literature on this is overwhelming by now).

The upshot is this: a) tropical rice systems have a tremendous inherent capacity to exhibit strong, natural levels of pest suppression (exogenous phenomena—that is, out of direct control of humans); and b) that the management access points to agroecosystems (endogenous factors), which affect the ecosystem service of natural pest suppression, are at the plot-to-landscape level, and have to do with support or interference in the assembly of natural communities of organisms. Interference comes either through chemical disruption or unfavorably modified landscapes (vegetative and natural wetland) patterns in time and space.

Stakeholder Response to Changes in Ecosystem Models

Agricultural inputs in general and insecticides specifically, were introduced in the absence of a well-specified ecosystem model. Therefore, operational efforts in pest control have historically been initiated with only a rudimentary idea of the ecosystem-level impacts—the pragmatic philosophy necessarily being, 'one works with what one has at the time'. However, with development over time of more realistic ecosystem models we, as a global society, became better positioned to see the larger ecosystem-level implications of our past practices, and to better inform our operational efforts from an understanding of ecosystem structure and function (as well as from developments from the Normative domain). In practice, however, the response to this evolution in our mechanistic understanding of agro-ecological systems has been sluggish.

In an ideal world, stakeholders would be responsive to changes in ecosystem models. In the rice case, however, we see certain large-scale problems that create inertia to change within the larger system, and this inertia is probably found in most systems to a large degree. Rather than go into detail here, we provide a simple typology. The list is meant to be illustrative, not comprehensive or detailed:

Industry: High inertia

- No scientific contribution to ecosystem-level knowledge, or to an ecosystem approach
- Economic interests are threatened by the implications of a changing ecosystem model
- Continued promotion of old system models to stakeholders

Governments: Moderate inertia

- Some stuck in old system models
- Bureaucratic inertia
- Seeking operational simplicity despite mechanistic and normative influence

Research & Extension: Moderate inertia

- Some stuck in old systems models
- Some stuck in old models of communication
- Some stuck in old models of roles & responsibilities

Farmers: Highly variable inertia

- Good response in small-group level
- Counter-intuitive nature of problem related to complex (indirect) pathways of cause-and-effect
- Poor access to good training
- Vast numbers to be trained (logistics)

Strategies and Interventions

The best strategy for shifting away from old, counterproductive conceptual and operational models has proven to be a decentralized, participatory, community-based education and awareness-raising approach. This is conditional, depending on the prevalence of institutional inertia and the nature and size of the target audience.

The past 10-15 years have seen a concerted effort to change substantially the input-driven research and extension model. Specifically, approaches to participatory farmer education, which come under a bewildering array of names and styles, are increasingly seen as the tool of choice among non-governmental organizations (NGOs) as well as most of the larger development organizations.

The various FAO programmes for IPPM, based on participatory farmer training, began in Asia in the late 1980s with the creation of the Farmer Field School system. This farmer-training approach was based on principles and techniques derived from adult, non-formal education (NFE). The NFE is a "participatory" approach aimed at helping farmers develop a broad range of skills related to agronomy, entomology, and critical thinking based on observation, experimentation, and the construction of conceptual models. The objective is to put farmers in a position to make their own decisions based on an understanding of the ecological context and mechanisms underlying the functioning of their agroecosystems, plus a solid sense of externalities (costs to human and environmental health) associated with high-input farming. Farmer training follows essentially the same path of discovery learning as followed by a researcher, but begins with an examination and validation of local knowledge. By studying their fields, asking questions, making systematic observations, discussing with others and coming together to test possible solutions, the IPM farmers develop real and practical knowledge based on fundamental scientific methods that has been "interpreted" and transformed into a format that is accessible. IPM farmers have a saying: "the field is our book, go to the field to learn". This is far more than just a slogan, and represents an operational model that has proven highly successful.

DIVERSITY OF APPLICATIONS

A drivers-of-change framework allows us to distil a case study into a concise, two-dimensional graphic that portrays the key variables and interrelationships, and includes social, economic and ecological variables. This serves a useful function:

- **For the scientist**, the exercise forces the worker to define variables and hypothesize interrelationships (both direct and indirect). It also helps point to gaps in knowledge, and a questioning of underlying assumptions. The framework can be subsequently used to generate testable hypotheses (hence help to direct research). Therefore, from this early definition of a system model, researchers can derive direction and motivation to elaborate more specific mechanistic models.
- **For local stakeholders**, the exercise in developing a drivers-of-change graphic offers an excellent tool for collectively exploring the details of their circumstances, and provide clues on which types of indicators might be appropriate for monitoring. The graphical nature allows easier access for semi, or non-literate stakeholders.
- **For a project design team**, the exercise of developing such a graphic will also give valuable insights into what types of indicators will be appropriate for monitoring, and which drivers might be critical to address in a response framework. From an operational perspective, access to historical information from an established KMS

would allow rapid retrieval of cases that might provide examples (to be discussed with stakeholders) on how to proceed (or not to proceed) to best solve the problem.

- **For an author** developing a new case study, the development of a drivers-of-change graphic will give valuable guidance on the most prominent elements of the case study that need to be investigated and detailed.
- **For readers**, unfamiliar with the case study, the graphic serves to capture a quick overview of the system. Then, depending on the interest level of the reader, one can choose to examine more closely the text-based narrative for further details. Consider an analogy with a typical newspaper. A newspaper conforms to readers' heuristic probing providing, first, a bold-faced headline; then the first sentence and paragraph go further to capture the essence of the story in a few words. Interested readers can then pursue further details in the body of the article.
- **For policy makers**, such graphics facilitate rapid understanding of a single system, comparison among multiple system examples, and a platform for discussing proposed policy changes that will affect systems.
- **For analysts** looking at multiple systems, the graphic allows a quick "gestalt" of the system that greatly facilitates comparative (cross-system) analyses. Consider the large number of environmental case studies already developed and circulating; then consider the numbers still to come. The vast amount of text-based materials does not lend itself to rapid assimilation. A reader can become fatigued after reading only one or two case studies and trying to disentangle the essential relationships—how then do we proceed to a serious cross-system comparative analysis of many such case studies?
- **For designers** of a future KMS, such drivers-of-change frameworks will be important tools for determining variables and inter-relationships for indexing, retrieval and matching purposes. We need a system from which someone, seeking to do an initial inquiry on, say, a driver defined as *"systems in which investment opportunities by an urban wealthy class lead to degradation in natural, or protected systems"*, would be able to access a subset of such graphics as a type of information-laden "icon" for a group of case studies sharing the indexed value. This subset of graphics can then be rapidly surveyed for choosing case studies for more in-depth review. Clearly this has implications for how we choose indices for our environmental, case-based KMS—an eco-regional approach to indexing will be necessary, but not sufficient.

CONCLUSIONS

In this paper we have expanded on the CBD's Clearing-House Mechanism and the MA's drivers-of-change schema, combining them as the basis of a strongly case-based Knowledge Management System. The key purpose of this KMS is in decision support. Our rationale for a unified KMS is not motivated by new technology, but by the powerful role it can play in organizing and communicating diverse knowledge in new ways for a new audience of global participants. Ultimately, this societal rearrangement stemmed from a global Normative shift, with direct consequences for how knowledge, and implementing knowledge into policy and action, has been traditionally partitioned into Mechanistic and Operational frameworks. Now the Normative mandate dictates changing roles for Mechanistic and Operational members: to communicate information to, and to provide benefits for, ecosystem residents, who are the focal drivers of decision-making and the focal recipients of ecosystem services. First and foremost, Mechanistic and Operational actions must be translated into useable knowledge for the diversity of participants (stakeholders).

We promote Case-based Reasoning as one of the most natural, useful, and universal forms of communication and knowledge summarization. A KMS based on CBR can be integrated with other knowledge forms, such as heuristic, narrative, and local-indigenous. We provided examples emphasizing the ecosystem approach and using a form of the MA's drivers of change that can be used for many purposes and at multiple scales; it can capture the big ecosystem picture or it can be narrowly problem oriented.

During the writing of this paper, we were constantly reminded of Daniel Janzen’s arguments for the “gardenification” of nature, which he actively promotes in professional and public forums. The philosophy behind gardenification is consistent with that of the GBCI: it is based on the transformation of ‘locals’ to ‘ecosystem residents’, whom we must help make bio-literate from a very early age. They effectively become ecosystem ‘paraecologists’. We must acknowledge that conservation is highly place-specific, and although many organizations seek recipes (rule-based), they are not realistic strategies of intervention. In contrast, we need to individualize conservation strategies, just as for any form of management. Adaptive management naturally becomes decentralized management and participatory education—the basis of intergenerational learning and equity.

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APPENDIX

Below are short excerpts from *reports* on the first three case studies presented in the text.

CASE-STUDY 1. Seed Systems and Emergency Programs Case Study

Mainstreaming Agrobiodiversity In Emergency Operations: *Impact of Seed Relief following the 2000 Floods in Mozambique on Women Farmers' Access to AgroBiodiversity*

Seed relief after emergencies is often criticized for distributing crop varieties that are not traditionally grown in the region, and therefore not adapted to the local environment or to fit farmers' preferences. Such an approach, termed 'seeds and tools', has usually formed the basis of seed relief in the past.

In Mozambique in February 2000 torrential rains, a cyclone and the sudden opening of flood gates of dams in South Africa led to massive flooding. Some 207,000 people were affected, having lost houses, part or all of their crops or having their economic activity disrupted. In some districts, 90% of planted areas were submerged in the flood. As well as stimulating local innovations like the elevated seed storage shelter shown here, this disaster provoked massive relief efforts from the local and international communities, including seed relief. An FNPP-commissioned field study designed by the FAO Seed and Plant Genetic Resources Service and carried out by the Instituto Nacional de Investigacao Agronomica (INIA) together with ICRISAT, Nairobi, examined some genetic diversity effects of the disaster in Chokwe and Xai-Xai Districts, Mozambique. It assessed the longer term impact of the 2000 flood, subsequent seed relief efforts, and the 2001-2 drought on women farmers' crop genetic biodiversity. The results form part of the basis for ongoing efforts to re-design improved seed relief strategies by FAO, NGOs, and other emergency relief stakeholders.

Data from semi-structured interviews were compiled on how farmers acquired cowpea seed *before* the flood in 1999, *immediately after* the flood in 2000 and in the *following year*, 2002. Seed acquisition and diversity were examined in each year and for each group of farmers, *conservation of farmer's own seed*, *purchase from local markets*, *solidarity* (i.e., from friends and relatives) and from *seed relief agencies*.

The study was based in part on semi-structured interviews, conducted with two groups of women — those whose lands were inundated by the floods, those who escaped floods, and merchants at the grain markets. Seed was collected for diversity analysis. Crop diversity was assessed using farmer-knowledge, agro-morphological traits and variation visualized at the allelic (DNA) level using molecular markers.

During the year *prior to the floods*, an average of 72% of the women accessed seed entirely through the conservation of their own seed, while the remaining 28% of farmers supplemented conservation with seed purchase or solidarity from friends or relatives, or relied solely on purchasing seed.

Just after the floods in the flood-affected areas roughly 88% of these farmers now depended on relief agency seeds either entirely, or together with purchase from the markets or solidarity with friends and family, and only 6% of farmers depended on conservation in any form. More than ten relief agencies and NGOs participated in the effort to distribute seeds, and while there was some diversity in seeds among them, what they distributed tended to be quite homogeneous, leading to a loss of genetic diversity, particularly of the rarer alleles that tend to accumulate only over time.

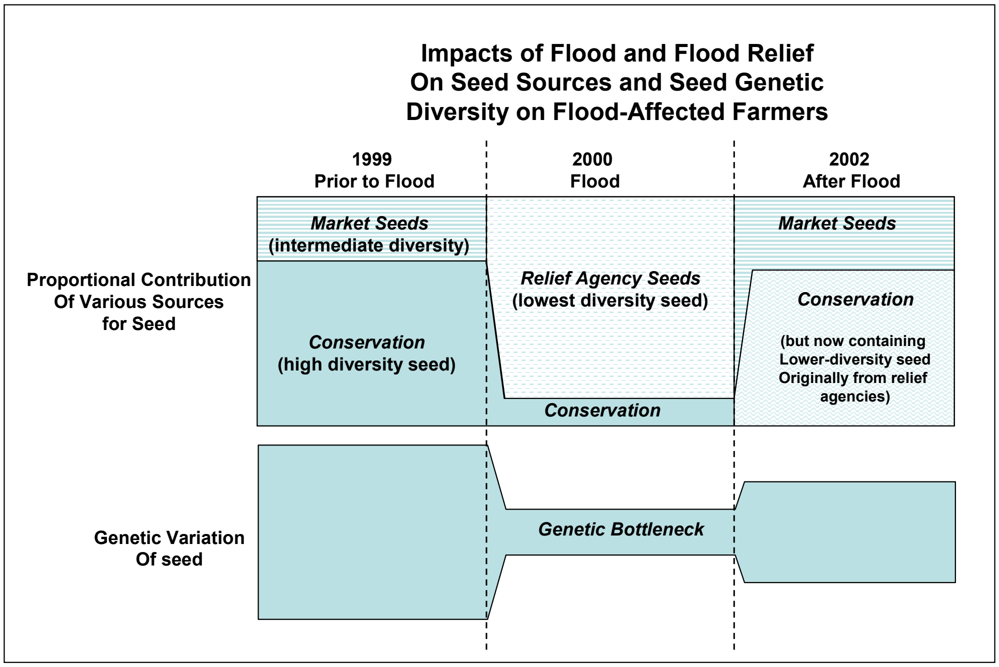
During this same time, for women whose farms were unaffected by the floods, 82% were continuing to acquire seeds from some combination of purchase, conservation or self-provisioning through on-farm seed savings and solidarity—thereby continuing to acquire seeds of highest genetic diversity, while the remaining 18% garnered some seed from relief agencies.

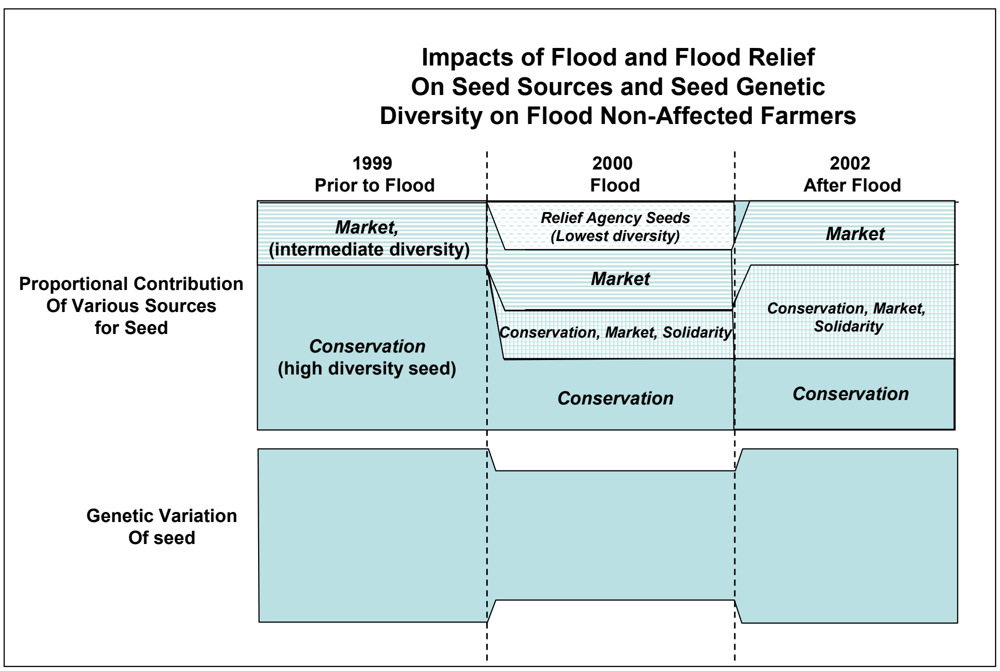
By 2002 44.4% of farmers from flood-affected areas returned to relying solely on conservation for their source of seed, while another 24% employed conservation, purchase and to only a slight extent, solidarity. Not only was this a significantly higher proportion than in non-flood affected areas (28.6% relied solely on conserved seed), but the genetic analysis showed that *seeds being conserved by farmers in the flood-affected areas had lost a significant proportion of their genetic diversity*. In other words, resource poor farmers who had lost their local genetic resources and had come to rely on less diverse seed stocks from relief agencies, were then subsequently recycling these same genetically-depauperate seed stocks.

In 2002, the greatest genetic diversity in cowpea seeds was found among the women who had not lost their crops in the flood (0.552). Farmers from non-flood affected areas also harbored the highest number of alleles (19). This was followed by farmers who had lost seed in the flood (15) and by seed sampled from the market (14). Seed relief seed had the lowest number of alleles (9). Six alleles were found exclusively in the area not affected by flooding, 2 alleles were found exclusively in the area that was affected by flooding, no unique alleles were found in the NGO seed and just one unique allele was found in the seed derived from markets.

Although crop genetic diversity has recovered to some extent in the flood affected areas, *it appears that the impact of the flood on the diversity is still evident two and a half years later.* The origins of this “rebound” are not clear as both the market and seed relief seed are of low diversity. It appears from these data that there is a significant input of diversity into the flood-affected areas from elsewhere, most likely from solidarity within and among local communities. Thirty-one percent of farmers received cowpea seed from friends and relatives.

In order to restore food and seed security after a disaster, it is important that diversity is restored in the agricultural system. *A relief approach that builds on the traditional coping and recovery strategies of solidarity and purchase from markets will be more effective in restoring diversity, than a system based only on ‘seeds and tools’ in which less diverse ‘improved’ varieties are distributed.* Two main problems are faced by farmers relating to access to seed, firstly transport to a place where seed can be acquired (this is a problem both in terms of cost and availability) and secondly the resources to purchase seed. Seed vouchers and seed fairs, recently tested by Catholic Relief Service and other NGOs, are gaining strong policy consideration by FAO’s Seed Service, Economic Development Division and Emergency Operations and Rehabilitation Division. Below are two illustrations, the first one of farmers severely affected by the flood and the second one of a comparable group of communities not affected so severely”.





Traditional farming systems in many parts of Africa are genetically diverse: many crops, and several varieties of each crop. *This diversity increases the ecological resilience* of the system to perturbations, both ecological and economic. The study clearly shows the bottle-neck created both by the loss of local varieties during environmental catastrophes, and the subsequent introduction of replacement seeds from relief agencies and NGOs. The results clearly point to the necessity for seed relief efforts to consider the potential loss of genetic diversity to areas that that have experienced significant and sudden loss of diversity in order to ensure food and seed security. It also points to the need for national governments and international agencies to proactively consider strategies for the securing of *in situ* genetic resources during times of national calamity.

CASE-STUDY 2. Palmyra Desert, Syria

The semi-arid rangelands of Syria, known as Al Badia in Arabic, and the Steppe in English, cover 55% of the country. The sheer size of Al Badia, as we shall refer to it, means that its wise use and management are an important national issue. In the past the livestock production system of nomadic Bedouins was managed for subsistence, their flocks entirely depending on communally-grazed and tribally-controlled rangeland forage. Animal numbers were subjected to environmental regulation and thus the exploitation of natural resources was sustainable. This situation has changed drastically over recent decades.

Al Badia currently appears to be in an advanced state of desertification. The surface covered by vegetation is reduced year after year, and productivity has declined dramatically; about 50 % over the past six years alone. The soil, no longer protected by vegetation, is being eroded by the action of the wind and the water. As a result, sand storms are increasing in strength year after year, as acknowledged by the citizens of Palmyra. Older Bedouins recall that only 40 years ago the landscape was completely different: Al Badia was abundant in vegetation and "gazelles outnumbered sheep". Now one often travels through Al Badia without seeing any wildlife at all. Wildlife populations are declining, while the number of species extinct and threatened with extinction is on the increase.

Pressure on the resources of Al Badia has increased drastically during the past 40-50 years because of the high rate of human population growth. In 1950 the population of Syria was 3.4 million. By the year 2000 it had reached 17.8 million, so that it had increased by more than five times within 50 years. During the same period, the number of sheep in Al Badia also increased by five times (from 3.0 million in 1950 to 15.4 million in 1998).

In addition to being faced with competition from sheep for grazing, the wildlife of Al Badia is put under severe pressure by hunting practices that are both unselective (i.e., all kind of species are shot regardless of their nutritional or commercial value) and unsustainable (i.e., the number of individuals shot per species is unlimited). The widespread Bedouin practice of using poisoned carcasses for controlling wolves also does much damage to wildlife because it is completely unselective and kills other species that do no harm to humans.

Al Badia is now exploited for twelve months a year, which is possible because most places are easy to reach with vehicles. The resulting degradation and destruction of habitats is another important cause of wildlife loss.

Unregulated activities which are currently considered to be responsible for the degradation and destruction of the ecosystems and habitats of Al Badia are the following:

- grazing of very large numbers of sheep by nomadic Bedouin pastoralists, which is often financed by money from people in the towns;

- the collection of firewood by uprooting of shrubs and cutting of Pistacha atlantica trees, mainly a habit of Bedouin pastoralists;

- the extraction of the underground water, mainly for the irrigation of the orchards of oases, but also for household and livestock use as drinking water, and for salt extraction from seasonal salt lakes (sabkhat).

Initiating a response to the degradation of Al Badia

February 1996 saw the start of a project entitled: "Range rehabilitation and establishment of a wildlife reserve in the Syrian Steppe". This project (hereafter referred simply as "the Palmyra project") is funded by Italian Cooperation and implemented by FAO. Its aim is to assist Syrian authorities with promoting conservation and sustainable use of biodiversity in their country, by developing the Al Talila Reserve and rehabilitating the rangelands which surround it.

In six years of activity the project has developed a model for promoting the conservation and sustainable use of biodiversity in the country, through intensive training of government staff, involvement of local communities, promoting programs for conservation education and the raising of public awareness. Technical work has been done and continues to be done on all three of the components which make up the Palmyra project, which are: Range Management, Extension, and Wildlife Conservation and Management. Ideally, the experience of this pioneer project (methods, practices and lessons learned) will be replicated in the future in other ecologically important environments of Syria, in the framework of the recently prepared National Conservation Strategy.

Management objectives for the reserve include:

- Reintroduction of locally extinct fauna
- Surveying, inventorying and photo-documenting of habitats, flora and fauna
- Managed camel grazing
- Involvement of local population and enhanced opportunities for income generation through conservation-related activities
- Increased education and awareness related to local conservation issues

In the context of the project, natural resource management involves building the capacity of national staff for implementing the inventory, planning, monitoring and evaluation that are necessary for sustainable resource management. It is also appreciated that there is a need for an holistic approach to resource management which involves all stakeholders (people with a recognized interest in the area), because their support will be crucial for the long term sustainability of the reserve and its surrounding rangelands. Community participation and Bedouin extension are thus emphasized because without the acceptance and understanding of the local people in the project area, long term sustainability of project activities will not be achieved.

CASE-STUDY 3. A Survey of the Services Provided by the Mt Kenya Forest Ecosystem to Surrounding Farms

Mount Kenya is an extremely important water catchment area of national significance and two of Kenya's largest rivers originate in the Mount Kenya Forest Ecosystem. Crucial to the functioning of the rivers is the forest belt which covers approximately 2000 km² and reaches up to 3 400m. The Mount Kenya National Park and the Mount Kenya National Reserve are nested within this watershed, which is one of the largest forest blocks remaining in Kenya and of considerable conservation value with numerous endemic plant species as well as rare or endangered animal species.

The objective of the survey was to determine the contribution that the Mount Kenya Forest Ecosystem makes to the livelihood and income of neighboring small scale farmers, and the extent to which this use contributes to the continued degradation of the National Reserve. The field work was carried out over a 2 month period from October to November, 2002 and consisted of interviewing 60 households lying within a distance of 30 km from the forest edge. Parameters such as household wealth, location (agro-ecological zone), distance from the forest, farm size and household size were taken to differentiate households.

The Mount Kenya Ecosystem is heavily populated in the agricultural zone with some 500,000 people living within a 5 km radius of the forest edge. The report gives a brief outline of land tenure and the settlement of the Mount Kenya area by different tribal groups. Most of the land is freehold and many households have title deeds.

The role of women as decision-makers is secondary to men in the domain of land utilization and crop and livestock production. Women are responsible for firewood collection and the harvesting of low value crops such as sweet potatoes, pumpkins and bananas. With regard to these crops, women have responsibility over production, marketing decisions and income. This lack of control over "valuable crops" is reflected in the importance given to these crops and the amount of land allocated to their production. Women, however contribute substantially to the labour force (71%) and more than 60% of the primary production is a result of women's input. Currently about 30% of all households sampled either have or have had a *shamba* (farm) in the forest which are primarily managed by women.

The Mount Kenya Forests have undergone, over the last 75 years, numerous excisions and the boundaries of the Forest have been altered in spite of strong protests by the general public as well as forest conservation organisations. While the National Park has remained intact, the Forest Reserve surrounding the park is suffering from encroachment and exploitation (see Figure above). Timber extraction, fuelwood collection, livestock grazing, and farming have all contributed to a reduction in species number and composition, stand structure and the health of the water catchment area.

Grazing. Local cattle breeds are almost absent in the area surveyed, with farmers relying on exotics and purebreds. The average herd sizes are small. For households next to the forest, 60% of all livestock are grazed in the forest. The system is clearly open to abuse and grazing has had a very detrimental impact on tree regeneration in the forest.

Cropping. Crop production takes up most of the land (78%) near the forest, while further away, crops take up approximately 40% of the land and livestock pastures the remaining area. Maize (40%) is the crop which is planted most with beans (28%) and Irish potatoes (24%) a close second and third. Only 1-2% of the farm area is planted with trees and bushes, although farms further away from the forest have more land under trees than farms nearer the forest.

Near the forest edge some 53% of all households have shambas in the forest whereas only 7% have shambas living further away. The shamba system was implemented as a way of providing cheap labour for tree planting as well as providing land for landless peasants; however, it has incurred unanticipated secondary environmental costs with farmers cultivating forest land much longer than intended and not maintaining the forest trees as originally planned.

Conflicts with wildlife. As Kenya does not have a land use policy, many people have settled in areas where wildlife is abundant or which are important wildlife corridors. The forest-adjacent areas have a long history of wildlife-human conflicts, especially with elephants, wild pigs and monkeys. The nearer one gets to the forest, the more the incidence of damage with 67% of households near the forest reporting damages and only 13% reporting damages some 5 km away. Elephant damage occurs mainly during the wet season when elephants move down the mountain and onto the farms. During the dry season, elephants migrate up the mountain and into the forest.

Firewood collection. Some 70% of all households who live near the forest reported collecting wood from the forest. However, farmers who live further away provide their own fuelwood from farm trees or buy from neighbors and urban markets. Firewood collection is for domestic as well as commercial use. Not only dead trees, but living trees are felled for fuelwood, and both events have negative consequences for wildlife habitat.

Water use. Water is a major forest resource, for which households take maximum advantage as water is free. About 72% of all households sampled use river water for irrigation. Approximately 40% of the income derived from forest activities is generated by water for irrigation. In the future, the importance of water is expected to increase as more commercial crops are grown on farmland. *There is no doubt that current use is unsustainable. This is verified by results from forest transects and by the decrease in water levels of all major streams and rivers coming off the mountain*. The trend in water use, if it is to continue, is probably the most serious treat to long-term ecosystem sustainability.

Other Indicators

The forest transects show that for one indicator of status, cedar trees (*Juniperus procera),* regeneration was very poor and there were large gaps in all age classes--a clear sign of general forest overexploitation. Furthermore, transects showed heavy human encroachment and widespread use of the forest products as indicated by numerous tracks, logging roads, tree stumps and livestock.

Even in its current degraded state, the Mount Kenya Forest Ecosystem still provides an extremely valuable service to surrounding farmers and landowners. Forest use nearly doubles household income and is therefore an extremely important aspect of the household economy. The task remains to devise means by which surrounding households can derive a living, in concert with practical and sustainable methods of forest management.

Past and Current Policies

The case study gives a summary of forest management and timber exploitation during the last 120 years, in which it is noted that in spite of numerous laws and policies, the Mount Kenya Forests continue to be severely overexploited. *Forest conservation has failed because the Forest Department does not have the will, manpower and the finance to enforce forest laws and efficient management systems.* The degradation of the Forest Reserve was the reason for making the Forest Reserve into a National Reserve and placing it under the administration of the Kenya Wildlife Service (KWS) rather than the FD. The recently formulated Mount Kenya Ecosystem Management Plan (2002-2007) proposes a substantial increase in law enforcement activities and the rehabilitation of degraded forest land. However, the present suggestion by KWS that the entire National Reserve be incorporated into the Mount Kenya National Park (a purely protectionist policy move) is not in the interest of adjacent communities and farmers, and therefore not practical.

The full case study provides a detailed description of current forest policies and laws which, although far reaching and in many cases innovative, have still to be finalised and passed by parliament. These policies and laws encourage the establishment and management of private and communal forests with the Forest Department providing advice and extension services where necessary.

The forest policy recommends that in future forests should be managed to provide not only industrial timber but a variety of other products and benefits which are important to neighbouring communities. The same applies to wildlife policies and laws which are outdated and need revision in order to allow for sustainable use and involvement of private and communal landowners in wildlife management.

Recommendations

The present use of the forest is clearly unsustainable and overgrazing, fuelwood collection, farming activities (shamba system) and logging are all contributing to forest destruction. Most critically, the use of water for irrigation has severely depleted the water flow from the forest catchment. A critical look at these activities is necessary and if necessary these activities should be phased out or regulated to such an extent that they become sustainable. Since farmers and villagers are reliant on the forest for many products, it is unrealistic to stop all uses at once and a phasing out time is necessary.

Measures which would facilitate improved management and income generation, according to the case study, would include:

- <u>Enactment of forest policies and laws</u>

The present forest policies and laws are innovative and far reaching but need to be enacted and if necessary passed by parliament.

- Zoned use

In order to rationalize the use of the forest, the authorities need to zone the Mount Kenya Forest Ecosystem and determine areas of prime importance to biodiversity, watershed management, timber production and village/community use.

- Water policy revisions

As farmers do not have to pay for their water, water is squandered and lost (an estimated 28%) and the Water Department needs to advise farmers on water saving devices such as drip irrigation as well as introducing a system of rates and payments.

- Diversification of forest management

Plantation forestry provides commercial sawn timber and a number of other products for the national and international market. This is an extremely important function and plantations of exotic timber if managed properly can supply all the local demand. The management of these plantations is best done by the private sector rather than the FD. While the majority of plantations should be privatised and sold to timber companies of international repute, some plantations should be managed by community forest associations. Those areas given to community forest associations should be managed to provide a variety of forest products and services which the community deem important.

- Incentives

The FD should provide a large range of incentives for forest investors such as is done in the agricultural sector. These are: low credit loans, long-term leases and forest management arrangements, protection from imported forest products, tax exemptions and rebates.

- Agro-forestry and extension services

The use of farm trees is well developed amongst farmers in the Mount Kenya region. A variety of species is used to provide a wide range of benefits such as fuelwood, construction timber, poles, fruit trees, soil mulching, nitrogen fixing and windbreaks. While farmers are generally aware of the benefits of trees in their farms, much can be done to increase production by improving management, species selection and planting techniques. The FD, ICRAF and other forest based NGO's must make more effort in advising farmers on the appropriate tree species and management techniques.

- Community participation in forest management and education.

Where feasible, communities should be given tenure and user rights to certain sections of the forest for management purposes. Communities must become the management authority and able to benefit from all forms of use. In order to do this in a sustainable manner, community-based, participatory education programs will be essential.

- Development of forest based tourism

Mountain forests have a great potential for tourism, especially for walking, riding, fishing, bird watching and other activities. This potential is not being fully used in the Mount Kenya Forests and every effort should be made to attract investors wanting to develop tourism options. Mount Kenya is already a world famous destination for mountaineers and it would be in the interest of KWS and the FD to prolong the stay of tourists by diversifying the tourist product. Although guides and porters are drawn from local communities, KWS should look into involving village associations in the management of camping sites, trout streams and dams as well as other income generating activities.
