# POLICY IMPLICATIONS OF EMERGING ECOLOGICAL TECHNOLOGIES

AEPI

Army Environmental Policy Institute

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# POLICY IMPLICATIONS OF EMERGING ECOLOGICAL TECHNOLOGIES

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## ABSTRACT

The two products presented in this document describe a portion of the issues presented by the current direction and Army toward identifying, developing, and applying technology-based solutions to military natural resource management issues.

Together, the reports represent a portion of the results of a multi-year effort on the part of the Army Environmental Policy Institute (AEPI) to examine emerging conservation technologies and their implications for Army land management and planning. They help move the Army ever closer toward the ultimate goal of an overall environmental program that simultaneously conserves natural resources and enhances mission readiness capabilities.

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# Acronyms

| | |
|---|---|
| AEPI | Army Environmental Policy Institute |
| BEST | Basin Ecosystem Study |
| CBA | Cost-Benefit Analysis |
| CEC | Community Environmental Council |
| CENR | Committee on the Environment and Natural Resources |
| CFC | Chloro-fluorocarbons |
| CIESIN | Consortium for International Earth Science Information Network |
| CRS | Consortium for Regional Sustainability |
| DEM | Digital Elevation Model |
| DoD | Department of Defense |
| DOE | Department of Energy |
| EC | European Community |
| EIA | Environmental Impact Assessment |
| EMAP | Environmental Monitoring and Assessment Program |
| EPA | Environmental Protection Agency |
| EROI | Energy Return on Investment |
| FIND | First Integrating Navigator for Development |
| GIS | Geographic Information System |
| GNP | Gross National Product |
| GRP | Gross Reservation Product |
| HDI | Human Development Index |
| IA | Integrated Assessment |
| IAF | Inter-American Foundation |
| IAM | Integrated Assessment Models |
| IBI | Index of Biological Integrity |
| IDLAMS | Integrated Dynamic Landscape Analysis and Modeling System |
| IDRC | International Development Research Center |
| IFAD | International Fund for Agricultural Development |
| IJC | International Joint Commission |
| INRMP | Integrated Natural Resources Management Plan |
| ISEW | Index of Sustainable Economic Welfare |
| ITAM | Integrated Training Area Management Program |
| IUBS | International Union of Biological Sciences |
| LMMS | Land Management Modeling and Simulation |
| LQI | Land Quality Indicators |
| LRAM | Land Rehabilitation and Maintenance |
| LRTAP | Long-Range Transboundary Air Pollution |
| MAB | Man and the Biosphere |
| MAIA | Mid-Atlantic Integrated Assessment |
| MBIS | Mackenzie Basin Impact Study |
| MCDA | Multi-Criteria Decision Analysis |
| NAIADE | Novel Approach to Imprecise Assessment and Decision Environments |
| NEXRAD | Next Generation Radar |
| NGO | Non-Governmental Organization |
| NRC | National Research Council |
| NSTC | National Science and Technology Council |
| OECD | Organization for Economic Cooperation and Development |
| OMNR | Ontario Ministry of Natural Resources |
| OSTP | White House Office of Science and Technology Policy |
| PCSD | President's Council on Sustainable Development |

| | |
|---|---|
| PNS | Post-Normal Science |
| PSIR | Pressure-state-impact-response |
| PSR | Pressure-state-response |
| QUEST | Quasi-Understandable Ecosystem Scenario Tool |
| RCW | Red Cockaded Woodpecker |
| RIVM | Rijks Instituut voor Volksgezondheid en Milieu (National [Netherlands] Institute of Public Health and the Environment) |
| SCOPE | Scientific Committee on Problems of the Environment |
| SD | Sustainable Development |
| SSM | Soft Systems Methodology |
| TARGETS | Tools to Assess Regional and Global Environmental and Health Targets for Sustainability |
| TES | Threatened and Endangered Species |
| UNDP | United Nations Development Programme |
| UNEP | United Nations Environment Programme |
| UNEP GRID | UNEP Global Resource Information Database |
| UNEP/CIAT | UNEP/Centro Internacional de Argricultura Tropical (International Center for Tropical Agriculture) |
| UNESCO | United Nations Educational, Scientific, and Cultural Organization |
| USACE | U.S. Army Corps of Engineers |

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# Chapter 1. Introduction

*Protection of the environment is the key to ensuring we can continue to conduct tough, realistic training and keep the Army trained and ready in the future.*

-General Reimer, Chief of Staff of the Army

This report contains two papers that are both related to a project on Integrated, Adaptive Ecological Economic Modeling and Assessment, sponsored by the United Nations Environment Programme and its Scientific Committee on Problems of the Environment (UNEP/SCOPE). The broad-level objectives of the project are (1) to review emerging methods in integrated ecological and economic analysis, in the context of case studies, to determine their practical applicability to problems of sustainable development; and (2) to suggest some initial criteria for determining whether particular actions contribute to sustainability. Some of the underlying concerns are to consider the gap between the theory and practice of sustainable development, and to provide support for a broader approach to environmental and economic issues, including consideration of distributional equity and the optimal scale of consumption relative to ecological limitations.

The first workshop of the UNEP/SCOPE project was held in November 1995 in the Pantanal region of South America. A second workshop was held in late July and early August 1996 in Boston, and was sponsored by the U.S. Army Environmental Policy Institute (AEPI) as an opportunity to integrate the more general concepts with concrete examples and case studies. The twenty-five UNEP/SCOPE participants benefitted by having a set of real-life issues with which to apply their thoughts, while the seventeen Army participants (representing Major Commands, Army Research Labs, and Training Centers) benefitted from insights of prominent thinkers with respect to the Army's efforts to balance natural resource stewardship and military readiness.

Both of the papers in this report relate to the second workshop. The first paper is entitled "State of the Art Use of Economic/Ecological Modeling." It represents a refined transcription of the proceedings of the Boston meeting. The second paper is entitled "Integrated Ecological and Economic Models and Indicators for Sustainable Development—A Literature Review." It attempts to take the views expressed in the first paper and synthesize them into a cohesive status report on the state of the discipline and its relevance to the Army. Much of the discussion in these papers focused on the complexity of the process of stakeholder involvement, and the importance of explicitly recognizing environmental problems as sociopolitical conflicts. The Army will benefit from gaining a better appreciation for the complexities of public involvement in regionally scaled environmental issues, and these papers can be viewed as a step in that direction.

# Chapter 2. State of the Art Use of Economic/Ecological Modeling

## 2.1 SCOPE/UNEP Project on Integrated, Adaptive Ecological Economic Modeling and Assessment, Boston University, July 31 - August 4, 1996, Second Workshop Report Summary

### 2.1.1 Participants

Judith Bradbury, Stewart Cohen, Judith Cortesão, Bob Costanza (Chair, SAC), Silvio O. Funtowicz, Gilberto Gallopin, Bengt-Owe Jansson, Ann Marie Jansson, James Kay, Joan Martinez-Alier, Peter May, Giuseppe Munda, Maryam Niamir-Fuller, Richard Norgaard, John O'Connor, Martin O'Connor, Jyoti Parikh, Dale Rothman, Jan Rotmans, Matthias Ruth, Olman Segura, Sylvia S. Tognetti (Project Officer), Marjolein van Asselt, Jeroen C.J.M. van den Bergh, Kate Vandemoer.

Participants invited by the sponsor (U.S. AEPI): Steve Ahmann, Michael Binford, Manroop Chawla, Virginia Dale, Scott Farley, Steve Getlein, Richard Haeuber, Tim Hayden, Bob Melton, Gonzalo Perez, David Price, Richard Price, Alan Sheerer, Ron Sundell, David Tazik (Contract Officer), Jim Westervelt, John Wuichet.

### 2.1.2 Introduction

The objectives of the Scientific Committee on Problems of the Environment (SCOPE) project on Integrated, Adaptive Ecological Economic Modeling and Assessment are to review emerging methods in integrated ecological and economic analysis in the context of case studies to determine their practical applicability to problems of sustainable development and to suggest some initial criteria for determining whether particular actions contribute to sustainability. Some of the underlying concerns are to consider the gap between theory and practice of sustainable development, and to provide support for a broader approach to environmental and economic issues that includes consideration of: distributional equity and optimal scale of consumption relative to ecological limitations, in addition to optimal allocation of resources or efficiency (the traditional focus of economics).

### 2.1.3 Results of the First Workshop

The first workshop was held in November 1995, in the Pantanal region of Brazil. A framework for Integrated Assessment was proposed in which the crucial aspects are the process of engaging stakeholders in the initial phase of establishing objectives for sustainable development, in defining the scope of issues to be addressed in the modeling effort, as well as in monitoring activities. It is based on the recognition that a higher standard of accountability and participatory methods are needed for dealing with complex environmental problems in which the stakes and uncertainty are high, particularly when there are conflicting values and a decision is urgent. This process, which is based on what has also been called a post-normal approach to science (by Funtowicz and Ravetz),

adapting to the environment rather than seeking to control it through narrow technical definitions of a problem.

There are no recipes for linking theory and practice—development projects should be viewed as experiments. Indicators by themselves only reflect the values of those who developed them. To be legitimate, they need to be related to a policy framework, and be embedded in a monitoring program that feeds back into the models. The models themselves are elements in the negotiation process by which they are informed and to which they provide feedback. Costs of a true participatory process may seem high, but it has been shown to work in communities that have an appropriate social infrastructure in place. In the long-term, once a process has been established, it is likely to cost less in terms of social alienation and delay in policy implementation.

There was also much discussion regarding the process of consensus building. The appropriate use of the consensus building process involves broad participation and identification and acknowledgment of areas of disagreement as well as agreement. The process can be, and often is, misused, however, in order to mask disagreement and prevent full participation. Steps must be taken to prevent these abuses and foster broad participation in consensus building as an ongoing process.

A key topic of discussion that emerged at the workshop pertains to the relationship between ecological economics and integrated assessment, and how one does or could contribute to the other. Attention to process issues is a particular area of overlap where ecological economics might learn from experiences of IA practitioners, for example in the use of gaming and policy exercises. Conversely, ecological economics can provide a dynamic and broader approach to economics in an IA framework that considers issues of equity and scale in addition to efficiency, as well as the experience of its practitioners with a range of tools such as multicriteria analysis, input output analysis, participatory approaches to dynamic modeling and research, and other considerations, many of which were reviewed in the first workshop. There was general agreement that there is a need for stronger links between these two research communities, as well as attention to the terminology and a recognition of the distinctions.

### 2.1.5 Army Land Management Case Study

The Army manages large but limited areas of land, both for military training, within the constraints of legal and regulatory compliance with environment laws, and has a conservation mission to meet national environmental policy goals—in particular the Endangered Species Act and a Department of Defense (DoD) mandate to implement "ecosystem management" as well as to sustain the land base for training. Changes that affect military training and intensity of land use requirements include:

- The end of cold war
- Smaller regional conflicts
- A switch from forward to U.S. based deployment

- Base closure and realignment
- The concept of environmental security

Training induced environmental degradation also interferes with the ability to continue to use land for training. Challenges are also external to an installation, that is, from encroaching urbanization, but jurisdiction stops at the fenceline.

A modeling framework is being developed that is more integrated in theory than in practice, intended to provide decision support for individual installations and pool information. The framework consists of simulation models in modular units, with GIS, model to model, and user interfaces, impact analysis and risk management tools, visualization tools and connection to external systems. Challenges in the modeling effort are to make them usable to land managers, who have not been using models being developed at research labs, and to fill gaps in understanding of ecological processes needed for simulation models. Another problem is that individual models focus on particular aspects of the landscape at a particular spatial and temporal scale, holding most of the landscape constant—an objective is to create integrated dynamic spatio-temporal ecological models.

An institutional challenge is presented by the mandate for ecosystem management and actions required to protect endangered species. Integrated Natural Resource Management Plans (INRMPs) for Army installations stop at installation boundaries and have no processes for participation across the fenceline. Yet participation is essential in that ecosystem management requires identification of management goals and this, in turn, requires participation by stakeholders in defining these goals. Participation is not just politically and ethically necessary, but also practically necessary because it includes plurality of judgment. Military lands may provide the largest contiguous area under one management entity with appropriate habitat for Threatened and Endangered Species (TES) (such as Fort Hood)—satellite images of many installations show them as islands of wildlife habitat and biodiversity in a sea of agricultural and urban development. However, access to data regarding crucial parameters may require interaction with other stakeholders (such as habitats on surrounding lands where owners fear legal restrictions, and areas in foreign countries to which species migrate). Some installations, such as Fort Bragg, feel that they bear a disproportionate share of the burden for endangered species, such as the Red Cockaded Woodpecker (RCW), because they provide most of the remaining suitable habitat. In private lands, most of the preferred nesting tree for the RCW was harvested. They are developing a long-term strategy and are looking to ecological economics to help identify an equitable distribution of rights and resources among stakeholders.

One project, done in collaboration with other agencies, did develop alternative regional scenarios for the area around Camp Pendleton to determine impacts on biodiversity. At Fort Riley, field testing is being done on Integrated Dynamic Landscape Analysis and Modeling System (IDLAMS) which does a trade-off analysis among multiple land use objectives, and in which management objectives have been linked to specific measures to identify and score various strategies. At Fort Knox, GIS overlays and models have been used to identify potential habitat for particular species and create biological resource risk maps. A large amount of effort has also gone into finding ways of measuring and reducing training impacts.

Related to the institutional challenge is the culture of the military, which demands perfection beyond that of other organizations, because mistakes can lead to deaths—based on a predictive approach that seeks to establish "true facts" as a basis for "correct" actions. There are also institutional constraints on what initiative can be taken in particular programs, which can be thought of as being at the "end of the pipeline," in that the land managers can only consider how to reduce direct impacts on land and have little to do with factors and decisions that affect training requirements and concepts of national security. Workshop participants suggested that work in Post-Normal Science shows that the "true facts/correct actions" model is no longer possible for tasks involving high decision stakes and high uncertainty, in that, in complex problems, "true facts" are often a matter of perspective, and relevant information may be excluded through narrow technical definitions. In a "post-normal" approach, a key question is, "what is at stake?" Coexistence should be approached as a design problem. As objectives, they should look to the development of agreement among the user community with respect to criteria for quality, and progress rather than perfection. It was also suggested that the role of worldview and assumptions embodied in it be considered. For example, the low tolerance for error—error is also information necessary to track and improve performance—when there are no errors, the potential for catastrophic mistakes increases (although from a trainers perspective, training is where mistakes are made to prevent catastrophic losses in actual battlefield situations). The concept of "negotiating scenarios" was also mentioned. The challenge to ecological economics is to assist in the formulation of a demonstration project.

### 2.1.6 Presentation Highlights

Use of integrated modeling together with other tools such as multicriteria analysis and spatial analysis, to examine implications of different interpretations of the sustainable development concept, associated decision making criteria and reciprocal relationships between local and global processes and impacts. Also, some specific problems in integration, the role of integrated models in decision support, and special characteristics of evolutionary modeling approaches (van den Bergh).

Use of simulation models as a game and information system designed both to entertain and educate stakeholders regarding trade-offs involved in reaching chosen scenarios, while making transparent the assumptions by which choices are constrained, the role of world view in selection of indicators and some specific aggregation problems (Rothman).

The added value of Integrated Assessment, (or, in many cases, the lack of it): horizontal and vertical integration, links between modeling and indicator frameworks and incorporation of plural perspectives and the assumptions associated with them. Pressure-state-impact-response (PSIR) provides an ordering framework. Distinguishing features are that it is iterative and cyclic. Processes include combination, interpretation, and communication. Among the weaknesses are: no unifying theory (that is, economic models used in IA have been based on a static view of the environment), tools are more linked than they are integrated, communication has been ad hoc, and broader disciplinary participation and rules of good practice are needed. The Tools to Assess Regional and Global Environmental and Health Targets for Sustainability (TARGETS) model was presented as an example of this approach to IA. We need to consider incorporation of ecological economic approaches into the framework (Rotmans and van Asselt).

Distinction between analysis and design or what we have versus what we want to have. Indicators should emerge from a policy framework and be embedded in a monitoring program. Elements in the design of a monitoring program include the development of a vision of sustainability that is translated into specific goals, principles, strategy and tactics. A conceptual model of ecosystem organization and influences on it provides a framework for relating indicators. Also, a program for collection, storage, processing of data and for evaluation and synthesis of the information. The program also needs to support decision making by allowing for an integrated evaluation of the system, recognizing feedbacks between society and environment and other factors (Kay).

Situational indicators were presented as a hierarchical framework that combines information regarding landscape type and land use, from coarse to fine scale, that only provides detailed analysis where necessary (that is, where there is a problem or an opportunity), and preserves local specificity regarding land use. Special considerations in the identification of indicators are the bias in what information is collected and available. Indicators should also be related to an explicit model and usable in a wide range of models (Gallopin).

Addressing the "so what?" question facilitates scientist stakeholder dialogue regarding impacts (rather than mitigation), to define critical issues, identify scenarios, and insure that research is relevant to critical issues. "So what?" also provides a basis for collaboration between environment and sustainable development (SD) communities; no single best method—assessment should be driven by goals and issues rather than analytical tools; among the added values is the legacy of collaboration (Cohen).

How ecological distribution, or asymmetries in access to natural resources and environmental services affect the results of different approaches to valuation, the relationship of different valuation methods to different assumptions regarding sustainability, the role of property rights in internalizing costs, impossibility of separating equity and efficiency, and the problem of identifying stakeholders in complex issues and giving them a voice (Martinez-Alier).

There is no optimum. Efficiency does not insure sustainability, defined as a problem of intertemporal distribution, because of uncertainty and indeterminacy. Distributed sustainability as an organizational concept—identify interests being served, whether the needs of the system are provided for, and what it contributes to other forms of life. Logic of giving and receiving and questions of reciprocity and relationships—desire for coexistence as a prerequisite (M. O'Connor).

Examples of real costs that are missed in a cost of illness approach to valuation of health damages from a developing country perspective (Parikh).

Complexities of actually involving stakeholders—a high level of commitment may be required, as well as leadership and fairness, and it is often difficult and time consuming to establish effective working relationships. There is a conflict between the need to bring stakeholders in at earlier stages in the process and the unwillingness of experts to present information at those early stages (Bradbury).

Distinction between science and wisdom, and the magnitude of difficulties in communication, particularly with indigenous groups (Cortesão).

Diversity as a criteria for sustainability in a coevolutionary framework in which there is mutual selection between the social system, the ecosystem, knowledge, organization, technology, environment and values (Norgaard).

Criteria for SD in a cultural context—is a development project consistent with cultural values? Does it strengthen institutions? Is there control over the resource base? Control of the resource base is to have control over destiny. Stewardship is not possible without it (Vandemoer).

The roles played by different institutional actors with respect to sustainable development, with particular focus on the multilateral institutions, who should be regarded as intermediaries rather than as agents of change—we need to find out who the agents of change really are and how to reach them. They are responsible for the "R" in "PSIR" (pressure, state, impact, response). A broad definition of wealth provides a unifying theme. In developing countries, a disproportionate share of wealth is derived from natural capital, and there is increased recognition of the role that social infrastructure plays in accounting for differences in wealth. Conventional indicators should be guided by discursive indicators that reflect socially established objectives—resources have different values in different countries because of segmented markets, and environmental problems are prioritized differently by different sectors (J. O'Connor).

## 2.2 Proceedings

### 2.2.1 Discussion of Agenda

Following brief introductions, Bob Costanza made some remarks regarding the objective of the workshop—to address some areas that were missed in the first workshop, to examine some particular issues, and to plan the publication that is to result from the project. He also provided an overview of the synthesis paper that resulted from the first workshop. Dave Tazik commented that the AEPI interest in sponsoring the workshop is to learn the state of the art, to present what they are doing with respect to management of military owned lands, and to find a better way of doing business. This was followed by a general discussion of the agenda and what the participants identified as key issues and important questions:

- Distributive effects of environmental problems, value conflicts, problems of poverty (Silvio Funtowicz).
- Need for an integrated multidisciplinary data base that doesn't exist (Jyoti Parikh).
- Consensus issues—some of the participants had reservations regarding the objective of achieving consensus. Gilberto Gallopin commented that, although he is not against consensus, true consensus may not be possible and it may be more useful for policymaking and research to identify areas of both consensus and dissent. Norgaard

commented that if we build on a consensus that is all messed up, we build on false facts, as was done in the case of development.

- According to James Westervelt, processes such as those outlined in the twelve steps are followed quite a bit, but everyone has his own perspective of the reality and it is not all brought together until the last point, when it is in the hands of lawyers and expensive. It needs to be put together at the scientific stage. He would like to see a contrast of how decisions are made with how they could be made and a cost/benefit (C/B) analysis of that. Others suggested cost-effectiveness as more appropriate.
- It is important to define who are the end users of the product (Maryam Niamir Fuller). Silvio Funtowicz said this is a key issue that introduces interesting aspects. It is difficult to identify users and attune them with developers and decision-makers. The European Community (EC) IA project is doing something on this to present in Toulouse in the fall which could contribute to this project. With respect to C/B analysis, it is important to consider qualitative as well as quantitative aspects.
- Modelers have not been included at the table in indicators work—indicators have gone as far as they can without insight from models (John O'Connor).
- The notion of an indicator is tightly coupled to the notion or model of decision-making (James Kay).
- Who are the decision-makers (Bob Costanza)? According to John O'Connor, stakeholders can be considered the highest level of decision-making—institutions such as the World Bank are only intermediaries. Silvio Funtowicz commented that we are the decision-makers.
- Stewart Cohen asked what stake this group (the participants) have in different types of models and approaches. Sylvia S. Tognetti commented that the objective in developing the project was to be inclusive of diverse perspectives and approaches. Jeroen van den Bergh commented on the complementarity of different approaches.
- Gilberto Gallopin—The twelve-step process outlined in the synthesis paper presents little that is new. We need to look at participatory research and management—there is much that can be learned from it. Richard Haeuber commented that process issues are also addressed in the political science literature. Bob Costanza suggested that historical context and citations to existing literature be added to the paper.
- Gilberto Gallopin—This workshop presents an opportunity to learn from the army and to compare world views—he was particularly interested in hearing them address how the army deals with uncertainty—demolish it? Ignore it? Live with it? He also said that we need a constellation of methods, there are no recipes.
- Regarding issues of cost of implementing such a process, Richard Norgaard commented that the process is only expensive because we do not have the infrastructure in place. People are not used to participating in this way, and there are also institutional barriers to be considered. Gilberto Gallopin said there are people doing it and it is not necessarily more expensive. Cost effectiveness is more useful than C/B analysis.

- James Kay recommended a chapter on process and stakeholder involvement that pulls the issues together.
- Manroop Chawla—A participatory process has been in place for twenty-five years in the preparation of EIS's but it has not made much difference. Sylvia S. Tognetti pointed out that this is because the EIS process is lacking provisions for monitoring and providing feedback. There is no follow-up once the document and the process are completed.

### 2.2.2 Presentations

**Modeling Perspectives**
***Moderated by Bob Costanza***

To start off the session, Bob Costanza presented some contrasting and distinguishing characteristics of different modeling approaches that were identified in the first workshop:

- Deterministic vs. evolutionary
- Objective vs. subjective
- Degree of resolution—space, time, complexity
- Generality, realism, precision
- Qualitative—quantitative
- Opaque—transparent
- Fixed—changeable
- Expert—participatory
- Single discipline/issue—multidiscipline/issue

**Jeroen van den Bergh**
**Use of dynamic models in conjunction with multicriteria, spatial analysis and other methods to determine intra-and inter-regional distribution of costs and benefits.**

Relevant themes in integrated modeling include:

- Characteristics of theoretical perspectives
- Integration of concepts and models
- Thermodynamic elements in models
- Spatial aspects of SD and integrated models
- Coevolutionary modeling
- Evaluation and decision support

Different interpretations of sustainable development give rise to often conflicting criteria for SD: intergenerational equity (non-decreasing welfare over time); weak sustainability (maintain total capital intact, substitutability of natural capital); strong sustainability (maintain natural and

other forms of capital independently, non-substitutability of natural capital); steady state (maintain constant stocks at optimum scale, minimize throughput); Holling-sustainability (maintain ecosystem resilience and diversity; adapt to ecosystem cycles, variation and uncertainty). Modeling can be used to demonstrate the implications that follow from these approaches.

In the integration of models, there are limits on the degree of complexity that can be considered with strict operations research models, which are only appropriate for well understood systems with one-dimensional goal functions. Sequential linking of different models is not a straightforward process because ecological and economic models are usually of different types. When models are designed to optimize different objectives, either an aggregate objective or a multiple object, conflict analysis framework is needed. There is also the difference between monetary and physical units of measurement.

He then characterized and compared twelve different theoretical perspectives with respect to modeling based on what is optimized and other important criteria (generality, realism, precision, formality, inclusion of thermodynamics, and inclusion of short and/or long term dynamics), and on the inherent trade-offs. A key topic in ecological economics has to do with whether it is useful to incorporate the concepts of thermodynamics into models. The primary focus of these models has been on materials balance (the first law). Some authors (Georgescu-Roegen & Daly) have suggested that entropy is at the root of economic scarcity. Jeroen van den Bergh thinks it is useful in that it can provide common ground for integration of ecological and economic models.

Spatial dimensions are important because of the reciprocal relationship between local and global processes and impacts. Regional scale models are more tractable than global scale models and allow for consideration of trade-offs that result from transboundary flows, external factors that influence regional development. Criteria for sustainable development suggested by regional scale approaches are: insure acceptable and sustainable level of welfare for the regional population; and, that it not conflict with SD at supra-regional level.

*(Co)evolutionary modeling.* In contrast with other approaches, (Co)evolutionary modeling is not based on the concept of equilibrium and non-equilibrium conditions, but instead regards economic processes as accidental, cumulative and irreversible. Special concerns include: qualitative change, structural change, uncertainty, diversity, mutations, selection, and adaptation. The key components of evolution are heredity, selection, and variation without which the process cannot occur. Therefore, criteria for sustainable development would be the preservation of biological diversity. In contrast with conventional economic models, this approach is non-mechanistic and non-deterministic, does not average out variability, and is not predictive although it can examine system stability, and identify trends and possibilities. This approach also allows for consideration of selection at the level of institutions rather than just individual actors. Parameters and variables are vaguely distinguished. It is complementary to standard economic models in that they deal with longer time frames. Usefulness in the context of dynamic modeling? Some say we cannot get to the core of the evolutionary mechanism. Dale Rothman commented that evolutionary models are inherently spatial and disaggregated.

*Role of models in decision support.* To be useful in decision support, measurable attributes of objectives or indicator variables need to be comparable over time, which, in the case of ecological and economic models, requires some form of aggregation as is done in cost-benefit analysis. In a cost-benefit analysis, evaluation criteria are reduced to monetary terms and discounting is used to consider effects over time. In multicriteria analysis, different time spans can be used as evaluation criteria. Uncertainty requires special treatment. Decision support systems also provide decision-makers with direct access to the models and information available to support the decision, which can lead to better understanding of the problem, and provide feedback, leading to better decisions.

The paper also provides examples of:

- An ecological economic growth and trade model that includes interregional economic relationships in a global context and the assumptions that are made.
- A model that examines long term economic and environmental relationships by linking resource generation and waste assimilation in a materials balance framework that considers interdependence of different economic sectors.
- The integration of dynamic modeling, multicriteria analysis and (potentially) GIS in the study of sustainable development in a particular region.

**Dale Rothman**
**Linking indicators and models in the context of QUEST**

Quasi-Understandable Ecosystem Scenario Tool (QUEST), was characterized as a "sustainability gaming and information system" designed to allow users to invent a future, choose policies with respect to changes in population, economy, social well-being, community design, land use, and environmental quality; and view consequences in a regional context. It is intended: to be fun to use and true to life; to allow exploration of visions and their consequences and trade-offs required; and to be flexible in considering multiple world views and alternative values. The tension between the first two design criteria (fun to use vs. true to life) has been well recognized and is one of the more difficult aspects in the development of this tool. But according to Rothman, the overall objective—to foster a better understanding of how SD could be achieved—requires a balance of these two.

Initially, QUEST is being designed for the Lower Fraser River Basin in British Columbia and is drawing on information being developed in an interdisciplinary research project, the Lower Fraser Basin Ecosystem Study (BEST). It is being designed for different levels of user sophistication and uses backcasting techniques in which the focus is on steps required to reach a scenario rather than on prediction of the most likely scenario. By comparing scenarios under different world views, that is, assumptions about how the world works, it is intended to reveal uncertainties in knowledge. Choices are constrained by these assumptions, existing patterns, and earlier management decisions. Conflicts force users to make trade-offs, while trying to be consistent with their own values. Scenario consequences are generated illustrating the results of the user's choices. The user's performance is evaluated not only for the achievement of goals, but also the consistency between their expressed

values and policy choices. Because of the difficulties associated with determining impacts associated with specific consequences, it is left to the user to form an opinion on actual impacts.

The indicators provided by the consequences module of QUEST range from specific (disaggregate) to general (aggregate), and include ecological, economic, and social consequences. A key issue is the relationship between specific indicators, which are tangible and provide detailed information but lack context; and general indicators, which are abstract and provide only general information; for example, in the aggregation of social, economic, and ecological health into single indices of sustainability. At higher levels of aggregation, there are problems of combining different units of measurement and failing to show, for example, that while some areas improved, others worsened. An overlapping hierarchy was suggested, whereby the lower level (specific) indicators and the values stated by the user provide the information needed for calculating the higher level indicators. One objective here is to show how different perspectives can influence the values of indicators. It was suggested (by Gilberto Gallopin and others) that a strict hierarchy may not be appropriate, as certain higher level indicators are not merely aggregations of lower level ones.

The selection and dynamic calculation of indicators poses further problems for a tool such as QUEST. It is important that they be relevant and informative. The specific indicators need to provide information for the higher level indicators, while also fitting with the modeling procedure. The actual calculation of the indicators, particularly the lower-level ones, are influenced by the world views of the user as discussed above. It is important that this process be transparent and understandable. The identification of potential indicators and development of the algorithms is done in a dynamic and iterative process, as more information becomes available and as linkages between indicators emerge. This is best done in a participatory process with the eventual users of the tool.

It is also important to consider how indicators are presented. An abundance of information will be available to the user, but those pieces which they have indicated as having most interest to them will be specifically flagged. As noted above, in the interest of transparency and making the user aware of uncertainty, the QUEST model is being designed to allow users to trace back the calculation of indicators to their assumptions and choices made. The user will also be presented with some nontraditional indicators, reflecting not only what was achieved but also the manner in which these achievements were reached. These will be compared to the values specified by the user earlier on in the game.

Overall, QUEST is intended to build understanding and to facilitate exploration rather than to be predictive. It is linked to real databases and real issues, however, providing a relevancy not possible with a purely generic tool.

**Jan Rotmans and Marjolein vanAsselt**

**An integrated talk: What the heck is "Integrated Assessment"?**

A formal definition: IA of Global Change as an "Interdisciplinary process of combining, interpreting and communicating knowledge from diverse scientific disciplines in such a way that the cause-effect chains of global change can be evaluated from a synoptic perspective with two characteristics: (1) added value compared to single disciplinary oriented assessment; and (2) useful information to decision-makers."

A key question to be addressed in the talk is "where is the added value?" IA is not a panacea there are few examples that lead to added values, and the best ones did not use models.

There are two dimensions to integration: (1) vertical—seeks to capture cause-effect relationships; and (2) horizontal—seeks to capture cross linkages and interactions between issues.

The pressure-state-impact-response (PSIR) framework provides an ordering mechanism for IA and is not linear, although it can be interpreted that way. IA can also be used to identify uncertainties, gaps in disciplinary knowledge, and trade-offs between social, economic, and ecological determinants. Tools used include integrated assessment models, simulation gaming, scenario-analysis, global and regional data sets, and qualitative analysis. It can be viewed as a cyclic procedure, from: perception of global change, to identification of cause-effect chains, to complex system characterization, to development of a modeling framework, to experimentation, and to assessment, which feeds back to perception.

Some key processes that shape it are: combination, interpretation, and communication. A problem with combining and integrating the disciplinary pieces of the puzzle is that there is no unifying theory, so everybody can claim they are doing it. There are no theoretical protocols for aggregation and disaggregation and no quality rules. The IA community is dominated by economists who are linking macroequilibrium models with their interpretation of the environment in a static, as opposed to a cyclic, approach. Rules of good practice are being developed.

Interpretation refers to an iterative process of understanding and explaining results between stakeholders—that is, between IA-ers and disciplinary scientists, and between IA and decision-makers. This has been an ad-hoc dialogue because there are no official fora and platforms. Communication refers to the transfer of knowledge to a broad audience. Among the problems are that there are few tools and methods, and that the process is not formalized. It is the most complicated and underestimated part of the IA process. The tools that have been used are simulation gaming, policy exercises, and jury panels. "Jury-Panels" refers to a tool being used in the ULYSSES the CLEAR projects, which consists of guided discussions on complex sustainability issues with a small group of lay persons, which are fed by scientific knowledge, mostly from IA models. The objective is to develop tools for the interpretation and communication aspects of IA.

Weaknesses of IA are that: it is an emerging field, it is premature, it lacks credibility, the tools are more linked than they are integrated, and it does not have broad participation of all disciplines, particularly in the social sciences. But there is no escape—the complexity of the problems

forces us to do it. The Journal of Environmental Modeling and Assessment was launched to create a community of IA practitioners and to address these issues. There are two schools:

- Macro-oriented models; such as DICE, MERGE, which are fully parameterized decision analytic formulations that incorporate cost-benefit analysis and optimization techniques.
- Biosphere oriented models; such as RAINS, IMAGE, AIM, GCAM, which are more comprehensive and process-oriented simulation models.

They then presented the modeling framework of Tool to Assess Regional and Global Environmental and Health Targets for Sustainability (TARGETS) which is intended as a heuristic device intended to reveal insights, perspectives, trade-offs, sensitivities, uncertainties, and images of the future. It is not a truth machine, and is not intended to predict, to be accurate, to be empirical, to regionalize, or provide detail.

In this modeling paradigm, subsystems are viewed as linked reservoirs, cause-effect chains are ordered based on the PSIR mechanism, modeling of the human and environmental systems are analogous, integration refers to analyzing interactions and feedbacks between subsystems, and the complexity of the whole system arises from linkage of simple subsystems. The major themes are: population, human health, economy, energy resources, global cycles, land resources, and water resources. Its added value is in the high level of horizontal and vertical integration, the generic design, and the plurality of perspectives. Also, the modeling and indicator frameworks are linked, with an interface that allows users to trace assumptions. Indicators consist of one-dimensional descriptions of the status and the dynamic behavior of a system identified with keywords, and that simplify, quantify, and communicate.

The scenarios generated provide images of the future in which: the pathway is not unequivocally determined; social, cultural and institutional indicators are included; large-scale transitions are characterized, and in which quantitative and qualitative aspects are combined. The transitions characterized include: social-cultural, information, political, demographic, technological, economic, urbanization, environmental, institutional, and in global legislation. The images are intended to reflect a plurality of perspectives along a spectrum of plausibility and risk.

The model also incorporates different cultural perspectives that are seen as influencing perceptions of the magnitude and significance of uncertainties. These perspectives, classified in accordance with cultural theory, are: egalitarian, in which the world is fragile and the management style is preventive; hierarchist, in which the world view is tolerant within limits and management style is to control; and individualist, in which the world view is robust and the management style adaptive. Each perspective has two dimensions: world view, consisting of a description of the world and its social, economic and environmental dynamics; and management style, which refers to policy preferences. In the energy model, egalitarians perceive natural resources as scarce, hierarchists see them as limited, and individualists see them as abundant. In climate change, perceptions of the threat would vary from "catastrophic," to "probably serious," to "the environment can adapt."

Trends are projected based on the different kinds of assumptions associated with the cultural perspectives (such as, CO2 concentrations and temperature increases). Some of the insights derived are: that coherent scenarios may produce counter-intuitive results (such as low emissions associated with high temperature increases and medium emissions with low increases); that a safe landing only occurs in the case of either structural changes in society or a robust environment; and finally, that state-of-the-art knowledge suggests that the climate is likely to change in the next century and the temperature is likely to increase beyond safe levels. In conclusion, the benefits are that it provides a method of addressing value judgments, provides a systematic framework for scenario development that leads to plausible spectra, and perhaps facilitates communication.

The next steps are to develop a set of theoretically underpinned, basic rules for good IA practice, and to organize platforms and fora. Key challenges are to develop ways of including institutional aspects, to develop actor-oriented models (that is, include humans), and include plural perspectives. Specific recommendations were to: mobilize existing knowledge on IA in fora and platforms; use the existing IA-material and try to improve it, rather than focusing on ontological debates on IA; and to use indicators as vehicles to communicate model results. Some questions that would be interesting to address in the workshop:

- What could be the contribution of social sciences to IA? Identify and define role.
- What could the role of decision-makers be and how could they be involved in participatory processes?

Gilberto Gallopin commented that IA is not new, to which Jan Rotmans responded that what is new is that the current generation of modelers are aware of uncertainties and are not trying to "give answers."

James Kay asked if there was a difference between PSIR and Stress Response (not really), and sought clarification on the distinction between "complicated" and "complex." For example, James Kay does not consider GCMs as complex—they can be brought back to three elementary equations, but use a lot of data. Complex models are those built up from many interrelations and feedbacks.

The exchange led to an extensive discussion regarding the distinctions and the relationship between ecological economics and integrated assessment, and ultimately about use of ecological economics in an IA framework, and the need for collaboration among these research communities. This issue was also addressed extensively in the working session (see below).

**Contrasting Criteria and Implications for Identification of Indicators for SD**
***Moderated by Silvio O. Funtowicz***

In introductory remarks, Silvio Funtowicz commented that there is no possibility of rules of good practice without communication—that is, agreement on terminology is needed, even though, as Richard Norgaard said, there are no fixed meanings. In the European Community (EC), they are trying to establish rules of good practice on which to build.

**James Kay**

**The ecosystem approach and monitoring**

Indicators need to be embedded in a monitoring program. Typically, in the development of lists, experts implicitly impose their values. Linear lists are misleading because nobody actually does it that way. At a meeting of experts, in which the experts were asked to produce indicators for Canada, they refused on grounds that it was not their job. Rather, they saw their job as one of building a process to involve stakeholders. He sees the objective as producing a picture or narrative informed by science, or the "ecologically possible," and by values, or what people want.

The steps in formulating an ecosystem monitoring program are:

- Develop a vision of what sustainability means and a narrative of what we want things to look like (sustainability for whom? for what?) This might be based on policy statements and translated by policymakers into specific goals that provide the impetus for the monitoring program.
- Identify the principles that follow including strategy, which is translated into tactics by experts.
- Describe the ecosystem status and potential in terms of holarchic structure, across a range of spatial and temporal scales and in terms of type.
- Describe the ecosystem organization and influences (attractors, context, and feedback) (about generating a narrative about what is going on and why). This provides a conceptual model of the world in the context of goals, delineates the system to be monitored, and provides a framework that relates indicators to each other in the system context.
- Develop indicators or measures of attributes of the desired state, in a hierarchical way, that characterize the system in a way that is meaningful to the users.
- Design monitoring program, consisting of collection, storage, and processing of data and consistent and appropriate methods of manipulating the data to derive values.
- Synthesize and evaluate the information to provide an overall picture of ecosystem status relative to the vision or to assess progress. A methodology for reporting these results to the users is also crucial.

Key questions at this stage of the process are:

- Does the monitoring program meet the needs of the people for whom it is undertaken?
- Are the policy goals achieved?

When the answers are yes, we can go back to the data collection stage. Otherwise, it is necessary to go back to the diagnosis and policy modification process (with respect to achievement of policy goals), and to redevelop the monitoring program elements.

These steps then provide the basis for management and self-governance, which require indicators for monitoring purposes. Other key considerations are potential futures (flips in system state), and adaptability. It is also part of the conceptual structure for "Post-Normal Environmental Stewardship," in which decision-making is supported by a conceptual model of the ecological and societal relationship, and an issues framework that provides the narrative or a general vision based on culture and values. In the issues framework, the "Soft Systems" methodology, (developed by Checkland) is used to clarify values, identify the problem (based on the Checkland CATWOE method) and provide a synthesis that identifies preferences. Decision-making takes place in the context of an integrated management, monitoring, and governance structure.

Key attributes of a monitoring program are:

- Be relevant and decision supportive.
- Cover a wide range of hierarchically nested spatial and temporal scales with sensitivity to changes, and include abiotic, biotic and cultural factors.
- Based on a conceptual systems model that explicitly recognizes relationships and feedbacks between society and environment.
- Allow for an overall integrated evaluation of the system.
- Be adaptive and flexible to changes (environmental, informational, technical, political context or societal values); and to diverse operational situations—yet be tailored for specific ecosystems.
- Be practical, through cost-effectiveness and use of existing expertise, data and tools.

Some considerations with respect to the relationship between social and ecological systems—ecological systems provide the context for societal systems which can in turn alter the structures of ecological systems, as well as the context for self-organizing processes of ecosystems (such as altering the drainage patterns into a wetland), which can in turn alter the context for societal systems. This relationship between process and structure in the landscape was illustrated with the Holling "figure 8" and as spiraling out from family to neighborhood to municipality (on the social side), and from species to community to landscape on the ecological side. The key question for sustainability then is whether the context is maintained for the processes we depend on for context as well as the integrity of the processes. What is new in environmental problems is that we are changing context globally rather than just locally, and have closed the contextual feedback loops from higher and lower levels. Modeling is used to identify feedbacks that people think are important and to facilitate "Virtual Governance."

Factors that would allow for an integrated evaluation of the system are:

- Collection of different types of measures.
- Monitoring for both threats and ecosystem integrity.
- Sensitivity to magnitude, direction, and duration of known stresses.

- Continuous measures from stressed to non-stressed conditions.
- Assessment of the systems organizational status (structure and process), states, flows of energy, materials and information, quantity and quality and whether changes are reversible or controllable.
- Use of historical and baseline information to identify variability and trends.
- Reflection of knowledge of naturally occurring changes as part of normal system behavior; recognition of inherent uncertainty in ecosystem behavior and responses.
- Assessment of emergent properties of the system.
- Assessment of cumulative effects and comparison with threshold values.
- Assessment based on both scientific objective measures, as well as experiential subjective judgment.

In the development of indicators, selection criteria need to be agreed upon by participants, and all potential indicators should be identified and evaluated regardless of constraints. Feasibility and subjective judgment become aspects of the selection process when trade-offs need to be made between meeting different criteria. Indicators will be based on the conceptual model of the system and issues framework, as well as on available data and the level of reporting that is necessary. General criteria include relevance to management as well as policy issues, relationship concerns identified in the conceptual model, based on sound knowledge that has been demonstrated to be practical; data obtainable at a reasonable cost that is accurate, comparable over time and that provides historical baseline information; and understandable and appropriate to users. It is also important to distinguish those indicators immediately available from those that could potentially be used, from those that could possibly be used subject to further research. They should be specifically related to policy objectives and to aspects of the conceptual model that they measure.

James Kay illustrated the concepts in his presentation with a project he recently did for Ontario Ministry of Natural Resources (OMNR) Canada "State of the Landscape Reporting—The Development of Indicators for Land Use Planning and Protection." In this project, a broad policy statement regarding land use planning for the province, "Protecting resources for their economic and environmental benefits," is translated by policymakers into the goal "provision of natural resources for economic value of harvesting," which is then translated to the strategy, " Ecological and Natural Heritage features and economic areas will be protected from knowledge incompatible development," which is translated by experts to the tactic "define the land use rules: that is, no negative impact on significant wildlife habitat." Municipalities and field staff translate this, using data, information and tools, to designate and delineate protected lands in municipal plans. In the context of social, cultural, economic and other public policy conditions, these are then translated by individual landowners into decisions regarding land use, which leads to the state of the landscape as defined by the ground land use configuration, and, together with natural and other human disturbances, leads to the state of the economy and environment.

**Gilberto Gallopin**

**Situational indicators for land management**

Gallopin reviewed some key issues and discussed some different approaches to indicators and problems associated with them. Because of distributional asymmetries, it is difficult to get even standard economic indicators. What exists is unavoidably biased because of greater information availability in developed countries, and because what information is gathered is primarily from the economic and social realm, leaving developing country concerns and environmental factors underrepresented. Frameworks are limiting because of the variety of purposes and situations for which indicators are used. For example, trends over time should not be a universal condition since spatial distribution may also be relevant.

The wide range of indicator definitions suggest that is also important to say what is not an indicator, but, in general, indicators consist of variables related to attributes of interest, and for which there may be target values. In that a system is an abstraction defined by the observer, the significance of the variable and its associated values, arises from interpretation, but most definitions have excluded qualitative considerations. Value consists of relative worth, as decided through the political process, and may be introduced through use of relative weights in an aggregation function.

Different indicators are required at different scales or hierarchical levels of perception. The state of the whole as described by the overall set of distinguishing features is referred to as a vector, which may be numerical (such as ship coordinates) or non-numerical, (such as data in an individual population census form). A vector is also a profile, which provides a gestalt view of the whole— a related research issue related to human perception has to do with the best structure of the profile in terms of apprehension of the total pattern. A vector indicator embodies a set of objectives, which may be conflicting and which limits optimization techniques. The Dansereau environmental pie provides more information than individual indicators because, like its successor, the "amoebae", it shows a pattern. Weighting reflects value judgments, whether explicit or not. He also distinguished nominal scale variables (those without mathematical properties, such as, blood type), ordinal or ranking scale variables, metric variables (associated with distances in interval or ratio scales), and situational indicators.

Situational indicators refer to indicators derived from the combination of landscape functions and the type of production system at coarse, medium and fine levels. At the coarse level, landscape units are identified based on coarse characteristics (soils), and classified as no problem, danger, or opportunity, using remote sensing, GIS, groundtruthing, and data from secondary sources. At the medium level, areas identified as dangerous or as presenting an opportunity are analyzed to determine actual existence and magnitude of a problem, using such techniques as Rapid Rural Appraisal, field surveys, and expert consultations. If necessary, at the fine level, field measurements and experiments are conducted. A global monitoring system based on these concepts could also preserve local specificity and is applicable to situations in which suitability for different uses can be defined.

The pressure-state-response (PSR) framework links pressure variables to state variables. But land use is not a continuous monotonic variable—its impact depends on the landscape type and the socioecological system. Indicators of PSR can be useful, but we need indicators of system

behavior based on an explicit model. Since there is no universal model or theory, a key criteria for selection of indicators is the ability to use them in a wide range of models. The role of scientists can be broadened to include the translation of information into a form that is usable by policy makers, and helping to convey the implications, weaknesses, and appropriate uses of them.

**Stewart Cohen**

**Challenges and opportunities for scientist-stakeholder collaboration in integrated assessment of climate change**

Science has focused on the "What if ?" aspects of climate change, rather than "So what?" and what should be done. Integrated Assessment has focused on mitigation, rather than potential effects on ecosystems, resources and the societies that depend on them which are unique to each region, which leads to the underestimation of actual costs. "What if " questions present challenges of raising stakeholder awareness and understanding, use of alternative analytical tools, and incorporation of local knowledge. In addressing "so what" questions, a dialogue between scientists and stakeholders based on recognition of multiple objectives can allow for both communities to learn from each other, as stakeholders react to "what if" scenarios. Special challenges are: overcoming the mismatch of scales between global environmental stress and local/regional scales of actors and responses; overcoming various actors' "leaps" from initial indicators of stress (such as changing global temperatures) to the policy debate over eco-taxes and other measures, without recognizing the costs of inaction.

IA is a nonlinear process that relies in large part on skills for which there is little academic recognition, such as the personal contact and communication required to involve stakeholders. Current practice in IA of climate impacts includes: analogue and model-based scenarios that facilitate the development of a common vision of the future; expert judgment, economic models, decision-support models, IA models, testing of management and policy instruments, and themes and places as a focus for integration. Terms of reference for a scientist-stakeholder integrated assessment are to: define critical issues and regions; identify scenarios; review and rank proposals for sectoral and cross-sectoral research activities; and facilitate communication. Proposals would be evaluated for relevance to critical issues as well as for scientific quality. The advantages of scientist and stakeholder IA are: stakeholder ownership, scientist-stakeholder links, legacy of collaboration in the study area, and description of indirect impacts. The constraints are: that most participants are part-time or volunteers; it is difficult to manage and coordinate; leadership is needed from within the study area; time is needed for generation of new data and development of a common GIS platform.

The Mackenzie Basin Impact Study consisted of scenarios, sectoral impact studies, and four integration exercises: resource accounting using I-O analysis and community surveys; a multi-objective model; a land assessment framework; and human settlement patterns relative to permafrost thaw. Observed climate change impacts in the region include a warming of 1.5 C in this century, permafrost thaw and landslides; low water levels in fall and winter on many lakes, severe fire seasons, and a fish kill because of warm water. In addition to increased permafrost thaw and landslides and a decline in basin runoff, scenarios for the region also show dramatic change in ecosystems, decreased forest yield in spite of increased productivity because of increased fire frequency, increased uncertainty in planning and maintaining infrastructure, difficulty of measuring

economic impacts (for example, possible benefits to the agricultural sector could be offset by losses to forestry and tourism). Community impacts would also depend on future economic and institutional changes and on the responses of aboriginal and resource-based communities. The "so what" questions for stakeholders include:

- The implications of changing water levels for water management, ecosystems, parks and navigation
- How changing land and ice capabilities would change land use patterns and infrastructure
- Whether climate change impacts on renewable resources would encourage or discourage expansion of the wage economy and nonrenewable resource development
- Collaboration between climate change and sustainable development research communities

The results came as a surprise to stakeholders, and provided a vision of the future that they saw as an important consideration for long-term planning. Responses varied, from those who were resigned to reactive adaptation, to those who preferred proactive adaptation, with some suggestions for intervention in policy debates, both within professions and at national and international levels. There was recognition that this represents a different kind of environmental problem that requires a different approach to consultation and communication. There was a recommendation to establish a regional secretariat that could serve as a focal point for archiving information, and for facilitating communication and coordination of activities.

In conclusion, although this kind of collaboration requires considerable effort, it improves the process; there are various ways to define the study areas; scenarios and assumptions need to be consistent across sectors; additional criteria are needed in reviewing integration proposals because some models have stringent data needs; a common platform for GIS is needed; communication needs to include personal contact between scientists and stakeholders; and the choice of impact indicators should be specific to each region or country. Lastly, that there is no single best method for integration—the assessment should be driven by goals and issues rather than by analytical tools. He also commented that many of the questions came to light through stakeholder collaboration, within the overall study framework but outside of modeling activities, which should not be pursued at the expense of non-modeling and qualitative approaches. Next steps are: to incorporate regional impacts and adaptation into IA; link them with existing resource management and policy instruments; identify indirect impacts with the focus on places rather than sectors; and incorporate local knowledge.

Gilberto Gallopin distinguished between Integrated Assessment Models and Integrated research frameworks, or building models vs. build a narrative of possible futures. Richard Norgaard commented that the implicit model is that it is creating an interacting community of researchers.

**Economic Perspectives and Considerations**
***Moderated by Olman Segura***

**Joan Martinez-Alier**
**Distributional biases in valuation methodologies and "distributed sustainability" in the context of biodiversity issues**

Joan Martinez-Alier distributed a proposal for discussion (prepared with Munda and O'Neill), that classifies macro and microeconomic and policy approaches to valuation and tools used to evaluate projects, according to whether values are strongly or weakly comparable and commensurable. For example, under strong comparability and weak sustainability, there may be strong as well as weak commensurability of values. Under these assumptions, the objectives are maintenance of constant stock of capital and natural capital measured through the Repetto or El Serafy methods of correcting the Gross National Product (GNP), internalization of externalities at the "optimum" social level through Coasian bargaining or as measured through standard production functions, contingent valuation, and conventional utility theory. Values can then be compared in a cost benefit analysis. When values are weakly commensurable, they can be measured through the Hueting method of correcting the GNP or the Daly/Cobb Index of Sustainable welfare, cost-effectiveness analysis, lexicographic ordering of preferences, and industrial ecology and metabolism. They can be compared with cost-benefit analysis in which alternatives are ordinally ranked, cost-effectiveness, compensatory multicriteria evaluation, and discrepancies between willingness to pay and willingness to accept compensation. Under weak comparability and strong sustainability, values are incommensurable but can be analyzed at the macroeconomic level with satellite biological and physical indicators and theories of emergent complexity and co-evolution. At the microeconomic and environmental policy level, environmental limits are socially established. Valuation tools include sectoral indicators in physical accounts, biophysical production functions, use of the precautionary principle, environmental bonds, eco-auditing, and product life cycle analysis. Values may then be compared through non-compensatory multicriteria decision analysis, EIA, and the Sagoff "consumers" vs. "citizens" method.

Ecological distribution pertains to asymmetries in access to natural resources and environmental services and shifted costs between current and future generations and spatially, between different sectors of society. Externalities imply lack of a property right over particular forms of natural capital. Other terms used for this are: internationalization of externalities, and environmental justice and racism. Biopiracy is a term used by activists to refer to appropriation of genetic resources. There are now initiatives to establish community property rights over biodiversity.

Agricultural diversity is a product of millennia of coevolution. In situ conservation is disappearing fast. FAO's "farmer's rights" have not been implemented and the recent Leipzig conference was a failure. The question has been discussed in terms of "optimization," or how to keep neither too little nor too much in situ biodiversity (for example, traditional farmers) because it is expensive. That is, it has been discussed in terms of an "optimal portfolio of investments." But uncertainties about ex-situ conservation, and the possibilities of future co-evolution give a different view. It is not a matter of optimization. Key questions are: Who are the stakeholders for a decision in favor of traditional "organic" agriculture? The 1.5 million people who are still traditional farmers

with their families? How can they be heard? For example, Shaman Pharmaceuticals, worked with small evangelical groups instead of the native federation in Ecuador, in researching the medicinal values and potential uses of sangre de drago.

With respect to the value of life in climate change, there are no ecologically correct prices, just as there is no way of resurrecting extinct species. David Pearce thinks that equity concerns should be separated from efficiency and pricing. But he maintains that they cannot be separated because prices depend on the outcome of ecological distribution conflicts. Martin O'Connor commented that cost internalization is limited because the value of externalities is linked to power considerations.

**Martin O'Connor**

**Reformatting national accounts consistent with a post-classical theory of value**

Mr. O'Conner opened with a quote from Umberto Eco: "If God is infinite and omnipotent, and thus capable of imagining all futures in his mind, is this not tantamount to saying that God does not exist? There is not an optimum to be found, there are histories, collective and often conflicted, that are being made...." and commented that he is just offering one perspective—not "the" answer. In the valuation of environmental damages (for example, often put forward as an element for greening of national accounts), time discounting greening of national accounts, time discounting is an epistemological obstacle which does not help with decision support because it fails to reconcile future interests with the present. The less the future is discounted, the more it becomes a problem of distributional conflicts between the present and the future and between existing interested parties, for which optimization techniques are fairly useless. Allocative efficiency also has nothing to do with sustainability—it does not necessarily achieve intertemporal equity, and, in any case, is submerged in historical indeterminacy and uncertainty of content.

Implicit in various approaches to the quantification of environmental opportunity costs in monetary terms, is an inter-temporal general equilibrium framework in which the reference state or equilibrium is one that maximizes net present value or present value of utility. Results obtained depend on assumptions regarding substitution between different forms of capital, relative factor importance, consumer preference, and property rights. A simple model demonstrates that the optimum may shift by orders of magnitude and at least four qualitatively different PVU-maximizing time-paths are obtainable, depending on initial stock levels and specification of the social discount rate—but it does not allow for quantification of a sustainable economic output or even to say which of these time paths best represents the "business as usual" scenario. To support decision-making, we have to be able to say why value goes up or down and ask what are the real interests we have to address and what framework would allow economists to address the problem. Efficiency is irrelevant. Uncertainty could also be used as an argument, but he was only addressing distributional issues. If we look at a problem from only one perspective, we have to use criteria internal to the perspective that excludes others. Much of complex systems modeling is stuck at that point.

Mr. O'Conner suggested that monetary values are only appropriate for determining the economic resource commitments necessary to achieve social objectives, with the caveat that cost-

effectiveness may not be separable from distributional considerations of what is to be sustained. "Distribution of sustainability" was presented as an organizational concept, in which sustainability is seen as a problem of conflicting environmental values, notably between those who live values internally and "managers on the mountaintop." In this context, a multiple-criteria decision support framework would be more relevant than an optimizing one, and better reflect uncertainties and differences of opinion. Relevant questions to ask are: which systems of power, interests and institutions are most allied with the type analysis being used, and what groups are annihilated or difficult to give a voice to? Will the interest of the system in question receive what is needed and to what extent is it providing for other forms of life? This is a logic of giving and receiving, which is based on a different set of symbolic tools. It leads to questions of reciprocity and symbiosis in relationships, and provides a basis for conflict resolution. Ultimately, it comes down to whether or not there is a desire for coexistence.

Jan Rotmans questioned how it could be put into a model. Richard Norgaard commented that modelers are still useful to help open up the issue. But we need to be asking what the economy and the world would look like with more equitable distribution. Most analysis is based on the state of current economies rather than on the economies we want to have. Conflict resolution normally comes at the expense of excluding other options. With respect to actually developing accounts based on this approach, Martin O'Connor commented that it takes an actual research project and funding (several such projects are currently being undertaken, in European contexts of valuation and policy advice).

**Jyoti Parikh**

**Valuing damages of air pollution in India—SD criteria from a third world perspective**

Ms Parikh reviewed some of the practical problems inherent in valuation from a developing country perspective, as they became apparent in a study to value health damages of air pollution in Bombay, India. In the physical linkage method, a logical sequence of cause and effect is identified at each step and a dose response is determined. Valuation of physical damage is done through two key approaches: the cost of illness approach—in which key considerations are the direct cost of medical expenses and loss in earnings; and the human capital approach. Among the limits of the cost of illness approach in India are, that many do not go to hospital, as it is not affordable. Household surveys and time series studies were done which showed that not all were exposed throughout the day, but there is lack of data on a day-to day basis. Air pollution in rural areas has to be examined differently as it comes mostly from biofuels.

The presentation led to discussion regarding the value of doing valuation, based on monetary values, because of the implication that those with lower income and ability to pay have lives of lower value. She responded that, although valuation of life is controversial in an international context, that is not what they are doing. The objective here is simply to show that pollution matters—otherwise it will continue. Dale Rothman commented that, according to Repetto, if we leave out particular values, the implicit assumption is that they have no value and that it is better to be imprecise than precisely wrong. Others disagreed.

**Social Perspectives and Considerations**
*Moderated by Richard Norgaard*

**Judith Bradbury**
**"Lessons learned" with respect to stakeholder involvement**

Her remarks were about "lessons learned" by the U.S. Department of Energy in involving stakeholders. In the early eighties, the Department of Energy (DOE) interpreted involvement as provision of information and persuasion. This approach was evident in its program to site a high level radioactive waste repository—which was unsuccessful. More recently, however, DOEO's interpretation of stakeholder involvement has changed to one of attempting to involve stakeholders in the agency's decisions. A noteworthy example of this change can be seen in the recent establishment of citizens' advisory boards at a number of sites around the DOE complex. The boards are composed of local stakeholders who work with DOE and regulatory staff on decisions related to environmental restoration of the contaminated site.

Lessons learned that are pertinent to the meeting discussion include:

- The process of identifying and involving stakeholders is complex. For example, establishing the boards took many months. Some boards selected members on the basis of demographic representation; other boards selected members on the basis of interest group representation. One issue that arose in Washington State was that the three affiliated Indian tribes did not want to participate as stakeholders because they wanted a nation-to-nation relationship with DOE.
- Establishing effective working relationships among board members was frequently a difficult process (that is, it was not just the difficulty of establishing relationships between technical experts and lay persons). Stakeholders typically hold different values not only about outcomes but also about procedures, how consent should be obtained, and accountability established.
- Stakeholders need to be highly committed. It takes time and requires volunteers and part-timers to become familiar with complex issues, technical documents and regulations.
- Technical people are frequently unwilling to bring issues to the table at an early stage.
- Kate Vandemoer commented on the experience of tribes in the nuclear waste issue. When they were dealt with in the proper manner, and, after extensive discussion, many were willing to accept nuclear waste repositories, because they saw themselves as having a responsibility that others were unwilling to face. Indian reservations have also been a significant source of uranium and have a legacy of problems from uranium mining and processing.
- Maryam Niamir Fuller commented that IA does not occur in a political vacuum. It is necessary to work within the political arena. The term shareholder assumes an equal distribution of power. The process of stakeholder involvement involves tampering with the distribution of power or else just dealing with the status quo.

**Judith Cortesão**

**Science and culture: patterns of construction (in Brazil)—a developing country perspective**

We need to distinguish science and wisdom, which are both part of human culture. In situ conservation requires language for dialogue with stakeholders, whose indigenous knowledge is essential to the effort. In her talk, she sought to convey the magnitude of the cultural distance and difficulties in reaching a common understanding, particularly with indigenous groups who have had little outside contact. There is also a need to appeal to emotion. As an example of one effort to bridge the gap, she shared some colorful sculptures made with a variety of sea slugs from a collection at the Oceanographic Museum in Rio Grande do Sul. In conclusion, she suggested that, in communicating with local groups, we should first ask for knowledge and then, as token of appreciation, offer ours.

**Richard Norgaard**

**Criteria suggested by a co-evolutionary framework**

What if we build consensus on something that is wrong (for example, the current development paradigm)? We have been dealing by and large with mechanical models. But if the process is co-evolutionary we need to consider mutual selection—ecosystem on social system on ecosystem—as well as between knowledge, organization, technology, environment, and values. Co-evolution is sustained by diversity. Silvio Funtowicz commented that we are now co-evolving with bioengineering technology. Implications of that are a change in the human condition.

**Policymakers Perspectives**

***Moderated by Peter May***

**Kate Vandemoer**

**Contrasting criteria for water resources management among federal state and tribal governments and natural resource management practices in Native American communities**

In the United States there are three sovereign entities: the federal government, the states, and the tribes. Tribal resource management systems have evolved over a long period of time, but traditional practices have been replaced by a system devoid of values. Criteria for sustainable development have to be rooted in a cultural context. The tribal development paradigm is larger than economics—it includes cultural (practice and understanding), political (government), as well as economic (resources) factors. Values are in the center. In evaluating development proposals, she looks for consistency with culture, whether it strengthens institutions, and economic aspects. There is a dysfunction when these factors are developed in isolation of each other—for example, the alcohol problem could be related to a lack of control over the resource base.

At the Menominee reservation in Wisconsin, the elders were asked what criteria should be used for forest management. They said tall trees were important because they are a link to the creator. Diversity was another factor—they also elaborated how different plants are used for various

purposes. Their forest has produced hundreds of jobs. The Nez Pierce have the most sophisticated monitoring program for fish, are looking at the smallest organisms in the stream, and the size of sediment. They are also managing the wolf recovery program for the Fish and Wildlife Service.

Economic criteria are based on the recognition that the source of all wealth is natural resources. Control over the resource base is control over destiny. An emerging tool is Gross Reservation Product (GRP), which considers thresholds of soil erosion and water use.

There are different strategies which seek to be inclusive rather than exclusive. Communities need to be involved in planning. The basis for the success is asking the right questions, but when the Menominee got too successful they were terminated—so it became matter of survival. She also recounted some of her personal experiences as a hydrologist in working with the tribes and the way that their traditional knowledge was helpful in identifying a stream source.

**John O'Connor**

**Decision-making criteria for optimum development**

Empirical evidence may be presented as tabulated data (economics/produced assets), as text (sociology/human resources), and through images and GIS (ecology/natural capital). The disproportionate increase in word-oriented databases in recent years suggests a need to improve interpretive skills, but the focus is still on quantitative.

The objective of International Development Finance institutions is to "seek the optimum." Multilaterals are not agents of change but intermediaries. We need to consider who the agents of change actually are—who has the capacity to change what, how do we reach them, and what will help businesses and communities. Multilaterals are intermediaries rather than agents of change, although they often overstep the boundary and think of themselves as change agents. John O'Connor also pointed out the distinction between optimum and sustainable, articulated by Dasgupta, and commented that upbeat, solution-oriented tools give leverage.

John O'Connor's three main discussion points pertain to: progress in international fora; missing links for integrated models, and reaching agents of change. With respect to progress in international fora: there is an effort to find policy hooks or, get to the response (R) in pressure, state, impact, response (PSIR)—but science only measures P, S, and I. Response depends on agents of change. Intermediaries seek a response that optimizes goals for P, S, and I through subsidies and taxes, rent capture, and natural resource policies, and a policy matrix of best practices. Models are used to understand feedbacks involved and how weights given to P, S, and I factors determine R.

Nation-level indicators as found in core databases (WRI, DPCSD, WB, UNEP, etc.) provide a "common gene." There is an effort to decentralize indicator and model building via the internet and to improve efficiency through joint publications and niche definitions. There is some consensus

on the extent and grain of core data sets and accessibility is improving via the internet. Some niche definitions are:

- NGOs/pressure (P)
- UNEP/state (S)
- DPCSD/impact (I)
- WB/response (R)
- UNDP/national links
- CIESIN/systems
- DPCSD/official use

With respect to missing links for integrated models, a unifying theme is wealth, broadly defined. In developing countries, a disproportionate share of wealth is derived from natural capital. In developed countries, wealth is disproportionately derived from human resources and social infrastructure. The objective should be to maximize welfare or to minimize resource utilization relative to welfare. Social infrastructure is a key consideration—a study by Putnam showed that countries with more social infrastructure are wealthier, and the Bank is now worried about putting large infrastructure in places with a crumbling social infrastructure. Other work by Putnam suggests a current transformation in social infrastructure. Dasgupta speaks of trust as a commodity. Other relevant work on social infrastructure: Richard Rose—New Democracies Barometer; Dale Jorgensen—the stock-flow view of education; and John O'Connor—the dynamics of relative price changes. A distinction that can be made in social infrastructure in between hierarchical and associational processes.

Another missing link is clarity about analytic grain and extent in tabulated data. Land Quality Indicators (LQI) provide an example of a way to link hierarchically nested data to models and models to policy variables. Systems for open, distributed, and highly participatory knowledge base are being provided through such things as the Consortium for International Earth Science Information Network (CIESIN) information cooperative, which facilitates communications among many different sectors (namely, UN, multilateral and government, agencies, scientists, businesses, non-governmental organizations (NGOs), regional and municipal entities, and local associations). Feedback for local knowledge can come from indicators that link national and local levels. Also, from such things as the 2050 Project which is exploring the dynamics of altered behavior by agents of change (businesses and individuals); applicability filters; and a less arrogant view of empirical evidence. We need to show that integrated models can be used to build consensus about options by allowing for stakeholder use and by showing the implications of alternative valuation schemes. They can also be used to synthesize all available empirical evidence whether it is in the form of text, imagery, or tabulated data, and to develop strategies and identify tactical choices. As an example, John O'Conner presented an overview of the structure of the model "Threshold 21" which is also on the internet.

With respect to alternative valuation schemes, resources have different values in different countries (developing vs. developed) because markets are segmented. Also, environmental problems are prioritized differently by scientists, the business community, and NGOs. Conventional ecological and economic indicators need to be guided by discursive indicators that reflect targets and goals established as a social objective.

First Integrating Navigator for Development (FIND) provides hierarchically arranged links between tabulated data, text and imagery (GIS) in three dimensions: time, place and attributes. It can provide evidence related to specific questions. Texts yield verbal associational models for which FIND can then check for empirical evidence; and a qualitative data analysis can be provided based on quantitative profiles of stakeholder values and models. It is intended to answer the reporter's six questions: who/what (attributes), where (space), when (time), how/why (verbal chains), and to examine the implications of alternative weighting schemes.

With respect to establishing a method to bring stakeholders together, we should start with narratives. Stakeholder positions can be defined through existing narratives which can then be brought into the model, compared, and related to the empirical database. To conclude, John O'Connor reinforced some key points raised by other participants: we need to end up with a narrative (J. Kay); non-numerical indicators are legitimate (G. Gallopin); plain language reporting is important (S. Cohen); and, it is an iterative process (J. Rotmans).

**Discussion**

**Moderated by Bob Costanza**

Bob Costanza presented a draft outline for the final publication that is to result from the project which grouped the presentations given in this and the previous workshop under the headings:

- Introduction and synthesis
- Social and cultural issues
- Models and methods
- Valuation and decision-making
- Indicators and policy
- Case studies

Some general questions were identified as:

- The role of power
- Valuation—different methods
- Governance and decision-making
- The role of stakeholders

Terminology that should be agreed on or defined includes:

- Stakeholders or shareholders or?
- Models
- Integrated assessment

The book could reasonably go up to 500 pages. Each paper will be reviewed by one person internal to group, and two external. Papers should not exceed 8,000 words or twenty-five double-spaced pages. Sylvia S. Tognetti commented that the dividing line seems rather arbitrary between papers examining specific methods and policy issues and those categorized as case studies, since presenters were asked to discuss methods in the context of case studies. In papers classified as "case studies," the methods they highlight could be obscured.

A discussion followed regarding differences in perception with respect to ecological economics and integrated assessment, the relationship between the two (somewhat overlapping) research communities, alternative titles (see list at end of document), and overall objectives of the project. According to Silvio Funtowicz, we need to show that it is possible to be reasonable and constructive without reducing things to a single number, and that it is not the end of reason.

Jan Rotmans commented that IA is an iterative process that contains all the pieces and that has to be communicated. It also includes many tools that have not been mentioned that can be used in constructive ways, such as gaming and policy exercises. He viewed ecological economics as a subset of IA. Rather than "subset," Norgaard suggested instead that they have overlapping interest areas, and Martin O'Connor suggested the relationship could best be described as a confounded hierarchy in which each one exploits (includes) the other, and each one serves (is a component) of the other. There was general agreement of the need for stronger links between these research communities, and that the project should specifically address the contribution of ecological economics to an integrated assessment framework.

**Presentations Regarding Ecological and Planning Perspectives on Land Management Modeling for U.S. Military Installations**

**David Tazik** provided an overview of the military land management objectives, the research program, and their interest in this project. The Army mission is to: "Train as you would fight. Fight to win." They manage approximately 12 million acres in 112 major military installations for training, weapons testing, and arsenal and depot activities. Recent changes that affect training and land use requirements include:

- The end of the cold war era
- Smaller regional conflicts
- A switch from forward to U.S. based deployment
- Base closure and realignment

Environmental issues have also been incorporated into national security policy. In the national context, this is affected by the military contribution to resource degradation and their technological and organizational capability to help solve it. In the international context, regional conflicts are grounded in natural and cultural resource conflicts. Military conflict can be avoided by addressing the underlying resource problems.

Specific environmental issues of concern to the military include:

- Threatened and endangered species (TES)
- Land-based carrying capacity for training
- Land rehabilitation and erosion control
- Cultural resources protection
- An ecosystem approach to the management of training areas

The military is interested in how ecological economics can be used as a tool for allocation of scarce resources. Land capability needs to be considered for different kinds of values: military use, forestry, agricultural outlease, amenity values, and existence values.

AEPI is a staff support agency for the Assistant Secretary of the Army for Installations, Logistics, and Environment. They assist with proactive environmental policy development to avoid future problems. Specifically, they examine environmental trends, mission trends, and science and technology trends.

The U.S. Army Corps of Engineers (USACE) is responsible for developing the Nation's water resources and the operation and maintenance of existing water projects. Management purposes include navigation, flood control, hydropower, water supply, recreation, and fish and wildlife enhancement. USACE also provides environmental quality R&D for both civil and military lands. The Land Management Modeling and Simulation (LMMS) R&D strategy is intended to:

- Identify land management modeling objectives for both military and army civil works
- Evaluate the state of the art
- Enhance existing modeling tools and extend their capabilities and understanding needed for process models
- Integrate across labs, services, academia, and agencies
- Define timelines, products and funding requirements

Among the objectives are to develop process understanding and models needed to support mission land use sustainability; coordinate with policy and operations; provide a common hardware/ software environment for linking a variety of simulation models and standardized data acquisition and management processes.

Some specific technical requirements and analytical needs for military users are:

- Threatened and endangered species (TES)—population viability and habitat suitability
- Land capability—carrying capacity and community dynamics
- Land rehabilitation and erosion control—erosion and sedimentation; geomorphic processes
- Ecosystem approach to training land management—risk assessment; ecosystem processes
- Cultural resources—geomorphic process and site prediction modeling

Land management goals and objectives are translated into science and engineering principles and practices, which guide data acquisition, data storage and management, and data manipulation used in modeling and risk assessment. These tools are used to provide decision support for land use scheduling and management decisions. The strategy and action plan also includes the identification of relevant standards and evaluation criteria, knowledge gaps, technology barriers, as well as technology partnerships and transfer. By developing standard building blocks or common system components, the program seeks to provide a foundation for constructing and using modules and modeling tools tailored to specific user communities. Existing simulation modules are:

- Surface/groundwater flow/transport
- Carrying capacity
- Watershed/hydrologic transport
- Training alternatives
- Sediment transport/erosion
- Submerged aquatic vegetation
- Plant succession
- Mobility effects
- Next Generation Radar (NEXRAD), Digital Elevation Model (DEM), Geographic Information System (GIS) interface
- Decision support systems

Common support tools are:

- Human-computer interface
- Model encapsulation and model to model interface
- Impact analysis and risk management tools
- Decision support system components
- Visualization tools
- Connection to external systems

Gaps in process understanding are:

- Surface water-groundwater connectivity
- Sediment erosion and transport
- Plant succession
- Linkage of differing spatial/temporal scales for hydrology, biology and ecology
- Military-unique impacts on the ecosystem
- Risk-based ecosystem management
- Ecosystem restoration activities

They are expected to provide installations with the capability to evaluate the consequences of alternative land use and management strategies in support of their training mission, to support requirements for development of Integrated Natural Resources Management Plans, and incorporation of the tools and techniques into the Integrated Training Area Management Program (ITAM). He also commented that all of this information is more integrated in theory than in practice, but that they would like to bridge this gap and to develop a demonstration project.

**John Wuichet** commented that, like the Pantanal, the Army is a case study, the lessons of which may be applicable elsewhere. However, there are a number of circumstances that make the Army a unique case. Army culture has an unusually low tolerance for failure, and a high demand for perfection because, as in a medical context, if a mistake is made, people die. In the context of Army modeling, perfection means a capability for prediction. To illustrate how deep-rooted this nation is in the culture of the military, John Wuichet showed a cover from the front page of a widely circulated Army newspaper in which the headline reads "Pressure for Perfection Chills the Ranks." The article was about well-intended decision-makers who tried to experiment, then failed, and lost out on promotions. Many of today's presenters have stressed the need to move away from prediction as the focal point for modeling, preferring instead to use models as tools for creating a vision for possible future scenarios that can be worked toward. The Army, on the other hand, still wants prediction, and prediction requires consistency of data sets over time. Adaptive management is a principle of ecosystem management as expressed by official DoD policy. Yet adaptive management requires flexibility, which is directly opposed to the consistency required for prediction. Army modelers must carefully balance consistency with flexibility.

Questions: John O'Connor asked how the Army deals with fragmentation, to which John Wuichet replied that fragmentation issues are different in the East and West, due to the distribution of federal land holdings. Gilberto Gallopin commented that, if the medical profession also requires perfection because lives are at stake, the military might consider what it can learn from how medical decisions are made. Silvio Funtowicz added that the model of decision-making is tied to prediction and a belief in true facts, and that the risk model is based on prediction and quantitative associations, all of which are contrary to principles of adaptive management. Meanwhile, modelers are moving away from prediction toward fuzzier "decision support tools." Silvio Funtowicz asked if there is any program for changing that institutional culture, to which John Wuichet replied that modelers must teach-as-they-sell their wares to Army clients. Virginia Dale suggested that risk assessment could contribute to improving this situation.

**Rick Haeuber** stated that ecosystem management is a prominent recent policy alternative proposed to address a new generation of environmental issues emerging in the United States. Many federal agencies already have considered the concept and its implications for their activities. And, in fact, each of the major land and natural resources management agencies has drafted policy guidance regarding ecosystem management approaches.

Over the past few years, the Department of Defense (DoD) also has embraced ecosystem management as the philosophical foundation for its natural resources management and conservation activities. Set forth in an August 1994 memorandum from Deputy Under Secretary of Defense (Environmental Security) Sherri Goodman, the DoD adopted a set of ten ecosystem management principles. These principles were expanded and formalized as DoD conservation policy in the context of a recently released DoD Conservation Instruction (1996).

Integrated Natural Resources Management Planning (INRMP) has been identified as the primary vehicle for implementing ecosystem management on DoD lands. Guidelines for the completion of INRMPs have been developed and several draft INRMPs have been completed for Army and other DoD lands as tests of the INRMP process. However, the INRMP approach to implementing ecosystem management is still evolving.

Ecosystem Management Implementation Issues: Shortcomings of the INRMP Approach

1. General Observations

   The INRMP Preparation Guidelines (5/95 and 5/96 drafts) provide a blueprint or template for writing a document, but do not provide the process(es) necessary for implementing ecosystem management.

   Ecosystem management is considered a component of the INRMPs (that is, a chapter heading) rather than the INRMPs being seen as an implementation mechanism for ecosystem management.

   The INRMPs are ineffective in identifying the capabilities of installation land, natural resources and ecological systems and linking these to training and land use needs.

2. Ecological Approach

   The INRMPs do not identify or design a planning or management unit that is defined according to physical/biological criteria and extends beyond installation boundaries.

   INRMPs do not consider or understand the regional context (that is, the planned or proposed actions of adjacent administrative jurisdictions) and plan management actions within that context.

3. Stakeholder Involvement and Collaboration

   No efforts have been made, nor processes developed, for soliciting and incorporating the participation and involvement of parties "across the fenceline."

The INRMPs do not include efforts to develop a "vision of ecosystem health." No process exists for establishing desired future conditions for installation ecological systems and natural resources. Thus, plans contain no overall set of goals and objectives to work towards and no endpoints that can be linked to management actions.

The INRMPs do not establish mechanisms for prioritizing actions and resolving conflicts among contradictory goals. In part, this can be traced to the absence of a process for setting overall objectives.

4. Scientific and Field-Tested Information

In their assessments and inventories, the INRMPs focus only on ecosystem composition (such as lists of species), ignoring the structure and function of the ecological systems, or how the systems work.

Biological information focuses almost exclusively on game species and populations of other species of importance for economic or human use reasons.

The INRMPs lack clear, tangible measures of success.

5. Adaptive Management

No processes or mechanisms are established through which information on implementation, developed through field experience, can be fed back into the planning process.

Implementation Challenges—Can Models Help?

The above discussion demonstrates that many gaps still exist in using the INRMP approach for implementing ecosystem management. Such shortcomings do not mean that the INRMP approach, and the plans themselves, are inadequate tools for the task. On the contrary, all agencies and organizations engaged in implementing an ecosystem approach to management of land and natural resources are struggling with similar issues. For example, none of the federal agencies responsible for land and natural resource management have worked out a generalizable and widely accepted process for soliciting and incorporating stakeholder input. However, the shortcomings of the INRMP approach, and the plans it produces, reveal significant challenges that must be tackled before INRMPs become a viable tool for implementing ecosystem management on DoD lands. In some areas, models are readily available to confront these challenges. For other issues, existing models can be adapted to facilitate the use of INRMPs in implementing ecosystem management; and, in some cases, tools for successfully implementing critical concepts (such as adaptive management) have yet to be created. The following list is by no means exhaustive, but illustrates some of the serious issues confronting the DoD and its natural resource managers as the INRMP approach evolves.

- Develop a process-based approach for Integrated Natural Resources Management Planning.

- Develop a process for establishing and understanding the regional context of an installation.
- Develop a process for establishing a vision of ecosystem health.
- Explore potential collaborative processes for stakeholder involvement.
- Identify biological and physical process models that can be employed in understanding the structure and function of ecological systems.
- Establish standard, generalizable measures of success for monitoring and evaluating outcomes.
- Identify or create standard, generalizable adaptive management mechanisms and tools.

**Steve Ahman** discussed the Mojave Desert Ecosystem Initiative, the objective of which is to produce a database that pools scientific information from diverse agencies and research efforts, for use in dynamic sustainable land management decision-making. DoD is the major regional landholder but collaboration with other agencies has become necessary, particularly in light of recent legislation (the California Desert Protection Act of 1994) which creates a new national preserve, expands two existing national parks, and delineates new wilderness areas. The database is also intended to facilitate communication and provide a basis for collaboration. Initially, it will be a GIS consisting of an interconnected distributed database that utilizes the world wide web. Agencies identified information priorities for management purposes. Some particular problems being addressed are the need for uniform data coverage of a scientifically (vs. politically) defined ecoregion in what was previously considered wasteland (desert) of no economic importance, even though they make up 30% of the earth land surface and are inhabited by cultures least able to conduct [formal] scientific research. The effort is also intended as a model for sharing of expertise as well as data integration and stakeholder collaboration.

**Steve Getlein and Scott Farley** gave a presentation entitled: "U.S. Army ecosystem management: Military readiness versus natural resources?" in which they discussed trade-offs faced in the management of the Red Cockaded Woodpecker (RCW) at Fort Bragg. From the Army's perspective, Fort Bragg is bearing a disproportionate share of the burden for protecting the RCW because it is practically the only remaining suitable habitat, in that development in the southeastern United States has resulted in practically 100% harvest of the RCW preferred nesting tree, the longleaf pine. Decline in the habitat has also resulted from fire suppression which has led to the overabundance of hardwood species. At the same time, Fort Bragg has a shortage of training area, which creates what has been seen as an irreconcilable conflict. However, they have begun to work with the Fish and Wildlife Service to identify a long-term solution that goes beyond the fenceline. This will require collaboration with private landowners and giving them a stake in the recovery process. They are also working with the Nature Conservancy to develop strategies for protecting priority tracts of private land. Complementary strategies are also being pursued by the Forest Service and local land trusts. Other aspects of the overall strategy include surveying and monitoring of the RCW population, establishment of a database of cluster locations and habitat status, as well as research and public education.

**David Price** discussed "Land based carrying capacity models for military training." The problem, from the Army's perspective, is a lack of adequate land for realistic training. Integrated land management is seen as the only way of ensuring continued land use. There is a specific Army mandate to identify the carrying capacity, impacts, and suitability, or sustainability for specific activities, as well as the need to comply with requirements of environmental laws. The cost model used by commanders to allocate funds for training fuel and repairs does not include land repair and maintenance. However, an environmental section was added to the Installation Status Report to compare the environmental status of the installation to an Army standard as a basis for prioritizing allocation of resources. The benefits are increased availability of land for training, reduced maintenance costs (by matching ecological capability to mission impacts), and reduced environment compliance problems.

The installation status rating is based on erosion status curves, which show the relationship between erosion status and Maneuver Impact Miles. Research efforts are aimed at reducing impacts through improved relationships between training and land condition. Training miles differ from different kinds of events (standard or offroad usage) and types of vehicles. Distribution depends on training requirements and restriction zones. Assessment of impact and recovery rate, as indicated by canopy cover, is measured based on the independent variables: number of passes, recovery times, soil types, soil conditions and vehicle types; and dependent variables: vegetation, ground cover, erosion rates, and infiltration rates. The land based carrying capacity model includes a succession model, a management model, and a training model. Submodels included in the succession model are disturbance, animal dynamics, community structure, plant growth, soil, and climate. It provides input to the management model which considers impacts on T/E species, water quality and soil erosion; costs of increased revegetation and vehicle repair, decreased training time, and decreased wildlife populations. The management model feeds back into the succession model and provides input to the training model used to allocate activity. They also provided a list of factors considered in the submodels and the results of some of the simulations which show biomass of different species under different conditions over a twenty-year period. Sediment deposition is predicted for complex topography by substituting the unit stream power approach for the topographic factor in the Universal Soil Loss Equation. Recovery is accelerated through the use of pelletized cyanobacterial inoculants, developed for application to disturbed arid lands where microphytic soil crusts have the function of soil stabilization and nutrient cycling.

**Allan Shearer and Michael Binford** discussed a project on "Biodiversity and Landscape Planning" which is examining alternative future scenarios for the region of Camp Pendleton, California. It is hypothesized that the major threats to biodiversity come from increasing urbanization—more specifically, from loss of habitat to grading, paving, ornamental landscaping and other human activities, as well as the indirect, secondary and cumulative effects (such as hydrologic and fire influences). Key questions in the research framework are:

- How should the landscape be described?
- How does the landscape operate?
- Is the current landscape working well?

- How might the landscape be altered—by what actions, where, and when?
- What predictable differences might the changes cause?
- How should the landscape be changed?

The region is described with GIS. Models are used to evaluate dynamic processes and how land use changes would impact biodiversity. These changes are examined at the scales of individual restoration projects, a subdivision, a third order watershed, and regionally. The alternative scenarios all accommodate the regional population forecast using different mechanisms—such as spread of low-density growth, spread with a future conservation strategy, large lot ownership near important habitat areas, multi-centers of development, and concentration of growth in a single new city. The process models evaluate changes in the agricultural productivity of soils, twenty-five year storm hydrographs for the different riverbasins in the region, flooding heights, water discharge and soil moisture under the different land use scenarios; the role of fire in maintaining the habitat and the risks of fire and fire suppression, and scenic preferences for the landscape. Also, biodiversity is assessed in a landscape ecological pattern model, potential habitat models for ten selected species, and a species richness model.

The objective is to help stakeholders understand the implications of different alternatives and provide tools for management, rather than to provide recommendations. They did comment however that conservation dollars can only be spent on the base and raised the question of "what if" they could be used to purchase lands upstream to offset impacts on the base.

**Jim Westervelt** described the tools for dynamic landscape simulation being developed at CERL. Requirements for future modeling environments are:

- That models be constructed in a democratic and collaborative manner
- Allow for rapid development
- In modular units (like lego)
- Have a consistent user view
- Be adaptive and robust
- Be commercially attractive

Land managers are not making much use of the increased land simulation modeling being done at research labs. The problem is that these individual models focus on particular aspects of the landscape, at a particular spatio-temporal scale, on a particular challenge, and hold most of the landscape constant. An overall objective is to create integrated dynamic spatio-temporal ecological models.

They are working with existing information to adapt it and make it usable by managers. Some software design goals are also to allow model linkage at run-time; to run them with a common clock, to provide generic model encapsulation, and provide generic viewports. Control components would be a data cache that maintains information about objects on local machines and moves the information between data caches on other machines; a data register that lists all objects and data;

and a calendar that maintains the schedule for object actions and a single simulation clock. They would also like to make it available on the internet.

Gilberto Gallopin questioned the ideology of stringing models together. Silvio Funtowicz commented that the issue is evaluation of quality of what is on the internet. As an objective, they should look to the development of agreement among the user community with respect to criteria for quality.

**Ron Sundell** discussed the Integrated Dynamic Landscape Analysis and Modeling System (IDLAMS) as a tool for linking land stewardship to the military mission by helping to determine where to allocate resources and get a bigger bang for the buck. It integrates ecological models with decision support techniques, and GIS that incorporates remote sensing and field inventory data.

The multiple land use objectives for which IDLAMS provides a trade-off analysis are: threatened and endangered species, habitat, erosion control, natural resource income, maneuvers, and infantry. It also determines the cost of land management alternatives and allows for "what if" scenarios.

The vegetation dynamics submodel is central to the other submodels: military landuse, wildlife habitat suitability, vegetation change, land management, and erosion. Others may be added for water quality, wildlife, and cultural resources. These feed into a values based decision analysis mode. The objectives of the decision analysis model are alternative evaluation and optimization.

In the vegetation dynamics model, factors that influence natural changes are forest spread, the natural fire regime, and grassland succession. Military land use impacts are a result of Maneuver Impact Miles. The land management component allows the user to select land management activities (such as planting of turf grass or native grass, or fire burning). Land Rehabilitation and Maintenance (LRAM) provides regional cost estimates for management activities. An example was provided of application to Fort Riley, where the vegetation dynamics simulation was then used to identify suitable habitat for the Henslow's Sparrow, based on preferred vegetation cover and minimum contiguous area required for nesting. The soil erosion submodel was based on the revised universal soil loss equation.

Decision analysis techniques were then used to evaluate results. A workshop was held to identify a structure for management objectives, and relate them to specific measures, then used to provide value scores to each strategy. Fort Riley is being used as a site for field testing.

**Virginia Dale** presented an assessment of training impacts on ecological resources based on the integration of spatially explicit data in a GIS, with computer models that simulate changes in land cover in response to land use impacts, and susceptibility of species to those changes. Potential limestone barrens habitat at Fort Knox was identified based on overlays of appropriate soils, geology, slope and land use/land cover conditions. Validity is tested against known sites that contain species endemic to the habitat. A model is then used to create a biological resource risk map that identifies the size and proximity of sites that species can no longer use following specified human activities.

The model combines a landscape perspective with demographic modeling, assumes that landscape structure only affects female fecundity and not survivorship, is primarily probabilistic, and is designed as an assessment tool.

This approach was used to predict Henslow's Sparrow nesting habitat at Fort Knox. Together with their estimates of the Henslow's Sparrow life history parameters and the current landscape configuration, it provided the basis for their hypotheses that the Fort Knox landscape is a population sink for the Henslow's Sparrow, that its persistence requires recruitment from other parts of the species range, and that this may also represent the historical situation, given that Fort Knox is on the edge of the species summer range.

She also commented that, in looking at scenarios, they also have to look at management constraints. The models focus on early succession processes because they have to consider the next two or three years rather than decades. Ann-Mari Jansson commented that in some instances (in Sweden), military disturbances have been shown to enhance the habitat and asked whether training had been used for strategic disturbances. Regarding questions about other kinds of impacts, Dale said they are just looking at ground disturbances—for logistic reasons, it is easier to look at one factor at a time.

**Robert H. Melton and Timothy J. Hayden** discussed the need for ecological economic approaches to conservation and recovery of threatened and endangered species on military lands. At Fort Hood, which they used as a case study, the threatened and endangered species are the Golden-cheeked Warbler and the Black-capped Vireo. The Army plays a key role in this conservation effort because Fort Hood is the largest single contiguous area under one management entity that provides appropriate habitat.

A population viability analysis identified four crucial parameters that influence extinction probabilities:

- Total seasonal fecundity
- Survival to first breeding season
- Population carrying capacity
- Immigration from the surrounding metapopulation

However, access to data on these parameters, and access to populations to manage for these parameters both require interactions with local, regional and international stakeholders beyond the boundaries of Fort Hood—and beyond Army tradition, in which responsibility and influence stop at the installation boundary. For example, knowledge of the habitats of these species on surrounding private lands is poorly known, and they overwinter in Mexico. Private landowners are reluctant to allow their property to be surveyed for threatened and endangered species for fear of legal restrictions on land use. Cowbirds, associated with the surrounding cattle populations, cause a drop in seasonal fecundity through nest parasitism. The cowbirds can be controlled through trapping and shooting,

but control over the proximity of cattle is difficult and controversial for social and political reasons. Carrying capacity within Fort Hood depends on army land use for training purposes, which is also related to global geopolitical factors, as well as grazing intensity on leased grazing land.

Ecological economic approaches could be useful in finding equitable distribution of rights and resources among stakeholders, so as to also protect both the natural capital, as well as the cultural capital, in the form of trust and good relations with local and regional landowners. The situation specifically suggests the need for multiscale modeling to examine the question of sustainability of the habitats under different uses, and valuation of Fort Hood lands on monetary, military and ecological criteria.

**Discussion of Army Land Management Case Study**
**Post-Normal Science**

To start off the afternoon discussion, **Silvio Funtowicz** (upon request), presented the conceptual framework of "Post-Normal Science." Until recently, it was generally assumed that scientists could provide certainty; all they needed was enough resources, as well as independence in the choice, conduct, and evaluation of their research. Then the fruits of their free endeavors would be facts which would entail correct policy conclusions. It was the fault of the policy institutions if they either failed to guarantee the conditions for excellent research, or to utilize its results. Uncertainty was merely a technical problem, capable of solution within the research process by a combination of standard statistical methods with ever more powerful computer technologies.

In this account, which we doubtless all recognize, there was no place for scientific uncertainty that was relevant to policy. Science provided hard facts, in contrast to the soft values that dominated the decision process. The objective, value-neutral research of the scientist inevitably produced knowledge of the highest value for the conduct of our public affairs. Thus, the scientist occupied the central role, defining both problems and solutions, in the policy domain.

In policy issues, we should expect to find that facts are uncertain, values in dispute, stakes high and decisions urgent. We would be seriously misled if we retained the image of a process in which the true scientific facts entail the correct policy conclusions. The appropriate type of problem-solving practice is what we call "Post-Normal Science." To illustrate this, we use a graphical display of three related approaches, from the most narrowly defined to the most comprehensive. Two of them are familiar from past experience of scientific or professional practice; the last, where systems uncertainties or decisions stakes are high, corresponds to the practice of the science in the policy context (Figure 1). One way of distinguishing among them is by their goals: Applied Science is "mission-oriented," Professional Consultancy is "client-serving;" and Post-Normal Science is "issue-driven." These three can be contrasted with traditional academic research, which is "curiosity-motivated."

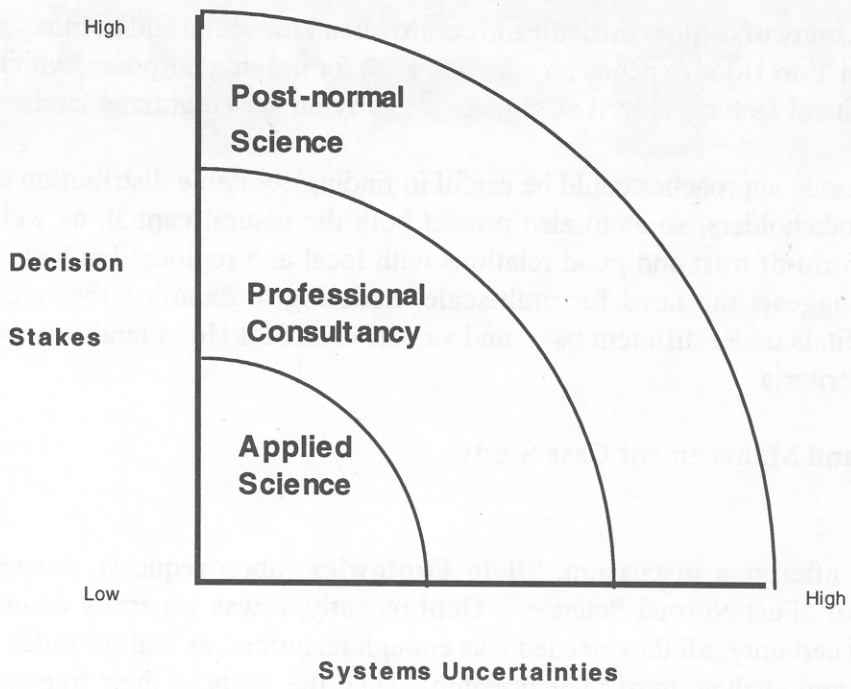


**Fig. 1. Post-Normal Science Conceptual Framework**
**Source: (Funtowicz and Ravetz 1992)**

The term "systems uncertainties" conveys the principle that the problem at hand is concerned not with the discovery of a particular fact, but with the comprehension or management of an inherently complex reality. By "decision stakes" we understand all the various costs, benefits, and value commitments that are involved in the issue through the various stakeholders. It is not necessary for us to attempt now to make a detailed map of these as they arise in the technical and social aspects of dialogue on any particular policy issue.

Post-Normal Science is complementary to Applied Science and Professional Consultancy. It is not a replacement for traditional forms of science, nor does it contest the claims to reliable knowledge or certified expertise that are made on behalf of science in its legitimate contexts. What can be questioned is the quality of that work in these new contexts, especially in respect of its environmental, societal, and ethical aspects. Previously the ruling assumption was that these were "externalities" to the work of science or technology; and that when such problems arose, an appropriate response would somehow be invented by "society." Now the task is to see what sorts of changes in the practice of science, and in its institutions, will be entailed by the recognition of uncertainty, complexity, and quality within policy relevant research.

Where scientific inputs are used in decision-making, their evaluation requires an extended peer community, analogous to those that are now involved in assessing the ethical complexities of biomedical engineering. Citizens have knowledge and understanding of problems that complements those of accredited experts; and a similar relation holds between decision makers and researchers. Thus, quality assurance implemented through recognized extended peer communities is the key to conflict resolution in the policy process. For it involves not just the "toleration" of the erroneous or

misguided views of others, but the welcoming of difference, and even of conflict, as the means to achievement of the best grasp of a reality that is inherently complex in its structure and in its values. This already happens in the case of the ethics of research and policy in biomedical fields; its extension to environmental issues is being achieved by similar struggles.

The activity of science in the policy context involves the management of irreducible uncertainties in knowledge and in ethics, and the recognition of different legitimate ways of using science and of knowing. Governmental, industrial, and even academic research are affected by these new requirements. In this way, the practice of science is becoming more akin to the workings of a democratic society, characterized by extensive participation and the embracing of diversity. Of course, this is not guaranteed to run smoothly or even successfully; but it is a better choice than one governed by rule by one vested interest, supported by force, secrecy and cover-up. We are living in the midst of a rapid and deep transition, in which all certainties, not merely those of science, are eroded; so we cannot predict its outcome. But we can help to create the conditions and the intellectual tools whereby the process of change can at least be understood and, perhaps to some extent, managed.

With respect to Army land management, there seems to be a gap between what is considered the best science, the ecosystems approach, and case studies that relate more to traditional engineering and in which probabilistic risk at complex installations is reduced to subjective possibilities. In the Mary Douglas approach, risk is reduced to cultural factors. In Post-Normal Science (PNS), we do not need to go to either extreme. All societies have the concept of danger—only modern societies have the concept of risk—which he defined as danger mediated by experts, and for which trust in experts is a prerequisite. But that trust is crumbling, as is illustrated in the case of Mad Cow disease where, in spite of expert pronouncements that the meat is safe, nobody is eating it. This has created economic chaos and almost brought the European Union to bankruptcy. To do things differently, an appropriate problem solving strategy is needed. The key question would be "What is at stake?"

**Huron Natural Area Case Study**

Also upon request, **James Kay** presented the case study of the Huron Natural area, with the caveat that it is set in a different sociopolitical context that provides a relatively strong social infrastructure, which provides the basis for what he termed "virtual governance." This term refers to the phenomena in which conservation occurs because of spontaneous community initiatives. The conservation effort at the Huron natural area was the result of citizen initiatives to protect the area and develop plans for this conservation before there was legal authority to do so.

A key consideration is the need to maintain the landscape context for what is referred to as the "figure 8" processes (based on the Holling model). This requires identification of all possible influences that could effect what goes on in the park. In defining the ecosystem, we need to identify the actors and their perspectives, select system perspectives, and envision and choose (rather than forecast) a future. The most difficult challenge is identification of the attractors. In Kay's diagram, landscape processes and structure mutually influence each other across a range of scales, from the local to the global landscape, and from the individual to the family, neighborhood, municipality, regional and global communities.

The park is in a subwatershed in a river basin, in a heavily populated region of Ontario, surrounded by lakes, and is relatively isolated. It is also under different kinds of development pressure and is in the plume of Detroit. So, the health of individuals needs to be looked at in context of their population, in context of the community, in context of the landscape, to construct a narrative of how the system behaves and/or could behave. The community did not own the land but its members made decisions to save it, and the city started quietly buying it up. They city also made it attractive for owners to sell. However, preservation of the area became a design problem when photos showed that it was agricultural in the '30s. There were also some who wanted the wetland bigger, while others wanted more trees. There was also a debate around whether or not to keep the beaver, because they cut trees.

Richard Haeuber commented that the political process is where you decide what you want to be there and that political scientists should be involved. According to James Kay, it requires a combination of what is potentially there, based on ecological information, with what we want to be there, based on values and culture. Gilberto Gallopin commented that the major critical choice is the level, or the scale at which the problem is dealt with, which is a value judgment.

**General Discussion**

- John O'Connor commented that we need to define how much of what is needed for training, what needs to be protected, and benchmarks.
- Gilberto Gallopin commented on the low tolerance for error—error is information necessary to track and improve performance—when there are no errors, the potential for catastrophic mistakes increases. He also commented on the epistemological implications of fighting to win, for which an identifiable enemy is needed—to shoot, a target needs to be isolated. So what if there is no isolatable target?
- Stewart Cohen—it might be useful to broaden range of variables.
- Martin O'Connor commented that the coexistence of different forms of life constitutes a design problem. Ecological economics is full of this kind of debate. It is a matter of tool design and how they are used. James Kay distinguished analysis from design as looking at what is there rather than what could be there. Design requires a whole different set of tools. Formal modeling deals with what is already there.
- One of the Army representatives commented that they still do not know what Army managers can use—it seems that a lot of theoretical work is still needed to be able to move from theory to application, and to be able to do a demonstration project.
- Gilberto Gallopin commented that recipes are not likely to work. As an approach, he suggested looking outside the boundaries of the system, up and down, and to consider the role of worldview, or what is considered important. The Army has a worldview that is different from Greenpeace—it could be useful to reflect on this, make explicit the assumptions embodied in the worldview, and see if it points to comparative advantages or weaknesses.

- Someone remarked that corporations are getting rid of the economists that gave them the numbers. According to Silvio Funtowicz, now we have to prove that there is something in between the quantitative and qualitative extremes.
- Martin O'Connor commented that good data is not enough as the basis for a good decision. The concept of "negotiating scenarios" leads to different information requirements.
- John O'Connor suggested the objective of progress rather than perfection, for which a process change is needed, such as is occurring at the World Bank. From process, we can then look at social and cultural issues, but there is no cookbook.

## General Discussion and Workshop Conclusions

**Some key points and issues identified by participants:**

- Linking theory to practice—
  - what are the tools?
  - how best to close the gap?
  - there are no recipes.
- Changes in decision-making process
  - from quantitative only to qualitative and quantitative
  - iterative
- Ecological economics is also about politics
  - data and models feed into and feedback from negotiation
  - institutional context is a design principle
- Alternative world views of different stakeholders need to be considered.
- Military installations and large infrastructural development projects, such as dams, should be considered as experiments, in contrast with a control style of management.
- The relationship of ecological economics to integrated assessment needs to be clarified and strengthened.
- Importance of leadership in the stakeholder decision-making process.
- Stakeholder involvement leading to a participatory consensus entails the redistribution of power (or empowerment).
- It is more complex than the "twelve steps" in that it is non-linear, iterative, and parallel.
- Environmental problems as socio-environmental conflicts that should be dealt with in a conflict resolution framework—we need to consider mechanisms for conflict resolution, prevention, and management—agencies now recognize these problems as train wrecks.
- Anticipation of stakeholders leads to participation.

- We can live with complexity or become paralyzed—we can not live without it.
- We can live with uncertainty and take shared risks.
- Adapting to, versus controlling the environment.
- Importance of process in defining options for management and selection.
- Local knowledge is extremely important in the process.
- Models should feed into monitoring and indicators.
- Biological and cultural diversity as elements in design for conservation.
- IA as a framework for mutual learning in which narratives, informed by participatory processes (such as roundtables), inform what is possible and what is desired, which inform the process. This iteratively produced narrative provides the basis for a temporary consensus and decision-making actions at a certain point in time, the results of which also feedback into the narrative.
- What is possible, versus what is desired.
- Role of scientists as stakeholders.
- Scale affects definition of issues, context, identification of actors, choice of tools/ methods, and sustainability.
- James Kay recommended a document written by Tim Allen for the Great Lakes International Joint Commission (IJC) which goes through the procedural steps.
- Role of individual leadership, use of tools, and communication within organizations, rather than organizational leadership.
- The Army is stuck at the end of the pipeline in terms of what they can do. Is there a non zero value for non traditional stakeholders? (John O'Connor)
- John Wuichet—suggested a comparison between the Army and the Pantanal case studies.

In closing, Silvio Funtowicz commented that it is not unfair to say that the exchange was a fascinating experience from which we have learned a lot, and thanked the Army for making it possible.

**Suggested alternative titles for volume:**

- Ecological economics for integrated environmental assessment
- The complex mission of ecological economics
- The uncertain quest
- Integrating perspectives, models, and assessment for sustainable development (in ecol econ)
- Applied Ecol Econ: linking integrated assessment and adaptive management or, between hard numbers and California touchy feely
- The uncertain quest: integrating perspectives, models, and assessment for SD [in ecological economics]
- The complex mission of ecological economics.
- Ecological economics for integrated [environmental] assessment —the uncertain quest
- Integrated Adaptive ecological economic analysis—a process for the design and evaluation of sustainable development programs
- Integrated environmental assessment: The complex mission of ecological economics

**Suggested alternative book outlines:**

- Introduction
- Synthesis
- Paradigm shifts and overlaps
- Stakeholder perspectives
- Modeling and analytical methods
- Sustainability indicators and monitoring perspectives
- Linking indicators and models
- Application issues

[modification suggested by Olman Segura:]

- Introduction
- Synthesis
- Paradigm shifts and overlaps
- Valuation and decision-making
  (including stakeholders perspectives, valuation and institutional arrangements)
- Indicators and policy
  (which may be separated but including modeling and analytical methods and sustainable indicators and monitoring perspectives and the linkage between indicators and models)
- Other application issues
  (which include some of the case studies that do not fit in the last two sections)

Applied ecological economics: a contribution to IA

- Introduction
  - Definition of ecological economics
  - Definition of postnormal science
  - Relevant IA activities
- Applied science
- Synthesis, lessons learned
- Contribution to "IA" framework
- Synthesis
- Case studies
- Evaluation of case studies in context of "IA"

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## 2.4 Memorandum and Agenda

### 2.4.1 Results of the First Workshop

The first workshop evaluated emerging methods in integrated ecological and economic modeling in the context of case studies and in terms of their contribution to an integrated assessment framework and practical applicability to sustainable development. A research agenda was also produced that considers issues of application in various cultural and developmental contexts—using the Pantanal as a case in point.

A framework for Integrated Assessment was proposed in which the crucial aspects are the process of engaging stakeholders in the initial phase of establishing objectives for sustainable development, in defining the scope of issues to be addressed in the modeling effort, as well as in monitoring activities. It is based on the recognition that participatory methods are needed for dealing with complex environmental problems in which there is high uncertainty, values are in dispute, stakes are high, and decisions are urgent. This process provides the basis for evaluating sustainable development activities relative to the problem, and for selecting methods accordingly. As is demonstrated in case studies, values are inherent in models and in analytical methods, and need to be made explicit. Key research priorities are in the development of valuation methods relative to the objective of sustainable development. This bottom-up approach is complementary to the traditional top-down approaches, provides the basis for political and scientific legitimacy in making value judgments and decisions with respect to unavoidable trade-offs, provides a basis for the development of effective institutions for resource management, and is crucial for the long-term success of development activities that are relevant to public concerns.

### 2.4.2 Objectives of the Second Workshop and Key Issues

The second workshop is intended to address the implications of issues raised in the first workshop, as well as gaps in coverage and to flesh out the content of the final volume that will result from the project. Among the key issues is the contribution of integrated models to indicators for sustainable development, with an emphasis on the role of stakeholders in defining the criteria for indicators and on contrasting criteria for decision-making that are inherent in the models upon which the decisions are based.

Indicators reflect what is important to diverse stakeholders and the criteria by which decisions are made. (Included in the "stakeholder" category are scientists and what they deem important from diverse disciplinary perspectives, as well as policymakers who have obligations to their constituents.) Models provide a tool for illustrating relationships and trade-offs among diverse objectives. However, much of the work on indicators has been based on a static pressure-state-impact-response framework that fails to capture the dynamic relationships and trade-offs among different objectives. There have also been attempts to determine a few highly aggregated summary indicators as a basis for policy evaluation at national and international levels, in a manner similar to the GNP approach. Missing in this approach is a recognition of the importance of the distribution of impacts among diverse regions and social sectors, as well as the unique elements of a particular place that people want to protect.

Conceptual frameworks linking dynamic models and indicators have been suggested in some recent reports. For example, a draft report by Donella Meadows, based on a recent workshop hosted by Rijks Instituut voor Volksgezondheid en Milieu (National [Netherlands] Institute of Public Health and the Environment) (RIVM) in the Netherlands suggests that the language of systems theory can be used to communicate the significance of relationships regarding the biophysical dimensions of the system to non-scientists, as well as for scientists to understand what is important to the communities in which they work in. The document also acknowledges that indicators reflect value judgments and concedes that it is easier to define the characteristics of ideal indicators than to actually identify specific indicators. Although it lists several favorite indicators of the participants, it stops short of advocating particular ones and acknowledges the role of stakeholders in this process. A recent RIVM report (Swart, Bakkes et al.) suggests building on the pressure-state-response framework by using integrated modeling to show dynamic relationships among indicators. Because of the limited knowledge of causal relationships, they also suggest a gradual transformation from a static to dynamic framework. However, because of high uncertainty in complex environmental problems, it may be unrealistic to expect sufficient knowledge of cause and effect relationships as the basis for these links—emphasis will be on dynamic "use" of models, to monitor hypothesized relationships and provide feedback to stakeholders as the basis for policymaking.

The SCOPE workshop will build on these and other reviews, and on the stakeholder process outlined in the first workshop, and will identify indicators suggested in particular case studies, as well as the process by which they were defined. Although different case studies will be presented, special attention will be given to a case study from a northern industrialized country as a case in point (as was given to a case study from a developing country in the first workshop). One possibility is to examine conflicts that result from changes in adjacent land uses, such as the encroachment of urban development in areas adjacent to areas managed for other purposes such as agriculture, wildlife conservation, outdoor recreation, and national defense training.

The workshop will consist of presentations that provide an overview of indicator work that is consistent with this perspective. Some case studies will also be presented regarding communities who have been through the process of defining what is important to them and of preparing their own plans for resource management and conservation which reflect local knowledge and values. Roundtables will be then be held to examine indicators suggested by case studies and to identify conflicts and inconsistencies among them. This is expected to provide the basis for identifying areas of cognitive dissonance and unresolved issues, and for developing recommendations regarding a structure for long-term partnerships among scientists and communities for addressing these areas.

### 2.4.3 Agenda and Participants

[Since a few participants will arrive late because of flight booking difficulties, we are beginning late on the first day.]

**Wednesday, July 31, Morning Session (Day 1)**

10:00 Coffee

10:15 Introduction; project overview; recap of the first workshop and unresolved issues.
Robert Costanza (Chair SAC)

10:45 Overview of conceptual frameworks linking integrated models and indicators for sustainable development and related projects.
Sylvia Tognetti (Project Officer)

11:15 General discussion of meeting agenda.
Some focal points: institutional constraints on problem definition; the need to link local, regional and global scale analysis in a complementary framework; criteria for SD as they are reflected in different approaches to ecological and economic modeling; and identification of specific criteria held by diverse stakeholders (including modelers and decision-makers) in case studies presented.

12:00 Lunch

**Wednesday, July 31, Afternoon Session (Day 1)**

Modeling perspectives
*Moderator: Bob Costanza*

1:00 Use of dynamic models in conjunction with multicriteria, spatial analysis and other methods to determine intra and inter-regional distribution of costs and benefits.
Jeroen van den Bergh

1:30 The Quest model—an interactive model designed for transparency of criteria that can also be used to elicit user criteria.
Dale Rothman (on behalf of John Robinson et al.)

2:00 Incorporating diverse perspectives and uncertainty in Integrated Assessment Modeling and lessons learned regarding the IA process and the role of critical intermediaries.
Jan Rotmans and Marjolein VanAsselt

2:45 Discussion of modeling approaches

3:00 Coffee break

Contrasting criteria and implications for identification of indicators for SD

*Moderator: Silvio Funtowicz*

3:15 State of the Landscape Reporting—The Development of Indicators for Land Use Planning and Protection. James J. Kay

3:45 Situational Indicators for Land Management. Gilberto Gallopin

4:15 The MacKenzie Basin Impact Study—potential for scientist-stakeholder collaborative research on and monitoring of the impacts of climate change. Stewart Cohen

4:45 Discussion

5:00 Adjourn

6:00 Reception

**Thursday, August 1, Morning Session (Day 2)**

Economic perspectives and considerations

*Moderator: Olman Segura*

9:00 Distributional biases in valuation methodologies and "distributed sustainability" in the context of biodiversity issues. Joan Martinez Alier

9:30 Reformatting national accounts consistent with a post-classical theory of value. Martin O'Connor

10:00 Valuing damages of air pollution in India—SD criteria from a third world perspective. Jyoti Parikh

10:30 Coffee break

Social perspectives and considerations

*Moderator: Richard Norgaard*

10:45 Defining "Stakeholders" and resources. Judith Bradbury

11:15 Science and culture: patterns of construction (in Brazil)—a developing country perspective. Judith Cortesão

11:45 Discussion: Criteria suggested by a co-evolutionary framework.

12:00 Lunch

**Thursday, August 1, Afternoon Session (Day 2)**

Policymakers perspectives
*Moderator: Peter May*

1:00 Contrasting criteria for water resources management among federal state and tribal governments and natural resource management practices in Native American communities.
Catherine Vandemoer, U.S. Department of Interior

1:30 Decision-making criteria for sustainable development.
John O'Connor

2:00 Plenary discussion.
*Moderator: Bob Costanza*

3:00 Coffee break

3:15 Plenary discussion continued.

5:00 Adjourn

**Friday, August 2, Morning Session (Day 3)**

Case study: Ecological and Planning Perspectives on Land Management Modeling for U.S. Army Installations
*Moderator: David Tazik*

8:00 Conservation policy and environmental planning.
John Wuichet, Peter Rzeszotarski, and David Eady

8:20 U.S. Army conservation planning processes: a critique.
Rick Haeuber

8:40 The Mojave Desert: America's vast, little chartered wasteland.
Steve Ahmann

9:00 Camp Pendleton habitat conservation plan.
Michael Binford and Alan Sheerer

9:20 U.S. Army ecosystem management: Military readiness versus natural resources?
Scott Farley and Steve Getlein

9:40 Coffee break

10:00 Spatial dynamic ecological modeling.
Jim Westervelt

10:20 Land management modeling and simulation.
Richard Price

10:40 Dynamic landscape modeling links land stewardship to the military mission.
Ron Sundell, Pam Sydelko, and Kim Majerus

11:00 Land based carrying capacity models for military training.
David Price

11:20 Assessment of training impacts on ecological resources.
Virginia Dale, Tony King, Linda Mann, Ron Kickert, Tom Ashwood, and Mark Smith

11:40 Ecological modeling in support of threatened and endangered species.
Tim Hayden and Bob Melton

**Friday, August 2, Afternoon Session (Day 3)**

Ecological and Planning Perspectives on Land Management Modeling for U.S. Military Installations

*Moderator: David Tazik*

1:30 Roundtable Discussion. Discussion will focus on a few major questions that emerge from the morning session; for example, what are the major limitations to effective conservation planning on Army lands?

4:30 Adjourn

**Saturday August 3, (Day 4)**

Roundtable discussion on unresolved issues and development of proposed conclusions and recommendations.

Point of departure for discussion: Rapporteurs summaries of presentations.

*Moderators: Maryam Niamir-Fuller and Bengt-Owe Jansson*

**Sunday, August 4, (Day 5)**

Recommendations and Conclusions.

*Moderator: Bob Costanza*

# Chapter 3. Integrated Ecological and Economic Models and Indicators for Sustainable Development—A Literature Review

## 3.1 Introduction

### 3.1.1 Scope of This Review

This review is part of the SCOPE/UNEP project on Integrated, Adaptive Ecological Economic Modeling and Assessment, partially sponsored by U.S. Army Environmental Policy Institute (AEPI). The overall objectives of the project are to review emerging methods in integrated ecological and economic analysis in the context of case studies to determine their practical applicability to problems of sustainable development. Some of the underlying concerns are to consider the gap between theory and practice of sustainable development, and to provide support for a broader approach to environmental and economic issues. This broader approach includes consideration of: (a) distributional equity and appropriate scale of consumption relative to ecological limitations; and (b) optimal allocation of resources or efficiency (the traditional focus of economics). Project activities included a planning meeting and two workshops.

This document is intended to review the literature regarding the relationship of ecological and economic models and conceptual frameworks to indicators of progress towards sustainable development, and to highlight the relevance of the overall project to military land management policy issues. Because of the abundance of activity on the topic of indicators, and the availability of some recent comprehensive literature reviews on the subject of indicators themselves, the emphasis will be on the following:

- Key issues and conceptual frameworks (some of which were identified in referenced literature reviews)
- Some recent key documents not covered elsewhere
- Links or integration between local, regional and global as well as intersectoral approaches

Special attention will be given to participation and decision models, as well as overall social and economic aspects of indicator development and participatory approaches. These are among the weakest areas in the literature (categorized as relevant to indicators) and are arguably the most important, given the role of perception and interpretation in the identification and use of indicators.

Special attention will be also be given to literature relevant to land management and land use conflicts from the perspective of northern industrialized countries. This land management is also a key interest areas of the sponsor, the U.S. Army Environmental Policy Institute, which provides policy advice regarding the management of large areas of land for military training purposes. These military training areas, training important as core areas for protection of wildlife habitat, are increasingly encroached upon by urban development and other conflicting land uses. These issues

are also of importance to other land management agencies and are at the core of some of the most controversial and seemingly intractable environmental problems.

### 3.1.2 Overview of SCOPE/UNEP Project

Participants in the first workshop were asked to present particular methods in the context of a case study that illustrates practical application, and makes explicit the values inherent in the approach. The Pantanal region of Brazil, where the workshop occurred, provided context for discussion of developing country concerns, as well as a case study of a complex problem in sustainable development. In the second workshop, participants examined some crosscutting issues regarding practical applications, including the relationship of ecological economic models to indicators for sustainable development, the process of integrated assessment, and theoretical considerations. As a case study, special attention was given to land management at military installations and the issues of concern to U.S. AEPI, which sponsored the workshop. The overall product was a participatory conflict resolution framework that draws on all of the material and which is the subject of a synthesis chapter that will be part of a final volume.

At the first project workshop, a framework for Integrated Adaptive Ecological Economic Modeling and Assessment was proposed, in which the crucial aspects are the process of engaging stakeholders in:

- The initial phase of establishing objectives for sustainable development
- Defining the scope of issues to be addressed in modeling efforts
- Monitoring activities

The framework is based on the recognition that meaningful public participation provides the basis for legitimacy in dealing with complex environmental problems in which there is high uncertainty, values are in dispute, stakes are high, and decisions are urgent. The process also provides the basis for evaluating sustainable development activities relative to the problem, and for selecting methods accordingly. Although the need for public participation is becoming more widely acknowledged, enlisting public participation is easier said than done and more effective methods of involving the public are needed. Failure to acknowledge and consider diverse and legitimate perspectives has brought about what many consider a crisis of legitimacy for institutions that profess sustainable development.

As is demonstrated in case studies, values and criteria are inherent in models and in analytical methods, and need to be made explicit. Key research priorities are in the development of valuation methods relative to the objective of sustainable development. Implications for both research and for indicators are the need to be able to deal with disaggregated and distributional data (as a complement to aggregated data and generalizations) regarding the perspectives of those who are affected by changes, as well as acknowledging the value of local knowledge and experience. In other words, we need to redefine the interface between science and society, keeping in mind that researchers as well as decision-makers are also stakeholders. This bottom-up approach is complementary to the traditional top-down approaches, and, in addition to political and scientific

legitimacy in making value judgments and decisions with respect to unavoidable trade-offs, provides a basis for the development of effective institutions for resource management, and is crucial for the long-term success of development activities.

The second workshop was intended to follow up on issues raised in the first workshop, as well as to fill in gaps in coverage and to flesh out the content of the final volume that will result from the project. Among the key issues addressed was the contribution of integrated models to indicators for sustainable development, with an emphasis on the process of actually involving stakeholders in defining the criteria for indicators, and on contrasting criteria for decision-making that are inherent in the models and methods used to support decision-making. If we view environmental problems as problems of social and political conflict resulting from the externalization of environmental and social costs, for which the burden falls disproportionately on the most vulnerable and marginalized populations, as well as future generations, then it becomes imperative that these problems be addressed in a conflict resolution framework.

### 3.1.3 Army Land Management Policy Issues

The second workshop was sponsored by the U.S. Army Environmental Policy Institute, which provides policy advice for management of military lands at Army installations, under the multiple criteria of use for military training, and compliance with environmental laws. Particular environmental concerns are the requirements of the Endangered Species Act and a DoD mandate to implement ecosystem management. Military lands may provide the largest contiguous area under one management entity with appropriate habitat for threatened and endangered species (for example, Fort Hood) in the United States—satellite images of many installations show them as islands of wildlife habitat and biodiversity in a sea of agricultural and urban development. The lands are under increasing pressure because of changes that affect military training and intensity of land use requirements. These changes include:

- The end of cold war
- Smaller regional conflicts
- A switch from forward to U.S.-based deployment
- Base closure and realignment
- The concept of environmental security

Training-induced environmental degradation also interferes with the ability to continue to use land for training. Some challenges, such as encroaching urbanization, are external the installation fenceline and to Army jurisdiction—but are not unrelated to military presence in the region.

Army research staff have addressed the problem by developing a modeling framework that is intended to provide decision support for individual installations and pool information, although this solution is admittedly more integrated in theory than in practice. The framework consists of simulation models in modular units, with GIS, model-to-model and user interfaces, impact analysis and risk management tools, visualization tools, and connection to external systems. From their perspective, challenges in the modeling effort are: to make them usable to land managers who have

not been using models being developed at research labs; and to fill gaps in understanding of ecological processes needed for simulation models. Another problem is that individual models focus on particular aspects of the landscape at a particular spatial and temporal scale, holding most of the landscape constant—an objective is to create integrated, dynamic, spatio-temporal, ecological models. A large amount of effort has also gone into finding ways of measuring and reducing training impacts.

At Fort Riley, the Army is field testing the Integrated Dynamic Landscape Analysis and Modeling System (IDLAMS), which does a trade-off analysis among multiple land use objectives, and in which management objectives have been linked to specific measures to identify and score various strategies. At Fort Knox, GIS overlays and models (developed by Dale/ORNL) have been used to identify potential habitat for particular species and create biological resource risk maps. In one project done in collaboration with other agencies, alternative regional scenarios were developed (by Shearer and Binford) for the area around Camp Pendleton to determine implications of different land use patterns for biodiversity as a tool for stakeholders to understand the alternatives in the development of conservation plans.

Ecosystem management represents an institutional challenge more than a technical one because access to data regarding crucial parameters may require interaction with other stakeholders (for example, habitats on surrounding lands where owners fear legal restrictions, and areas in foreign countries to which species migrate). The Army also recognizes that participation is essential in defining goals for ecosystem management. However, Integrated Natural Resource Management Plans (INRMPs) for Army installations stop at installation boundaries and have no processes for participation across the fenceline. Some installations (such as Fort Bragg) feel that they bear a disproportionate share of the burden for threatened and endangered species, such as for the Red Cockaded Woodpecker (RCW), because they provide most of the remaining suitable habitat. On private lands, most of the preferred nesting tree for the RCW has been harvested. The Army is developing a long-term strategy and is looking to ecological economics to help identify an equitable distribution of rights and resources among stakeholder.

### 3.1.4 Relevance of Ecological Economics to Army Land Management Concerns

Given the Army role in addressing situations of conflict at different levels—from stakeholder conflicts surrounding military installations to regional and global conflict, in which the Army is increasingly finding itself in the role of peacekeeper—the recognition of environmental problems as sociopolitical conflicts can provide the basis for a framework that is conceptually consistent at these different levels. A Multi-criteria Decision Analysis (MCDA) framework could be used to anticipate land use conflicts as well as to consider the problem from different perspectives. An MCDA framework could also be used to develop some common criteria with which to evaluate the relationship between the missions of defending national security and protecting the environment, which might be considered subgoals of what is at root the same objective—of sustainability, or security broadly defined. There has been some resistance from decision-makers to using such methods because, unlike cost-benefit analysis, they do not provide a single correct answer. Instead, they provide the basis for deliberation, negotiation, and a more reflective approach to decision-making.

decisions. According to Hays, author of one of the classics of environmental history (Hays 1959), this also had the effect of suppressing rather than resolving social and economic conflicts over resource use in a time of great uncertainty and economic struggle as a result of rapid industrial growth, and reducing public participation to an administrative exercise designed to prevent decisions, in effect already made, from arousing too much resentment.

In the meantime, many of those water development projects defended through CBA have become environmental restoration projects at many times the cost of the original project, and in which the civilian side of ACOE is looking to more participatory evaluation methods in partnership with other government agencies. Among the better known examples is the $276 million effort to restore curves into the Kissimmee River in the Florida Everglades—a 166 km river that was channelized and straightened by the U.S. ACOE between 1961 and 1971 as part of flood control efforts and which drained 12,000 to 14,000 ha of floodplain wetlands, at one eighth of the cost of restoration (ENR 1990).

Participation is not just politically and ethically necessary but also practically necessary because it includes plurality of judgment. Information that anticipates conflict and informs negotiations is also more useful for decision-making than cost-benefit analysis. The key questions to be answered are "what is at stake" and "what is to be sustained." Participation is also necessary for defining the mutual interests that provide the legitimate basis for policy. From this perspective, coexistence is a problem of design and scenario negotiation. Given the current period of transition to a post-cold war era, as well as what appear to be increasingly rapid rates of global environmental, social and economic change, and the multiple roles of the military, now may be also be an appropriate time to consider the kind of institutional change needed for use of a participatory conflict resolution approach and multi-criteria decision analysis with respect to the fundamental problems encountered in sustainable development.

## 3.2 Definitions

Ecological economics can be distinguished from conventional approaches to economics in that ecological economics includes questions of distributional equity and scale of consumption in its conceptual framework, in addition to efficiency (Costanza 1991; Daly 1992). Although most practitioners of conventional economics acknowledge the importance of such questions, they are generally seen as external to the conceptual framework, to be addressed only after resources have been most efficiently allocated. Equity and scale are essential to the goal of sustainable development because the use of economic instruments in isolation can place a disproportionate and unfair share of the burden on the most vulnerable and least advantaged members of society, who may be external or marginal to the decision making process, and make the problem worse. Also, while methods such as cost-benefit analysis, which is based on the concept of efficiency and optimization, may be appropriate for well-defined problems in which there are low stakes, low uncertainty, and no conflicting values, their appropriateness is highly questionable in complex problems which have the opposite characteristics, such as climate change and infrastructural development. In the conceptual framework of Post-Normal Science (Funtowicz and Ravetz 1992) (see Figure 1), complex problems require a bigger toolbox and participatory research methods because high stakes decisions

and value judgments cannot be made by experts and policy makers alone. The need for a shared vision growing out of social discourse, with contributions from diverse perspectives, and the problem of communication, are seen as a fundamental problem motivating the development of participatory approaches to ecological economics and to integrated assessment.

Definitions of *indicators* identified by Boyle (1996) generally refer to indicators as quantitative measures of system conditions and trends. Depending on objectives, indicators might consist of single or multiple variables, might also incorporate qualitative and subjective information, might be diagnostic of causes or simply informative of changes, and might provide a basis for monitoring processes as well as conditions. A more general definition that encompasses all of these possibilities is that indicators are measures of performance and policy effectiveness which are meaningless outside the context of policy and/or monitoring objectives toward particular social goals (Boyle et al. 1996).

A review of definitions by Gallopin (in press) also includes: "a measure of system behavior in terms of meaningful and perceptible attributes" (Holling 1978), as well as "measure," "statistical measure," "proxy for a measure," "measuring instrument," "index," "something," "an empirical model of reality," and, in the most general terms, a "sign." Gallopin also distinguishes nominal scale variables, which refer to variables with no mathematical properties (such as blood type) from ordinal or ranking scale variables in which properties may be ranked, and metric variables that can be associated with measurements of distance, in an interval or a ratio scale. Finally, situational indicators, that is, the concept of "indicator species," imply a set of associated conditions. A set of distinguishing features is considered a vector or a profile that gives a picture of the whole, and which may embody conflicting objectives.

Given the variety of definitions, Gallopin (in press) suggests it is more important to say what is not an indicator. Also, given that indicators represent distinguishing properties of a system from the perspective of the observer, he stresses the importance of qualitative and interpretative factors, in that their significance arises from the interpretation made about them or the meaning they are assigned. To this we add that, to be effective as feedback mechanisms that tell us whether or not particular goals are being achieved, indicators need to reflect the concerns of diverse stakeholders because they provide a basis for making inferences about the behavior of the system, most of which is unobservable, based on the relationship between *experience* and factors that can be observed.

In this review, ecological economic models and indicators are both examined in terms of how they contribute to an *Integrated Assessment* framework, or IA. One common definition of IA is: "procedures to arrive at an informed judgment on different courses of action with regard to environmental problems. The information required refers to physical, chemical, biological, psychological, socio-economic and institutional phenomena, including the relevant decision making

processes" (Jaeger 1994). Although much of what has been called IA has consisted of quantitative models, equally important are issues of process. A working definition adopted at the first workshop of this project is:

> Integrated Assessment is an adaptive and participatory process that includes a pluralistic set of modeling and assessment tools and perspectives (horizontal integration) to link all stakeholders (including users, scientists, and policy-makers - vertical integration). It is adaptive in the sense that policies are seen as iterative experiments that we can learn from and improve upon, rather than as once and for all solutions. This process requires that assumptions be made explicit, and facilitates the development of a shared vision of the future.

Although individual disciplines are considered important components, Integrated Assessment can be distinguished from mainstream scientific inquiry by the need to provide policy-relevant information about issues of interest (Bailey et al. 1995). As described by Rotmans and Van Asselt (1996), it seek insights that cannot be derived from a single disciplinary analysis. The authors define Integrated Assessment as "an interdisciplinary and participatory process of combining, interpreting and communicating knowledge from diverse scientific disciplines to allow a better understanding of complex phenomena," Two characteristics that could also serve as evaluation criteria are that it:

- Contain added value compared to insights derived from disciplinary research
- Provide decision-makers (and society) with useful information

Some particular challenges described by Bailey et al. (1995) are: to provide a framework and management structure in which "diverse approaches are widely accepted and given an opportunity to contribute fully to the assessment;" and to facilitate interaction between practitioners and users, whose "needs should help direct the nature, aims and criteria of success of an assessment" in contrast with viewing them as a black box.

Thus, IA includes but is not limited to modeling. *Integrated models* are, generally speaking, models that integrate different kinds of information, including biological, physical, social and economic, to determine implications of complex environmental problems such as climate change. These models have been developed by scientists with some involvement of policy-makers and with emphasis on quantitative aspects (Bailey et al. 1995). The models have also been weak on socioeconomic aspects. Given the emphasis on process approaches to IA, this review includes models of participation and decision-making as intrinsic elements of the system. The framework in Figure 2, proposed by Rotmans and Van Asselt (1996), and which also represents discussions held at the SCOPE workshop, illustrates the relationships between different elements of the process, in which IA is seen as a cyclical framework of mutual learning. The framework is also elaborated on in the section on participatory processes and decision-making.

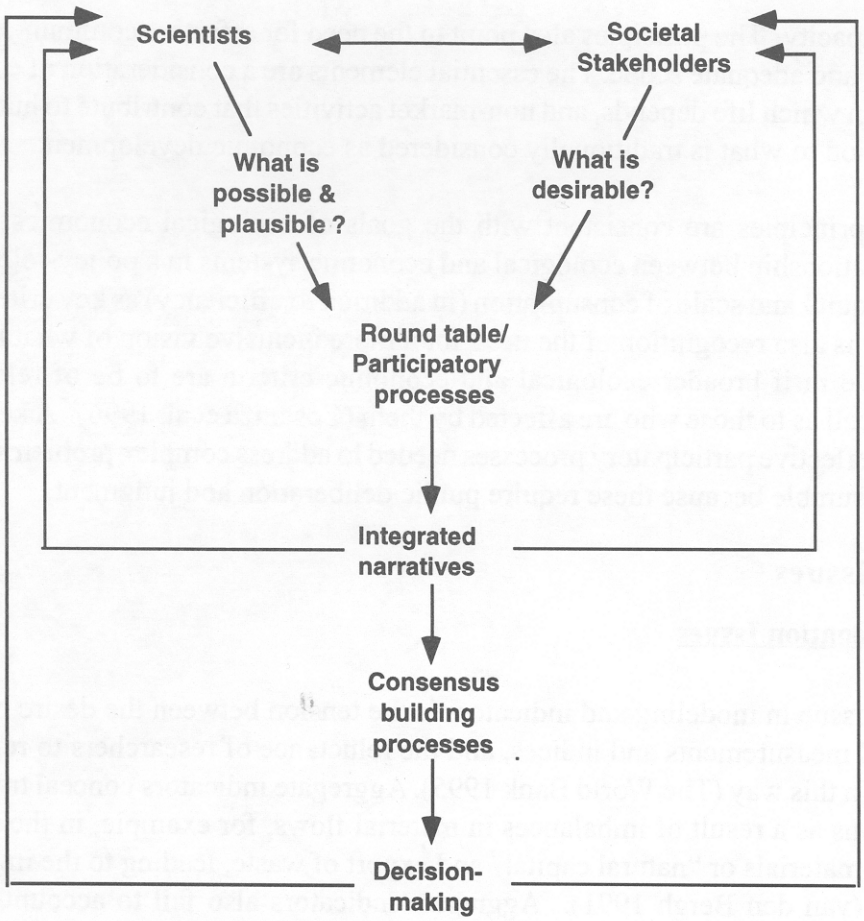


**Fig. 2. Integrated Assessment as a Cyclical Framework of Mutual Learning**
**Source: (Rotmans and Van Asselt 1996)**

## 3.3 Some General Principles Associated with Models and Indicators

It is not possible to identify and evaluate appropriate indicators without reference to conceptual frameworks, models and general principles that define the objectives. Some general principles around which there appears to be an emerging broad consensus among those actively involved in research and policy regarding indicators for sustainable development are the "**Bellagio Principles**" (see Appendix A), which were developed at an expert meeting organized by the International Institute for Sustainable Development in 1996 and subsequently endorsed elsewhere. In these ten principles, process is at least as important as if not more important than the technical task of indicator identification.

First and foremost of these principles is the need for a guiding vision and goals which, to be effective, need to be defined through processes of public deliberation. Broad participation implies participation of a broad range of stakeholders, explicitly including decision-makers, to insure that there is a link to policies and resulting action. These diverse perspectives can also contribute to the holistic perspective needed for the assessment, which needs to be an ongoing, iterative adaptive process that involves collective learning, feedback to decision-making, and development of

institutional capacity. The principles also point to the need for effective communication, openness, practical focus and adequate scope. The essential elements are a consideration of equity, ecological conditions upon which life depends, and non-market activities that contribute to human/social well-being, in addition to what is traditionally considered as economic development.

These principles are consistent with the goals of ecological economics, which seek to address the relationship between ecological and economic systems in a policy-relevant framework that includes equity and scale of consumption (in addition to efficiency) as key criteria for decision-making. There is also recognition of the need for a more inclusive vision of what kind of a society we want to live in if broader ecological and economic criteria are to be of relevance to actual decisions, as well as to those who are affected by them (Costanza et al. 1996). A key challenge is to develop more effective participatory processes needed to address complex problems in which values are incommensurable because these require public deliberation and judgment.

## 3.4 Key Issues

### 3.4.1 Aggregation Issues

A key issue in modeling and indicators is the tension between the desire of policy-makers for aggregated measurements and indices, and the reluctance of researchers to represent complex open systems in this way (The World Bank 1995). Aggregate indicators conceal trade-offs between different regions as a result of imbalances in material flows, for example, in the disproportionate import of raw materials or "natural capital" and export of waste, leading to the impoverishment of other regions (van den Bergh 1991). Aggregate indicators also fail to account for site-specific problems that undermine global sustainability through cumulative effects, although they may be useful for comparing local to global trends.

For example, the Organization for Economic Cooperation and Development (OECD) indicator of sustainable wood production is based on the ratio of annual harvest to mean annual increment or growth, which suggests that globally, consumption patterns are in balance with the supply capacity of world forests. According to a World Bank report on monitoring environmental progress (1995), not revealed are problems with local availability of wood products and fuelwood, damage from current activities, losses to pollution or soil degradation, and variation in growth rates across regions. Also important is the amount of unfragmented forest—a factor important in maintaining watershed functions and in providing habitat for top predators, although even national level data still does not reveal specific local phenomena. For biodiversity, geographically explicit indicators are needed to show where and why habitat loss is occurring. With respect to air pollution, the report suggests a focus on driving forces, that is, the magnitude of particulates generated by particular economic activities. With respect to water supply, microlevel detail that considers the different information requirements for urban and rural areas is important because global indicators regarding connections to water supply and sanitation services say nothing about the quality or cost, and whether or not water supply and sanitation services are actually received. As is discussed in the section on distribution issues, aggregation methods also conceal economic distributional biases.

### 3.4.2 Sustainability Criteria

The concept of sustainability is consistent with the economic concept of income as defined by Hicks (1946), which is the amount that can be consumed without becoming impoverished, with the objective of being as well off at the end of the week as at the beginning. Although there is general agreement that sustainability implies meeting the needs of the present without sacrificing the ability of future generations to meet their needs, as defined by the World Commission on Environment and Development (1987), or, in economic terms, non-decreasing per-capita well-being over time (Pearce et al. 1996), different theories and interpretations of how to meet those objectives give rise to often conflicting criteria for decision-making commonly lumped into the categories of weak and strong sustainability—and a seemingly infinite array of corresponding indicators.

**Weak sustainability**, with the objective of maintaining total capital intact, assumes substitutability between manufactured and natural capital, and strives to "get the prices right," based on the assumption that environmental problems are the result of externalities associated with market failures. **Strong sustainability** has the objective of maintaining natural and other forms of capital independently, assumes that natural and manufactured capital are complementary and non-substitutable, and recognizes the non-linear character of natural systems. Some other criteria are: intergenerational equity (non-decreasing welfare over time); steady state (maintain constant stocks at optimum scale, minimize throughput); and resilience (maintain ecosystem resilience and diversity; adapt to ecosystem cycles, variation, and uncertainty). The choice of indicators is therefore closely related to such criteria or policy choices. Modeling can be used to demonstrate the implications that follow from these approaches (van den Bergh 1996).

**Weak Sustainability**

Weak sustainability is associated with aggregate indicators, in which environmental costs and benefits are reduced to monetary units through particular methods of valuation. These aggregate indicators include the **Environmentally adjusted net Domestic Product - "EDP"** or green national income, and **genuine savings**, in which the value of depleted resources and pollution emissions are deducted from net savings and reinvested or used for compensation (Pearce, Hamilton, and Atkinson 1996). According to Hamilton (1994), green accounting procedures do not lead to policy prescriptions, while savings rules indicate the amount of savings to be deducted and reinvested. According to Pearce et al., the genuine savings concept may apply to both weak and strong sustainability—under strong sustainability principles, the assumption is that the change in value of the remaining consumable stock will reflect its scarcity. Negative savings rates or declining stocks would then indicate unsustainability.

EDP is the basis for the **System of Integrated Environmental and Economic Accounting (SEEA)**, developed by the UN Statistical Division (United Nations 1993) and described in Bartelmus (1994), which has the objective of accounting for stocks and flows of natural capital and defensive environmental expenditures in satellites to national accounts. Underlying accounts of non-marketed physical stocks and flows appear in separate satellite accounts. The principal valuation methods used are market costs of natural assets and asset changes, maintenance or restoration costs for

environmental services that have social value (such as waste absorption and recreational benefits), and contingent valuation which measures willingness-to-pay for avoidance or mitigation or environmental effects. Bartelmus also provides a comparison of results from these different approaches based on case studies in Mexico (van Tongeren et al. 1991), Papua New Guinea (Bartelmus et al. 1992), and the Chesapeake Bay (Grambsch et al. 1993). Repetto (1989) corrects GDP by subtracting for oil extraction, timber harvesting, and soil loss. In a case study for Indonesia, this method shows that from 1971 to 1984 the GDP grew 4% instead of 7.1%. According to Bartelmus, the fact that these studies have mostly been carried out in developing countries, which have more resource-dependent economies, may be a reflection not only of their information needs, but also that greater methodological problems remain with valuation of pollution problems of greater concern in industrialized countries.

The **Index of Sustainable Economic Welfare (ISEW),** constructed by Daly and Cobb (1989), adjusts the GNP by making deductions such as depletion of natural capital and pollution costs, defensive private expenditures, costs of commuting and auto accidents, and by making additions that include household labor and improvements in public services. The ISEW also includes adjustments that reflect distributional inequality and foreign debt. According to Daly (1996), these are admittedly arbitrary but less so than judgments made in calculating the GNP itself.

**Strong Sustainability**

Strong sustainability is associated with objectives of maintaining ecosystem resilience and self-organizing capabilities rather than an optimum condition. It is assumed that there are multiple conditions of equilibrium and that there is a threshold of disturbance beyond which a system will not return to the original condition but will instead flip to an alternate state. Recognizing that high variability is intrinsic to natural systems, and that there is a cycle of change even within particular conditions, a more disaggregated but systemic approach to indicators is called for that recognizes inherent uncertainty and in which there is emphasis on the precautionary principle. In economic terms, the extent to which a species contributes to system resilience can be considered its insurance value (Perrings et al. 1995a).

Pearce et al. (1996) point to the lack of usable indicators for strong sustainability, but this lack may simply be a reflection of the different methods used by economists and ecologists and the fact that criteria associated with it require a systemic approach that does not lend itself well to aggregated indicators. As argued by O'Neill (1996), "biotic systems will not squeeze into simplistic models using dollars any better than they fit into simplistic models using calories. The biotic system is not a parameter but a complex set of interactions that must be built into the dynamic structure of the model." This does not mean that there are no indicators for strong sustainability.

**Resilience** is considered to be strongly related to biodiversity measured by functional rather than genetic distance (Perrings et al. 1995a). According to Perrings et al., the key challenges are: decision-making under ignorance, to specify a functional relationship between resilience and ecosystem goods and services, and to determine the "insurance premium" without any basis for estimating potential welfare losses, to determine bounds within which consumer sovereignty may be exercised as a condition for intergenerational equity, and to create conservation incentives through

valuation—by finding ways for local jurisdictions to benefit from it (Perrings et al. 1995a). A thorough, state-of-the-art review of the science associated with biodiversity and ecosystem function was recently undertaken as a collaborative project of the International Union of Biological Sciences (IUBS), SCOPE, Man and the Biosphere (MAB), and the United Nations Educational, Scientific, and Cultural Organization (UNESCO) (Schulze and Mooney 1994). Also, a thorough assessment including ecological, economic, and policy issues can be found in the Global Biodiversity Assessment conducted by UNEP (1995a).

Given that values are considered incommensurable, Martinez-Alier et al. (1996) emphasize physical indicators rather than monetary values, and more reflective and deliberative approaches to valuation that will be elaborated on in the section on processes. Niamir-Fuller (1995) suggests that, in conditions of high variability, a more decentralized approach to monitoring is needed because it requires more frequent and extensive temporal and spatial measurements. Greater emphasis is placed on minimum and maximum values than on averages, desired rather than climax conditions, soil conditions rather than vegetation, and, equally important, on local knowledge.

### 3.4.3 Measurement of Natural Capital

If we think of environmental degradation as a symptom of the failure to account for loss of Natural Capital in economic accounts and to value the contributions of non-market goods and services to human welfare, then a key issue for modeling and indicators is the representation and measurement of natural capital. Accounting for these goods and services can also provide a mechanism with which to identify the responsible social and economic sectors so that they can be held accountable for their fair share of the costs and so that these costs can be internalized (Parikh et al. 1993). This accountability might in turn create a source of funding for sustainable development—according to Archer, the amount of money lost to pollution and resource depletion in South Africa, approximately 10% of GDP, could cover the cost of reconstruction and development.

However, because of distributional asymmetries, it is hard to get even standard economic indicators (Gallopin in press). The information that exists is unavoidably biased because of greater information availability in developed countries and because the information is gathered is primarily from the economic and social realm, leaving developing country concerns and environmental factors underrepresented. Since a key factor that distinguishes developing from developed countries (as well as different social sectors within developed countries) is the extent to which wealth is disproportionately derived from natural capital rather than from human resources and social infrastructure, and the fact that many of their citizens are only marginal participants in the market economy, this is not a trivial issue. It also suggests that social capital is also a key consideration in accounting for differences in wealth.

Victor (1991) reviews the problems associated with measuring natural capital through five different perspectives associated with different concepts of capital theory. For example, in the neoclassical school, technological substitution is suggested as an indicator but, if it could be measured, the measures would influence expectations which would in turn influence whether or not resources are conserved. The ultimate paradox is that if the market works as is assumed in the neoclassical school, no indicators or policy intervention are needed, and if they do not, the suggested indicators

help because their underlying assumptions would be invalid. In other perspectives, there are the problems of physically measuring capital stock, of whether capital can be aggregately measured independently of prices, and of determining the amount of renewable sources of energy that could offset the use of non-renewable sources.

### 3.4.4 Biases in Existing Information

A bias towards the use of existing information could also distort the results because, if indicators are viewed as an information system, as suggested by Meadows et al. (1996), and if indicators determine what data are relevant and are collected, and if we select indicators based on already available data—we cannot expect to change anything. As discussed above, existing data consists disproportionately of social and economic data from developed countries. A recent study by Lonergan and Ruitenbeek (1996) on modeling sustainability indicators in the Fraser River Basin found that "the poor quality, inaccessibility and irrelevance of existing data are more pervasive constraints to reliable indicator modeling than is commonly thought" and that this data is often inadequate to support conventional statistical modeling approaches. The authors also suggest qualitative and policy-oriented modeling approaches and recommend that data collection be informed by modeling frameworks.

However, as articulated by Bartelmus (1994), "while data availability might very well be the principal reason for the imbalances in [what is accounted for], there are near-insurmountable problems in obtaining agreement—both nationally and internationally—on what are the key questions and key indicators to answer them." Since there is no universal model or theory, a key criteria for selection of indicators is the ability to use them in a wide range of models (Gallopin in press).

### 3.4.5 Participatory Processes and Decision-making

The above-mentioned problems in obtaining agreement on key questions and indicators, which are conceivably infinite, points to the importance of process. This section identifies some procedural frameworks useful for reconciling diverse perspectives, a prerequisite for the development of indicators, as well as specific models of participation and decision-making.

The importance of public participation in decision-making was highlighted in Agenda 21—the agreement signed by governments who participated in the 1992 UN Conference on Environment and Development, and in numerous official reports. Within the United States, public participation in decision-making is recognized as an essential element of ecosystem management and is required by law in environmental impact assessment. It has long been recognized that the effectiveness of the Environmental Impact Assessment (EIA) process is questionable; in 1986, a scientific committee of the National Research Council (1986) proposed that environmental impact statements be treated as a hypothesis to be tested, as a way of providing monitoring and feedback after the decision has been made to determine whether the effects were correctly predicted and whether the goal was achieved. For participation to be effective, there needs to be as much emphasis on how decisions are made as on the mechanism of participation. In other words, rather than trying to "squeeze biotic systems into simplistic models," a more appropriate question is how the decision process can be modified to take into account a systems perspective. The process also needs to be embedded in

the network of biophysical and socioeconomic feedback loops operating within the system context to which the decisions pertain.

O'Connor et al. (1996) identify two main categories of decision-making models involving substantive and procedural rationality. In **substantive rationality**, dominant in economic decision-making, decisions are based on statistically expected outcomes and their utility, independently of how the decision is made. This in turn has the effect of reducing public participation to a public relations exercise. In **procedural rationality**, there is recognition of uncertainty, irreversibility, and emergent complexity, as well as the subjective nature of probability. **Emergent complex systems** are defined as those involving policy, purposes, awareness, uncertainties, and ethics. "Probabilities are unknowable because they don't exist—decisions need to be understood in context of ecological-social-economic histories that are being made and understood within an emergent process in time." Rather than seek to legitimize arbitrary decisions and impose a gamble on current and future generations, emphasis is on learning, on the process by which risks are identified, and on the process of deliberation through which decisions are made regarding their acceptability and fairness in how the burden is distributed. Anticipating and resolving conflict regarding distribution of risks, or costs and benefits, becomes more important than aggregate costs and benefits which are seen as arbitrary. Renn et al. (1995) go so far as to suggest that the distribution and the tolerability of risks for social groups, regions, and future generations has become the major social conflict around which society is organized, and reflects a shift in social organization which implies a need for new forms of collective decision making and conflict resolution.

In the procedural rationality framework proposed by O'Connor et al. (1996) a "**sustainability tree**" is used to anticipate conflicts, which also represent decision points. In the tree, intermediate objectives and subgoals of sustainability are established that can be observed and measured. The subgoals, categorized as economic, social and ecological, although at their root inseparable, may be irreducible, may be incommensurable, and may define a multi-criteria situation that cannot be resolved through optimal choice. Instead, **Multi-criteria Decision Analysis (MCDA)** provides the basis for informed deliberation, negotiation, and a more reflective approach to decision-making. The objective then is to identify a path or course of action that is satisfactory given the economic, social and ecological imperatives, and to facilitate a process for collective decision-making regarding what interests are to be sustained. Biophysical indicators such as material flows are suggested as a backdrop to the analysis of social conflicts because they can demonstrate the inequities.

In what is called the **NAIADE** approach to MCDA (**Novel Approach to Imprecise Assessment and Decision Environments**), developed by Munda (1995; 1994), fuzzy set theory is used to consider uncertainty and impacts for which there is little or no quantitative information. This approach also allows decision-makers to find the most defensible decisions, that is, decisions that could most reduce conflict, based on equity considerations, because it provides a framework in which to consider distributional consequences among different stakeholder groups.

Typically, in the development of indicator lists, experts have implicitly imposed their values. These represent valid but only partial perspectives that cannot be evaluated outside the context to which they are applied. More recently, at least some experts have begun to see their role as one of building or restoring a process for involving stakeholders, through participatory approaches to

research (Boyle, Kay, and Pond 1996; Waltner-Toews 1996). Waltner-Toews (1996) suggests that the framework of "**ecosystem health**" is particularly appropriate for this because the concept of health provides a conceptual framework that encompasses both the hard science (biomedical, externally measurable) and soft systems (health/illness, internally perceived) components, as well as providing a language for discourse that is understood by both experts and the general public. Proposed criteria for ecosystem health are integrity, adaptability, and efficiency, which can be evaluated only relative to goals and needs as they are articulated by stakeholders.

In what has been called "**State of the Landscape**" reporting (Boyle, Kay, and Pond 1996), indicators are embedded in a monitoring program. This program requires the identification of goals, which may be derived from existing policy statements or from a process of stakeholder participation to generate a vision of what is desired, and a characterization of the ecosystem, which defines what is possible. The result is a conceptual model of the world in the context of goals that relates indicators to each other, and to sectorial sub-goals, in a system context. Indicators can then be identified that are meaningful to stakeholders. This iteratively produced narrative provides the basis for a temporary consensus and decision-making actions at a certain point in time, the results of which also feedback into the narrative. A monitoring program also needs to include the design of an information system, and a methodology for reporting results. A key aspect is the evaluation of whether the program is meeting user needs and whether policy goals are being achieved. If not, the process needs to be reiterated before going back to the data collection stage.

The "State of the Landscape" framework is based on a conceptual model of human and environment relationships in which ecological systems provide the context for societal systems which can, in turn, alter the structures of ecological systems, as well as the context for self-organizing processes of ecosystems (for example, altering the drainage patterns into a wetland), which can in turn alter the context for societal systems. This relationship between process and structure in the landscape was illustrated with the Holling (Holling 1986) "figure 8" as spiraling out from family to neighborhood to municipality (on the social side) and from species to community to landscape on the ecological side. The key question for sustainability then is whether the context is maintained for the processes we depend on for context as well as the integrity of the processes. What is considered new in environmental problems is that we are changing context globally rather than just locally and have closed the contextual feedback loops from higher and lower levels. Modeling is used to identify feedbacks that people think are important and to facilitate "Virtual Governance" (Boyle, Kay, and Pond 1996).

Although science cannot pretend to resolve resource conflicts, it does have a crucial role to play in informing the decision process and in defining what is possible, based on ecological information—in contrast with what is desired, which is based on values and culture, and which needs to be defined by all stakeholders (Kay 1996). However, these are not mutually exclusive—stakeholders may also contribute local knowledge to the scientific process, and scientists themselves make value judgments which need to be made explicit. It is also important to distinguish analysis from design, or looking at what is there from considering what could be there, which requires a different set of tools. Formal modeling deals with what is already there. A critical choice is the level, or the scale at which a problem is dealt with—although this is a value judgment, scientists can show the implications of different ways of defining the problem. According to Gallopin (in

press), the role of scientists can also be broadened to include the translation of information into a form that is usable by policy makers, and helping to convey the implications, weaknesses, and appropriate uses of this information. A key research challenge is to be able to deal with disaggregated and distributional data (as a complement to aggregated data and generalizations) regarding the perspectives of those who are affected by changes.

Costanza et al. (1997 in press) propose a **collaborative two-tiered valuation and decision process** that is consistent with the "State of the Landscape" described above. In a "reflective tier," environmental problems are characterized through model building of human communities in their ecological context, and dialogue between scientists and other stakeholders to connect policies to impacts and propose action criteria. In an "action-level tier," policy guidance is generated from the proposed action criteria and applied. If it leads to undesirable consequences, the process is reiterated.

These kinds of processes are new only in their application to problems of sustainable development and draw inspiration from participatory research and management sciences. "**Soft systems methodology**" (SSM) (Checkland and Scholes 1990), an approach that was developed in the 1970s in the field of management science, was intended to integrate theory and practice of systems thinking, and explicitly recognizes the role and importance of interpretation in modeling complex problems. The development of SSM was stimulated by failures of systems engineering in messy, complex problem situations, and by recognition of the human dimension of what had been defined as technical problems, as was seen in the Challenger disaster—initially seen as a technological failure, but later recognized as a flawed decision-making process in which the concerns of the engineers had not been communicated to the person who made the launch decision.

SSM consists of a cyclic process of inquiry that provides a conceptual framework for ordering a complex situation. Elements include:

- Find out about the situation of concern
- Select and model relevant human activity systems (also referred to as holons)
- Use these models or interpretations as the basis for inquiry and comparison with the real world situation
- Use the comparison to structure the debate
- Use the debate thus generated to define purposeful action, which changes the situation and the whole cycle begins again

SSM also includes both logically and culturally based streams of inquiry. The social system is viewed as the interaction of roles, norms and values, for which indirect kinds of inquiry are needed as responses to direct questions will typically consist of "the official myths" (Checkland and Scholes 1990).

A key objective of SSM is to formally articulate the learning cycle between experience and purposeful action. Management is recognized as a process of coping with a flux of interacting events, in which SSM provides a tool for engaging and activating interested parties in this learning

cycle, and for building a collaborative process. Another objective is to find accommodation between different interests in the situation rather than to improve the model or to necessarily achieve consensus. Creation of meaning based on experience and purposeful action are seen as the emergent and defining characteristics of human activity, which is conceptualized as a system designed to take purposeful action. An important distinction between the social and natural sciences is in human intentions as a causal determinant. SSM also distinguishes "system" as a technical term from system as an abstraction. The term "holon" is used to refer to systems as abstractions that have emergent properties, layered structure, and processes of communication and control that enable it to survive in changing environment. A technical definition of the world as a system is said to presume unrealistic levels of knowledge (Checkland and Scholes 1990).

Daniels and Walker (1996) developed a **collaborative learning framework** for ecosystem management, designed for addressing complex and controversial problems in land management. Decisions are embedded in an iterative process of learning and practice, in which public deliberation facilitates a mutual understanding of what is possible. The learning process is broken down into four adaptive modes:

- Concrete experience
- Reflective observation
- Abstract conceptualization
- Active experimentation

The process is also described as an approach to systems thinking in that, as a result of perceived patterns, the learners create cognitively structured systems. **Systems thinking**, developed by Senge (1990), is defined as "tasks, methods, tools, and principles oriented toward understanding the inter-relatedness of forces and elements and viewing them as part of a common process." A collection of papers in Gunderson et al. (1995) also address both theoretical and adaptive management, including social learning, as well as practical issues in a set of case studies.

Another systems thinking approach used to identify mutual objectives among often conflicting interests is the **Future Search process** (Weisbord 1992; Weisbord and Janoff 1995). This process is based on the premise that differences are realities to be lived with rather than problems to be solved. The objective is to "get the whole system in the room" so that participants can discover choices, develop a shared picture of reality, and share responsibility. One choice is whether to accept irreconcilable differences and work together on common ground or to continue to work in opposition. A tangible result of focusing on common ground is the development of new action plans made possible by working together, and by having the right people in the room, and then carried out through mutual support and reinforcement among participants. This approach also sets up conditions under which people can choose new ways of relating, and facilitates communication across key social boundaries.

The process begins by "reviewing the past and owning the present," which results in a narrative that illustrates the extent to which perspectives overlap, aspects of the problem that are missed in viewing it from a single perspective, and valuable contributions to the objective that have

not been generally recognized because of compartmentalization and lack of communication. A key distinction between the Future Search process and what is achieved in more formal and official processes intended to produce a consensus, is in creating the conditions needed for participants to be able to suspend political posturing and explore a wider range of possibilities than might otherwise be possible. In addition, the participants can establish the trust needed for an open dialogue and mutual understanding.

Renn et al. (1995) review and evaluate several **models of participation**, using the Theory of Communicative Action as a basis for a practical set of criteria for fairness and competence in the process (developed by Webler [1995]). The models reviewed include **Citizen Advisory Committees**, **Planning Cells**, **Citizen Juries**, **Varresbecker Bach Participatory Process**, **Regulatory Negotiation**, **Mediation**, **voluntary siting of noxious facilities and compensation**, and **Dutch Study Groups**. We do not review them all in detail here, but highlight some key points. Problems are categorized based on the degree of conflict, as a basis for matching them with the appropriate kinds of models. Those that involve factual arguments regarding probability, cause, and extent of damage are addressed through expertise. At the second level are problems of public confidence and trust in institutions in which the emphasis is on mutual awareness and on clarifying mutual expectations. At the highest level of conflict are conflicts between different values, lifestyles and world views, in which resolution requires reaching consensus on underlying issues. Negotiated rulemaking and compensation are seen as appropriate for addressing technical problems. Mediation and Citizen Juries are seen as most appropriate for problems involving institutional legitimacy, while Citizen Initiatives and Dutch Study Groups were deemed appropriate for problems involving value conflicts. Citizen advisory committees are appropriate for both factual and trust related disputes, and planning cells relevant to trust and value conflicts.

A key consideration is whether the participatory process has any relationship to decision-making. As noted by Crosby (1995), who found the Citizen Jury process otherwise effective: "the Citizens Jury process is at odds with the way governmental decisions are made in the U.S. Except for a few idealistic legislators, the process was viewed as a bother at best and, at worst, as a real challenge to the way business is currently conducted." Another trap is the propensity of decision-makers to reframe higher level conflicts regarding trust and value differences as lower level conflicts defined in technical terms, and treating value concerns as irrational—a practice which creates further distrust. Renn et al. (1995) conclude by calling attention to the value of participation in generating norms, new values derived from empathy or understanding the concerns of others, and the quest for social rationality or the common good.

**Decision Models**

In addition to the appropriateness or mismatch between decision models and participatory processes, the decision model shows what information is driving decisions and thus provides the basis for relevant indicators. Decision models also need to be considered because, as suggested by Perrings et al. (1995a), "catastrophic losses with low [or indeterminate] probability are not amenable to treatment by conventional decision models." This section provides a few highlights regarding decision models as factors driving what is considered to be relevant information, without any pretense of being exhaustive, which is beyond the scope of this review.

An **Ecosystem Valuation Forum** convened in 1991 by Environmental Protection Agency (EPA) reviewed what is considered "decisive information," which was defined as that which is "necessary and just sufficient to allow choice" or to affect the decision one way or the other (Bingham et al. 1995). Choice is said to imply value and is seen as revealing a threshold value for what is at stake. According to Bromley (1976), it is important to distinguish public and private choices because, a "Pareto optimal" in which there winners and losers, is not the same as socially optimal—public choice involves a restructuring of rights and shifts comparative advantages. According to Norgaard (1991), the restructuring of how resources are allocated needs to precede valuation because it affects prices and values.

To comply with an executive order that requires benefit-cost analysis for environmental regulations, much of the focus has been on information that is feasible to obtain and will reduce uncertainty such that the confidence intervals between costs and benefits no longer overlap. Under uncertainty, the gap is considered the cost of insurance. With high uncertainty and irreversible effects, cost effectiveness of preventing undesirable consequences was considered appropriate (Bingham et al. 1995).

Ruitenbeek (1991) shows how the decision process affects the selection and, vice versa, how indicators, or what information is provided, might potentially affect the decision process. The focus is limited to decision theory in economics. The decision process is seen as the analytical framework in which different kinds of often contradictory information is reconciled. Also, since there is no optimum collective decision process that translates indicators to "correct action," the process used will involve a trade-off between allocative efficiency, decision-making efficiency, and democracy, and will have different information requirements. The process selected is related to what the decision-maker sees as the proper role of government and the extent to which it intervenes in markets with coercive regulation, which, at a minimum, is needed to enforce property rights. If the decision-maker is interested only in efficiency, then the only information required will be the optimal level of pollution. If equity is a consideration, individual preference information is needed. Information requirements also depend on whether indicators are viewed as objectives, inputs or constraints.

A recent NAS/NRC report (National Research Council 1996) addressing the subject of how decisions are informed regarding acceptability of risk, also draws heavily on the criteria developed by Webler (1995) discussed above. Analysis and deliberation are presented as complementary, mutually reinforcing elements in an iterative decision process, in which deliberation frames analysis and analysis informs deliberation. The crucial element is a characterization of the risk at an early stage, such that it addresses the significant concerns of all interested and affected parties.

A review and guide to the literature on some of the better known decision models, forms of logic, and different rationalities can be found in Baron (Baron 1994). These include statistical models and probability theories, utility theory and decision analysis, choice under uncertainty, quantitative judgment, moral judgment, and equity considerations. A review of decision-making frameworks with respect to climate change is found in Arrow et al. (1996), which illustrates the limitations of using quantitative decision analysis under high uncertainty: there is no single decision-maker or globally optimal strategy; it is difficult to value alternative decision outcomes; probabilities

need to be quantified. On the other hand, Arrow et al. (1996) find the method useful for structuring information and making it cognitively manageable. The alternative to decision analysis is negotiation, which has more information requirements. A thorough review of the logic of cost-benefit analysis can be found in Munda (1996) and Hanley and Spash (1993). MCDA (Munda 1995), discussed above, is also relevant to decision models. Less familiar but worth mentioning are the Theory of Communicative Action, the "Garbage Can Model" of organizational disorder, an interpretive view of economic processes and decision-making.

The **Theory of Communicative Action** (Habermas 1984), the ideal upon which the above described criteria developed by Webler (1995) are based, diagnoses the problem of modern societies as that of relying almost exclusively on instrumental (or scientific/technical) rationality (such as cost-benefit analysis) in decision-making processes, to the exclusion of other forms of rationality (categorized as law/morality, and art/art criticism). This reliance on instrumental rationality has led to token public involvement and jeopardized society because, as described above, other legitimate stakeholder concerns are seen as irrational. The ideal is a communicative rationality, which combines the other three forms, towards the objective of reaching an uncoerced mutual understanding as a basis for action. This uncoerced understanding enables people to enter into social relations that encourage personal development as well as social and cultural reproduction, and to consider the type of society they want before committing to new relations. Inherent in the structure of language is a commitment among speakers to cooperate because it is assumed that their statements can be defended. While strategic action and adversarial processes still have a place, consensual forms are seen as more appropriate in engaging citizens at early stages (Webler 1995). Webler and Renn et al. (1995) use this ideal as a yardstick for evaluating the fairness and competence of diverse participatory processes.

The "**Garbage Can Model of Organizational Choice**," originally developed by Cohen et al. (1972) and most recently revisited by Warglien and Masuch (1996), refers to an alternative model of decision-making, resembling a primordial soup, in which "preferences are unclear and ambiguous, goals are badly specified and incomplete... people do not know exactly what they want, what they wanted is subject to reinterpretation, and what they will want has yet to be learned." As originally described by Cohen (1972), "participants arrive at an interpretation of what they are doing and what they have done while in the process of doing it. From this point of view, an organization is a collection of choices looking for problems, issues and feelings looking for decision situations in which they might be aired, solutions looking for issues to which they might be the answer, and decision-makers looking for work." Another observation is that problems, solutions, participants, and choice opportunities do not necessarily follow a logical sequence—disorder may well be in the eye of the beholder and in the conception of choice.

In what is referred to as "parallel, emergent behavior," complex patterns may result from simple interactions. "The logic is one of matching, of finding mutual correspondence and reciprocal support between the elements in the choice process," which is accomplished through interaction in which a broader set of values and perspectives come to be considered. Decision-making under uncertainty is said to actually improve because solutions emerge as the problem is attacked from these multiple perspectives. For example, solutions and ideas may arise in the research process, which may be more effective when there is initial confusion—excessive early integration in a

sequential plan of development steps may kill the most interesting and unexpected outcomes. It is considered a "parametric adaptive" model in that it takes the behavior of others as a parameter in a process of reciprocal matching between participants, problems, and solutions (Warglien and Masuch 1996).

It is also recognized that, even if people know what they want, they do not always behave consistently with their objectives because of following organizational procedures, having weakness of will, or retrospectively establishing goals that rationalize decisions already made. A purely rational organizational design that ignores this inconsistent behavior is not merely false but may be the cause of misadaptation and ineffectiveness in bureaucratic organizations. It is important to distinguish formal and informal organizational structures, in that disproportionate emphasis on formal procedures (such as charts, rules, and management techniques) does not eradicate but instead shifts uncertainty to new areas of unpredictability and negotiation (Warglien and Masuch 1996).

Finally, to reinforce the importance of process, we call attention to another **interpretive view** of how economic decisions are made, derived from the literature of economic anthropology (Robben 1989), which illustrates the importance of perception in that people typically act in accordance with their beliefs. This is a perspective that recognizes that different social groups have different interpretations of the economy, which they believe to be the universal truth, and upon which their behavior is based—until things break down as a result of conflicting interests, which instigates social discourse and reflection. Through discourse and reflection, a broader range of factors is taken into account in evaluating what choices are available, which leads to new and broader interpretations of what is included in what is mutually understood to be "the economy"—in other words, shifting the boundaries between economy and society. This process leads to new forms of practice, which lead to new experiences that affect future discourse (possibly ad infinitum).

This concept is illustrated in a study conducted by Robben (1989) in a fishing community in northeastern Brazil, where, in the normal mode of operation, when the weather was good, decisions revolved around the amount of bait, ice and fuel, the phase of the moon, and what species had been caught by others. Poor weather conditions and scarcity of fish broaden the decision-making context and lead to discourse that reveals what is included in the economic universe of the different kinds of fishermen. For example, boat owners become concerned over relations with wholesalers and see the market place as a boundary between economy and society. Consequently, their relationships with the boat fishermen are depersonalized. Boat fishermen become concerned about indebtedness to boat owners, and money needed to maintain social networks, which are not seen as distinct from the economy. The canoe fishermen were more concerned with their independence and are oriented towards their households. It was not until after fish became scarce that the causes of overfishing began to be vigorously debated between canoe fishermen, boat fishermen, and beach seiners who had previously been scarcely aware of each others' existence. This debate brought out in the open the scarcity of natural resources, an awareness of the ideology of capital accumulation, an incipient and growing social stratification, and a shift of interest from the domestic to the public domain.

In sum, more important than any particular interpretation of the economy, is how societies respond to disruptions and uncertainties—at some scales and locations, a routine fact of life; at others, a matter not of if, but when. Also important is the process by which different perspectives

are reconciled into new interpretations when what are considered to be normal modes of operation break down, which provides the basis for adaptation. This interpretive framework also provides a plausible explanation of the growing interest in incorporating ecological and social factors into new common understandings which can provide the basis for new and more sustainable economic practices, such as is occurring in ecological economics.

### 3.4.6 Appropriate Scale

A critical choice is the level, or the scale at which a problem is dealt with—although this is a value judgment, scientists can show the implications of different ways of defining the problem. The choice of appropriate scale depends on the problem being addressed and has implications for the kinds of solutions proposed. Conceptually, particular problems need to be understood with reference to a theoretical construct that is larger than the problem (Waltner-Toews 1996). However, even spatially and temporally, the boundaries are conceptual—according to Waltner-Toews, to view boundaries as "real," in what is referred to as a "hard systems" approach, is to assume the problem can be mechanically described as changing in response to external pressure, as is implied in the "pressure-state-response" indicator framework. From this perspective, decision-makers are seen as external forces that may influence the system through policy and technological instruments, rather than as intrinsic to the system—which implies instead that the definition of boundaries is a value judgment and indicators can be interpreted only in context.

With respect to temporal scales, although researchers may be interested in a long-term perspective, it may be necessary to consider the short-term needs and interests of stakeholders as a means of initiating action. Spatially, a regional approach is generally considered the most effective for analytical purposes and is more manageable because there are fewer ecosystems and economic interactions to consider, less aggregation of data, and greater uniformity of data as well as political interests. A regional approach also adds a spatial element that can be used to illustrate reciprocal relationships between local and global processes and impacts (van den Bergh 1991); for instance, the effects of erosion in a headwaters region of a river basin may cascade throughout the basin. Conversely, climate change could alter rainfall patterns that maintain the river basin. Another consideration is the capacity for collective efforts to improve regional welfare—which is more likely to occur at the regional level, and that can perhaps be facilitated by more disaggregated indicators because they provide more direct feedback. Variables that become important at the regional level are cross-boundary flows of environmental and economic goods and services and external incentives that determine the context of development (van den Bergh 1991). Lonergan and Ruitenbeek (1996) also found the regional level most appropriate in terms of data quality and commensurability.

A global level review of methodologies for environmental reporting and assessment conducted by UNEP and Rijks Instituut voor Volksgezondheid en Milieu (National [Netherlands] Institute of Public Health and the Environment) (RIVM) (Swart et al. 1995) points out the lack of intermediate level models. Highly aggregated models are said to provide a tool for conceptualization with respect to long-term dynamics as well as a context for identification of indicators in a systemic framework, which the review also suggests could be disaggregated to the level of economically, politically and institutionally relevant actors. The review also suggests that low aggregation models can be used to construct relationships that might hold at larger scales. This would apply in particular

to land and water issues which are "distinctly local in character" and for which disaggregated approaches are needed. The report recommends that global and regional integrated models be complemented by partially integrated models that capture specifics where necessary. Pilot studies are suggested as a way of beginning to reconcile top down frameworks with the "bottom-up reality of available data and statistics."

### 3.4.7 Distribution Issues

Missing in aggregate measures of natural capital (mentioned above) is a recognition of the distributional nature of environmental problems, both spatially and temporally. Another way to conceptualize economic and environmental interdependency is to view environmental problems as shifted costs (O'Connor and Martinez-Alier 1996), both spatially (such as seen in asymmetries between SO2 emissions and acid rain burdens [Castells and Funtowicz 1995]) and temporally (such as seen in the asymmetry between emissions of CO2 by the current generation and the burden on future generations).

Apart from ethical considerations, distributional issues also point to methodological problems in the internalization of social and environmental costs because the value of externalities (or asymmetries) is not separable from power, legal rights, and income distribution (O'Connor and Martinez-Alier 1996). O'Connor and Martinez-Alier make the case that a missing market represents successful cost-shifting by those who benefit from it. In other words, a zero-price may indicate a relation of domination in a situation of conflict, rather than non-scarcity. Valuation of externalities requires some form of property right which in turn requires political power to enforce. Prices are a function not only of consumer preferences but also of the distribution of wealth or property rights. Therefore, externalities have a lower value when those who are damaged are poor and/or powerless. Since the poor are in a position of having to "sell cheap," the creation of markets and establishment of property rights may lead to dispossession and social conflict rather than sustainability—which also has a social cost. The authors suggest that this social conflict can be viewed as resistance by communities and whole societies to the ecological and cultural costs associated with the "commodification" of nature by expanding industrialized economies, in which nature and non-industrialized economies and the human domestic sphere are viewed as reservoirs of capital.

As an alternative to viewing the growth of commodity output as a one-way process of raw material appropriation and waste disposal, O'Connor and Martinez-Alier (1996) suggest a logic of reciprocation, in which sustainable development is viewed as a symbiosis between economic and ecological production, with an emphasis on managing and renewing reproduction, transformation and renewal of habitats that provide life support underpinning commodity production systems. This requires a co-evolutionary framework in which a key consideration is co-existence. Key questions would then be whether the resource base, environment, technologies, and culture are evolving in a mutually reinforcing manner (Norgaard 1988; Norgaard 1994); whether the movement of resources is significantly a two-way or predominantly a one-way movement; whether regions are evolving along mutually compatible paths; and whether regions are contributing as much to the knowledge and institutional bases of other cultures as they are culturally dependent on others (O'Connor and Martinez-Alier 1996).

This conceptualization of environmental problems as problems of distribution implies the need for indicators of spatial distribution, and presents the challenge of considering disaggregated data as well as qualitative information and conflicting criteria. As a starting point, O'Connor and Martinez-Alier (1996) suggest the "**Ecological Footprint**" (Rees and Wackernagel 1992) or "Appropriated Carrying Capacity of Environmental Space" as an indicator of reciprocity because it demonstrates distributional imbalances. Also, **human appropriation of Net Primary Production** (Vitousek et al. 1986) calculated at regional levels could provide a useful basis for comparison. Multi-criteria evaluation is suggested as a framework for decision support.

### 3.4.8 Qualitative Considerations

In that a system is an abstraction defined by the observer, the significance of the variable and its associated value arises from interpretation and judgment. However, most definitions have excluded qualitative considerations. National income accounting and selection of appropriate indicators are not merely a technical matter, because what is measured and accounted for reflects social values and objectives, as well as the criteria by which decisions are made.

Physical indicators may require the definition of threshold values and critical loads for pollutants, as well as concepts of danger, health and integrity upon which indicators may be based, which involve value judgments and trade-off (Castells and Funtowicz 1995). For example, scientific arguments were used as the basis for arguing that standards for discharge of metals into the Chesapeake Bay should be based only on the bio-available fraction rather than on total discharge. However, this argument does not consider accumulation of metals in sediment and long-term toxicity through effects on benthic organisms and via the food chain, which also provide a scientific basis for advocating stronger protection. Proposed sediment criteria were strongly opposed by the same interests that used "better science" to argue for weaker standards based on dissolved rather than total metal discharge. Other factors that are not normally considered in establishing toxicity criteria include cumulative effects of diverse chemicals, organisms that are affected at levels below what are established as lethal concentration level, human developmental and reproductive effects, and secondary effects resulting from effects on community structure (Savitz 1996). The point is that is it impossible not to be selective in the use of science in policy and that this selectiveness reflects value judgments.

Quantitative and qualitative information can be viewed as complementary rather than as mutually exclusive. An example of **combining quantitative and qualitative approaches** is provided in a study done as part of the Mackenzie Basin Impact Study, in which Lonergan et al. (1995) combined results of quantitative general circulation models and economic impact models with a qualitative analysis using participatory research designed to assess potential impacts of climate change in native communities in the Mackenzie Basin. An indicator framework that explicitly incorporates qualitative considerations is the "**Grassroots Development Framework**" of the Inter-American Foundation (IAF) (Ritchey-Vance 1996) (see Figure 3) that is discussed in the section on Grassroots indicator frameworks.

### 3.4.9 Uncertainty, Quality and Post-Normal Science

In complex environmental problems, rather than reducing uncertainty, science is faced with the challenge of coping with increasing uncertainty and is typically expected to provide support for "hard decisions based on soft facts." **Quality assurance** of the scientific information assumes increasing importance in complex problems, because science often at best provides models and simulations that are untestable, and whose credibility rests on the qualitative factors, such as professional judgment, rather than precise numbers derived from a mathematical expression of the problem (Funtowicz and Ravetz 1990). Funtowicz and Ravetz (1990) developed a notational system, "**NUSAP,**" intended to provide a basis for good practice in the management of quantitative information, and that could be considered an approach to constructing indicators that convey uncertainty and quality of information. The authors also suggest this system can be used to detect instances in which uncertainties in the information are so high that the results are to be considered completely indeterminate.

NUSAP refers to the categories of Numeral, Unit, Spread, Assessment, and Pedigree, which, from left to right, represent quantitative to qualitative information. Numeral and unit are standard and self-explanatory. Spread is used to indicate the inexactness (which may be in the form of range, variance, plus/minus, within a factor or a logarithmic range). Assessment is used to represent a judgment of the reliability of the information, which may be in the form of statistics (such as confidence limits, significance levels, Bayesian statistics) or less formally, in a nominal form (such as total, high, medium, low, optimistic, pessimistic). Pedigree, in the form of a rank, expresses a qualitative judgment of quality and uncertainty at a deeper level, based on an evaluation of the process by which the information was produced (Funtowicz and Ravetz 1990).

When, in addition to high uncertainty there are also high stakes and conflicting values, a **post-normal approach to science** is suggested, in which extended peer review through public participation in the decision becomes more important (Funtowicz and Ravetz 1992) (see Figure 1). This approach is suggested because these kinds of decisions require value judgments—although these decisions should be informed by expert opinion, they should not be made by experts alone. Inherent in this approach is the need for a relationship of mutual respect between experts and stakeholders, whose local knowledge and experience is equally important and provides a valid basis for value judgments.

## 3.5 Relationships Between Models and Indicators

The implicit relationship between models and indicators is coming to be recognized more explicitly, as is suggested in the UNEP state-of-the-art report (Bakkes et al. 1994), and in the National Research Council review of the EPA Environmental Monitoring and Assessment Program (EMAP) program (National Research Council 1995). In that review, models are seen as hypotheses regarding endpoints, key variables, and indicators. It was recommended that this relationship be made more explicit. Two documents in particular explicitly review the relationships between models and indicators and are summarized here.

A workshop on indicators for sustainable development, organized by Meadows (1996), identified some general principles and concepts of systems theory that are relevant to the identification of appropriate indicators:

- Indicators come from values (we measure what we care about), and create values (we care about what we measure).
- The choice of indicators is one of the most important inputs to the behavior of a system. Changing indicators is one of the most powerful interventions one can make in the behavior of a system.
- Indicators are partial and imperfect reflections of reality. Of necessity they are based on uncertain models as well as different world views. Defining appropriate indicators is a learning process that takes time, experience, trial, and error.
- The process of indicator development is as important as the indicators that are actually selected. The process works best with a combination of expert and grassroots participation.
- Systems insights can help design indicators that identify critical linkages, dynamic tendencies, and high leverage points for action.
- Distinguish between stocks and flows. Stocks are indicators of the state of a system and its response time. Flows may be leading indicators of change.
- Exponential growth rates (the strengths of vicious or virtuous cycles) are sensitive points to monitor in systems.
- The ratio of change rate to response time is a critical indicator of the degree to which a system can be controlled or a problem corrected.
- Watch for unbalanced or missing control loops.
- Nonlinearities in systems (turning points, danger points, thresholds) are key points for the placement of indicators.
- A primary and often-ignored indicator of the long-term viability of a system is its evolutionary potential.
- Wherever possible, indicators should be reported as time graphs rather than static numbers.
- Indicators should be combined with formal dynamic modeling.

(Meadows, 1996)

A recent study by Lonergan and Ruitenbeek (1996) in the Fraser River Basin in Canada regarding modeling and indicator frameworks, reviewed appropriate model types and ecosystem units, published sustainable development goals for the basin, existing data sources, and applied three modeling frameworks: correlation models, deterministic input/output models, and a dynamic

complex system model. Because of its close relationship to the subject of this review, we include a more extensive summary of its findings:

- Correlation models were found to be useful for showing coincidental correlations from which links can be inferred between indicators and underlying structure, based on other knowledge. Also, they allow screening out poor data; identification of efficient sets of indicators by removing redundancies (such as high correlation among health indicators); and estimation of specific relationships.
- Deterministic I/O modeling, despite constraints of linearity and fixed technology, was useful for understanding links among indicators, particularly between economic indicators and waste production. This type of model also gave a sense of the magnitude of expected changes under different scenarios, and provided input for qualitative modeling exercises.
- Complex System Models were used to show adaptive feedback loops; to incorporate qualitative relationships and policy variables or institutional arrangements in the dynamic "rule set" of the system (that is, health care response policy variable is sensitive to the level of pollution generated); and to specify non-linear relationships. Many indicators are endogenously generated (such as population growth results from birth, death, and net migration rates). These indicators can be used to interpret policy trade-offs and indicator links.

In general, Lonergan and Ruitenbeek found that indicator exercises often degenerate into laundry lists of variables or compendiums of historical statistical data for which interpretation becomes a basis for disagreement and discussions on meaning of sustainable development. The authors also found that these indicators lack an ecosystem-based and projective perspective (providing instead a snapshot of current conditions or a description of the past); that these indicators ignore links between policy goals and sustainable development; and that social, economic and environmental indicators are typically addressed in isolation. They also found poor quality of data for various statistical reasons which also did not allow for comparison.

In the review of sustainable development goals, they found that 157 goals could be meaningfully reduced to five broad categories for purposes of examining trade-offs. Indicators were selected from four issue areas (ecological, social, economic, and institutional) to reflect the state (or current conditions), options (or intergenerational distribution), and entitlements (or intragenerational distribution) resulting in thirty-nine indicators.

Lonergan and Ruitenbeek recommended that sustainability goals be linked to a small slate of indicators. Recommended criteria for selection were that they be: representable at different scales and aggregation levels (from sub basin to basin); available for more than a single time period; and derivable from existing information sources. Also, the goals should reflect more than one issue area (for example, respiratory illness can provide a surrogate for air quality and human conditions) and be flexible—goals typically change as more information becomes available, and as preferences change. Another criteria is that the goals be non-tautological or linkable to broader issues. A goal should not also be an indicator, because non-normative indicators allow for diverse interpretations.

The bottom line was that it is more fruitful to focus on a small number of indicators within selected classes because, within classes, many indicators are closely correlated and substitutable; modeling and data gathering should be focused on the regional level because data quality is not reliable at smaller scales and less commensurable. Modeling was found to be most useful for identifying qualitative policy trade-offs, and should focus on general policy related tasks. Linking of deterministic and qualitative modeling is useful for making projections and policy links. Data gathering can be scaled down. The best data was that associated with human health and that was easy to scale up or down.

## 3.6 Modeling Frameworks

### 3.6.1 Some Conceptual Issues

Norton (1995) distinguishes a **serial approach**—in which component models are independently developed and linked, that is, by first describing the ecosystem and then evaluating changes using an economic framework, from a descriptive normative or **constructive approach** that integrates science and values, and in which values are internal to the system rather than absolute and objective. It is worth noting the work of Gregory Bateson, an anthropologist who articulated similar contrast in perspectives at least as far back as the 1950s, and who is credited with the "transformation of cybernetics from a science predominantly concerned with application of feedback as control towards a science concerned with problems of how society constructs its own models of change and stability, and then proceeds to hide those constructions in its rationalizations about social and ecological order" (Harries-Jones 1995). According to Bateson, one of the major fallacies of the scientific community is the premise that it is possible to have total control over an interactive system of which oneself is a part, a fallacy that he also viewed as one of the major sources of social and individual trouble. He saw false presumptions of an ability to "control" and "manage" ecosystems through quantitative measurement as a primary source of error in ecological science. He also held that values and constraints, as well as knowledge and beliefs, are internally constructed (rather than absolute), as a result of communication among individuals (Harries-Jones 1995).

We are only beginning to come to terms with the implications of these concepts, which are becoming operationalized in post-normal approaches to science (Funtowicz and Ravetz 1994a) reflected in adaptive management of ecosystems (Gunderson, Holling, and Light 1995; Holling 1978; Holling 1986), in transdisciplinary fields such as ecological economics (Costanza 1991; Funtowicz and Ravetz 1994b), in participatory models discussed above, and generally, in participatory approaches to research that recognize the value of local knowledge and experience. As mentioned previously, **Post-Normal Science** is characterized as a strategy for dealing with environmental issues in which there is high uncertainty, values are in dispute, stakes are high, and decisions are urgent (Funtowicz and Ravetz 1991). This is in contrast with **"normal" science**, characterized as an extension of laboratory, puzzle-solving approaches that are not appropriate for addressing complex global environmental problems. As discussed above, in the section on qualitative considerations, another feature common to what we refer to as the **constructive approach** is in treating quantitative and qualitative information as complementary rather than as mutually exclusive.

### 3.6.2 Sustainable Development Models

Faucheux et al. (1996) developed a typology in which models of sustainable development are classified in four categories: neoclassical, evolutionary, ecological economic, and neo-Ricardian. **Neoclassical models** are based on an equilibrium framework which assumes a reference situation, and extend traditional economic concepts regarding optimization and capital accumulation to incorporate the concept of natural capital. As is discussed above in the section on measurement of natural capital, the overall assumption is that substitutability between natural and manufactured capital will sustain non-diminishing per-capita consumption, providing that technical progress is sufficient. However, Dubourg and Pearce (1996) show that the objective of inter-temporal equity is not achieved because the criterion of efficiency can lead to a reduction in the future standard of living. They conclude that not all capital is substitutable and that it is important to distinguish critical non-substitutable capital from the non-critical.

In contrast, **evolutionary models** are not based on the assumption of an equilibrium condition and focus instead on conflicts and dynamic interactions between socio-economic and technical systems. Because of the complexity of these interactions, and because the evolutionary process is open, outcomes are uncertain and these models are not intended to predict. In that these models are based on inductive approaches, they may, however, be useful for illustrating the role of technical and policy changes which are conceptualized as endogenous, and in identifying strategies of institutional and technical change for making a transition to sustainable development (Faucheux, Pearce, and Proops 1996).

**Ecological economic models** regard ecological and economic systems as co-evolving, complex and non-linear, behaving in accordance with the laws of thermodynamics, and focus on persistence of a system under changing conditions. In addition to dynamic modeling, input-output frameworks are also useful for exploring links between ecological and economic systems. Because of uncertainty in ecological processes, resilience is seen as the basis for sustainability (Perrings 1996). Loss of resilience increases the risk of system failure and increases the need for management interventions (Faucheux, Pearce, and Proops 1996). To this we add that, although ecological economics has primarily made use of dynamic models and input-output frameworks, it has also drawn on a variety of other methods depending on the problem at hand, and does not see other approaches as mutually exclusive. Ecological economics has also emphasized modeling as an element of a participatory process.

**Neo-Ricardian models** are also co-evolutionary and portray ecological and economic systems in a multi-sector joint production framework. Sustainability is conceptualized as reproduction rather than in terms of growth. In one model, sustainability is achieved through obligations of reciprocity over time (O'Connor 1996). Another model identifies different combinations of activities and technological selection for a given type of production which allows the identification of incentives and disincentives towards the possibilities deemed to be more sustainable (Erreygers 1996).

### 3.6.3 Integrated Assessment Models

"**Integrated Assessment Models**" (IAM) refers to a group of models developed primarily to examine the implications of climate change for decision-making, although they could conceivably be used to evaluate any complex environmental problem (Rotmans and Van Asselt 1996). In a review of IAMs, Rotmans et al. (in press) characterize IAMs as metamodels intended to examine interrelationships between different issues, identify uncertainties, and develop and evaluate end-to-end strategies—in contrast with more detailed and complex expert models. Emphasis is more on interpretive and instructive value than predictive capability, and on communication among disciplines as well as between scientists, the public, and policy-makers and analysts. They propose a hierarchically interconnected framework of indicators as a communication device.

Rotmans et al. distinguish two main categories:

- **Macro-economic oriented models**—which are fully parameterized, decision-analytic formulations of the climate problem that are intended for use in Cost-Benefit Analysis and Cost-Effectiveness decision frameworks. As an example, in the DICE model (Nordhaus 1992; Nordhaus 1994), the decision is framed as a choice between current consumption, investment in productive capital, and investment to reduce emissions.
- **Biosphere-climate oriented models**—which provide a process-oriented picture of the problem, including geophysical and biogeochemical feedbacks, and are intended to provide insights into interrelationships. The socio-economic system is not yet adequately represented.

Key model parameters are:

- Energy-related emission paths
- Land use
- Technological change
- Population
- Biogeophysics (subdivided into atmosphere, oceans, and terrestrial biosphere)
- Ecological impacts
- Economic impacts
- Discount rates

Ecosystem types are defined in accordance with climate variables, but are not considered adequate because they are treated as static—there is no indication of how the distribution would shift in response to climate variation or of underlying processes.

**PSIR (Pressure-State-Impact-Response)** is the framework used for organizing relevant information—that is, demographic and consumption *pressure* leads to environmental and economic

*impacts*, which lead to *responses* in the form of changes in land use and energy consumption, which in turn influence future demographic and consumption patterns (*pressure*). Vertical integration refers to the chain of cause and effect relationships; horizontal integration, to cross-linkages and interactions between different pressures, which are less well addressed in models. In comparison of specific models used, the authors find the key difference between them to be in the aggregation level, but even those less aggregated are not designed to address distributional issues and diverse interests.

Rotmans et al. see the key challenges are to broaden current indicators with social, institutional and ecological indicators; and also to find a balance between: transparency and complexity, aggregation and realism, qualitative and quantitative linkages, and determinacy and uncertainty. Others have noted that the PSIR framework does not map well onto social systems (Meadows 1996). Others have also noted that the emphasis (in the interpretive social sciences) on complexity and variation in human motivation produces highly disaggregated data and analyses that do not fit into the end-to-end conceptual framework described above, although are essential for fairness of policies and for legitimizing the inherent value judgments and trade-offs (Bradbury and Rayner 1995).

## 3.7 Indicator Frameworks

As mentioned in the introduction, indicators themselves, and conceptual frameworks associated with them, have been the subject of some recent and comprehensive literature reviews that we will not attempt to duplicate here, although a few highlights will be mentioned. One of these reviews is an appendix to a report prepared for The Ontario Ministry of Natural Resources (OMNR) in Canada which focuses on indicators and monitoring frameworks (Boyle and Kay 1996). Another more general literature review was done by Pinter and Hardy at the International Institute for Sustainable Development (Pinter and Hardy 1995) (both are expected to soon be available in full on the Web). Rather than duplicate, we mention highlights as they relate to the above discussion of the relationship between models and indicators, and incorporate relevant references.

In the OMNR report, Boyle and Kay (1996) focus in particular on complex system approaches to indicators and monitoring framework, identifying several typologies or classification schemes. A **typology of indicator frameworks** developed by Davies et al. (1992) identifies the following categories:

- **Issues**—indicators specifically related to specific issues such as climate change, acid rain, and hazardous waste.
- **Environmental media**—indicators pertaining to specific media such as air, land or water; urban indicators are reviewed in a study Maclaren (Maclaren 1995).
- **Resource sector**—indicators that pertain to specific economic sectors such as forestry, energy, agriculture and fisheries.
- **Environmental processes**—indicators pertaining to various forms of the pressure-state-response framework. These processes, or indicators, seek to reflect environmental conditions or environmental responses to human activities, human contributions to

environmental conditions (stress), and human (management) responses to environmental conditions. Description and use of the PSR framework is found in Adriaanse (1993) with reference to the Netherlands, and Hammond (1995). Hardi and Pinter (1994) review the PSR model and key issues in indicator development: aggregation, cost-efficiency, need for time-series data, public awareness, institutional participation, ecosystem approach, and issue ranking.

**Environment health frameworks** include:

- **Environmental standards** guidelines and objectives
- **Integrative indicator species**
- **Environmental distress syndrome** (EDS) (Rapport et al. 1985)
- **Agglomerative indices** (see the Karr Index of Biological Integrity [Karr 1991; 1993])
- **Stress response statistical system** (Rapport and Regier 1992; Rapport et al. 1981)

Other frameworks, most of which have some overlap with those already mentioned, include:

- **Domain-based**—that is, environment, social, economic (Maclaren and Campbell 1995)
- Various approaches to measuring **ecological integrity**, such as thermodynamics and complex systems approaches (Allen et al. 1993; Kay and Schneider 1990), system response (Bella et al. 1994); and vegetation monitoring (Fritz 1993)
- **Cumulative effects** (Cocklin et al., 1992; Davies 1991; Munn 1994)
- **Policy and management frameworks** that seek to clarify relevant questions (see Dover 1995; Peterson 1994)
- **Grassroots frameworks** (see Hambly and Angura 1996; Ritchey-Vance 1996)

Many of these frameworks are hierarchically organized. In the **thermodynamics framework** for assessing ecological integrity (Kay and Schneider 1990), energy stocks and flows provide measures of system organization. Kay also outlines a framework for decision support indicators based on complex systems theory (Kay 1991). The **system response framework** (Bella, Jacobs, and Li 1994) recognizes mutually reinforcing relationships between technological, social and ecological systems which are adapting, and self-organizing systems, and focuses on system change. A **vegetation monitoring framework** (Fritz 1993) examines feedbacks between the local and global environment and uses a hierarchical framework to distinguish internal from external influences.

While acknowledging the importance of participation and stakeholder consultation, most current programs are based on the stress-response model. According to Boyle and Kay, the stress response model tends to narrow the definition of questions to known causes and effects. Ecosystem integrity frameworks attempt to broaden the scope by providing an approach to evaluating whole systems (Boyle and Kay 1996).

Some key references identified in Boyle and Kay (1996) that also provide overviews of this literature and case studies are:

- Davies (1991)—reviews seven programs that pertain to cumulative effects monitoring
- Hodge (1994)—a literature review that examines frameworks and typologies, looks at 220 State of the Environment reports, and proposes a framework that includes economic and system considerations and that is tested in the Great Lakes Basin
- Maclaren (1995)—a review and synthesis that includes three case studies
- Woodley Kay & Francis (1993)—a collection of case studies on the application of ecosystem integrity concepts
- Davies et al. (1992)—outlines a typology of frameworks and critiques existing frameworks in major programs

Indicators that are important from the perspectives of particular disciplines are often too specific for the policy stage but may be useful in interdisciplinary communication, in addition to calling broader attention to scientific concerns. Some publications that provide such disciplinary perspectives include:

- McKenzie et al. (1992), which contains the proceedings of an international symposium on ecological indicators sponsored by several United States agencies
- Moran (1995), which reviews data sets that are useful for investigating human and environment relationships from an anthropological perspective
- Berger (1996), which is based on a report of the International Union of Geological Sciences, and provides a set of geoindicators of rapid environmental change

Kelly and Harwell (1990) review the functions of indicators in **ecosystem recovery,** including intrinsic importance (for example, threatened and endangered species), early warning, indicators of sensitivity (when endpoint is insensitive), indicators of ecosystem processes, and indicators of ecosystem vulnerability.

### 3.7.1 Biophysical Indicators

**Energy-based valuation techniques** are often used to account for natural capital because they provide a broader common denominator than monetary measures. A commonly used measure is embodied energy, which refers to direct and indirect energy requirements for a given economic output and provides the basis for life-cycle analysis. These techniques can then be used to consider energy requirements:

- Constraints on availability
- Discharge of materials

- Heat and work to the environment
- Efficiency of energy consumption relative to production

O'Connor et al. (1996) propose using energy-based indictors as a complement to as a multi-criteria decision methods, to illustrate **asymmetries in material exchanges** or inequities in access to resources that underlie social conflicts.

A **comparison of the price of an input, in proportion to price of all inputs, to its energy cost in proportion to energy cost of other inputs** was used by Golley (1994) to show underpricing of water. In a case study of agriculture in arid lands in Spain, Golley found that, in general, the energy cost of water used in irrigation was 40% of all energy costs. In contrast, water was only about 2% of the monetary costs and was causing salt pollution. Because of this subsidy, the farmer had little or no information about the value of water and the relation between water use and crop production. If the price of water were instead raised to a level approximating its full cost, farmers might be motivated to shift toward crops which use less water and more closely allocate water to plant needs that would reduce salt pollution.

A **comparison of the ratio of energy inputs to outputs** in the production of maize in different countries was used to show that the United States had the lowest ratio of all inputs to yield (2.9) compared to, for example, Mexico, which had 12.5. The United States, however, had the highest output per amount of human effort (4,233–5,926) compared with 13.9 for Mexico (Pimentel 1987).

Cleveland (1994) uses energy and material flows to make the case that **substitution of non-renewable "stock" resources for renewable "flow" resources**, or depletion of natural capital, reinforces existing problems, through the establishment of **positive feedback loops** between depletion of natural capital, energy use, and human response. For example, the reduction of soil fertility caused by erosion requires an increase in fertilizer application to maintain production. This process establishes a positive feedback loop between soil erosion and the need for increased stocks of crude oil and phosphate rock to produce increased amounts of fertilizer to replace the nitrogen and phosphorus eroded from the soil. This in turn, increases the energy and resource cost of natural gas and phosphate, which increases energy costs and indirect energy costs of crops. Another example of that positive feedback system is the depletion of groundwater. The exploitation of groundwater for irrigation and municipal purposes at rates greater than the rate of recharge has caused sharp declines in the water level in many aquifers in the United States and other regions. The energy cost to lift water is a direct function of depth to water level. Thus, the depletion of groundwater natural capital initiates a positive feedback loop in which more energy is extracted to lift the same quantity of water a greater distance, which depletes fossil fuel resources, which in turn enhances the increase in the energy cost of pumping, and so on. A third example of the positive feedback is pest control—loss of natural capital in the form of natural defense mechanisms in the reduced diversity of monocultures eradicates natural predators more rapidly than target species, leading to the need for increased quantity and lethality of pesticides, which are also derived from crude oil.

To overcome some of the limitations of price as an indicator of scarcity, a biophysical framework has been proposed (Cleveland 1991; Cleveland and Stern) that measures resource scarcity in energy terms. This approach reflects the increased amounts of energy required to produce raw material from low grade sources—for example, more energy is required to produce metal from lower grade ore. Food grown on poor soil also requires greater amounts of chemicals and fertilizers. **Energy Return on Investment** (EROI) refers to the ratio of the quantity of energy extracted to the direct and indirect energy used in the extraction process.

An indicator of efficiency of energy use, the **energy/GDP ratio**, has been shown to decline over time, suggesting weak coupling between energy use and economic activity. However, another view (Cleveland) is that it results from a shift to higher quality fuel. According to Cleveland, energy use as measured in heat units does not distinguish the fact that a kcal of electricity does more work than a kcal of diesel fuel. In other words, electricity produces more GDP per Btu than oil, oil more than coal, and coal more than wood. Cleveland's analysis also shows that the variation in energy/ GDP ratio in industrial powers is due to shifts in the composition of fuel use.

A parallel indicator is **intensity of material use**, or material consumed per dollar of GDP produced. This has also been shown to decline over time, but only for some materials—as incomes reach a certain level, in what is referred to as an "Environmental Kuznets Curve" (an inverted u-shape). Arguments have been made that the curve reflects greater demand for environmental quality as incomes rise and people are able to pay for that quality. But it appears to apply only to the more tractable air pollutants, and does not seem to hold for CO2 emissions, resource stocks, or waste stock accumulation (Arrow et al. 1995). The curve also examines only per capita rather than total impact, and does not account for relocation of polluting industries to less developed countries (Cleveland).

Weterings and Opschoor (1992); developed **ecocapacity indicators**, which calculate limitations to resource use relative to estimated depletion, and targets for pollution reduction and what is considered a sustainable rate of consumption for renewables.

Ayres (1996) proposes **five physical criteria with measurable attributes** that could be calculated using existing data or with modest additional effort through existing government programs:

- Stabilization of greenhouse gasses
- Stabilization of acidity (pH) in rainfall
- Reduction of dissipative uses and waste of heavy metals to natural mobilization rates or less
- Elimination of agricultural practices based on pumping of fossil water from non-renewable aquifers
- Elimination of loss of arable land to salination and erosion beyond soil formation rates

Relevant measures are those which show the degree of economic dependence on non-renewable energy sources, measures of productivity of energy and materials consumed, and measures

of dissipative loss. Loss and dissipation of harmful substances are proposed as measures of pressure or stress. Within that category, it is also important to distinguish between uses that are inherently dissipative and uses in which material is potentially recyclable, cases in which it is technologically and economically feasible to recycle under current prices and regulations, cases in which recycling is technically but not economically feasible, and cases in which recycling is not feasible. It is also important to relate these criteria to subgoals, rather than equate them with achieving the ultimate goal of sustainability, given that, as is acknowledged by Ayres, it is possible for these measures to show environmental improvement even if the system as a whole continues to deteriorate because of other factors which are less measurable or which may require direct measurements and modeling rather than statistical approaches. Ayres also notes that more extensive reporting of data on material flows by industrial sector, rather than by nation, would make it possible for better calculations of productivity (output per unit of input) through input-output analysis. National figures are misleading because of the tendency for energy and materials intensive industries to migrate from north to south. Ayres and Ayres (1996) reviews materials cycles and data sources by industrial sector and possibilities for creating industrial ecosystems.

Duchin and Lange (1994) build on the Leontieff (1977) **input/output model** of the world economy to examine **energy and material flows**. Based on the World Model and World Database, the world consists of fifty interacting economic sectors in sixteen geographic regions linked by trade and capital flows in which energy and materials use are directly represented and flows of pollutants are added. The strength of this model is in making all of the assumptions regarding technological change explicit, which facilitates discussion and debate, in contrast with treating them aggregately as is done in more typical economic models. Duchin (1996, in press) uses the same structural approach at the more disaggregated household level, a level considered useful for considering lifestyles and for considering individuals in a social and environmental context. The household level is also the level at which fundamental decisions are made regarding consumption, fertility, health care, and education, as well as being a key source of influence on the formation of ethical values and civic attitudes. Although more work could usefully be done in this area, useful classifications of households are those developed by market researchers, for the United States. Other kinds of cluster analyses have been used for other countries, particularly those in which the market is less dominant. It is expected that this kind of cluster analysis would reveal unique aspects of different societies—and thus provide the basis for taking these differences into account in planning for sustainable development.

Kay and Schneider (1990) use **energy flows as measures of ecosystem organization**. Ecosystem integrity is defined as the ability to maintain organizational structure and function under changing conditions or external pressure. Structure refers to relationships between components (for example, amount of recycling, number of trophic levels, average specialization of resource niche), while function refers to the overall amount of energy captured by the system and how it is degraded (for example, respiration vs. evapotranspiration). As ecosystems become more complex, they develop more articulated energy flow networks. These networks have been examined using an **input-output framework** modeled after the work on Leontieff (1936) in economics and first applied to ecosystems by Hannon (1973). Ulanowicz (1986) also developed what is referred to as **ascendancy theory**, which is a way of arriving at an index that characterizes ecosystem organization based on measures of energy transfers and average mutual information. An overview of **network**

**analysis**, with explanations regarding the measures used, is provided in Kay et al. (1989). Kay and Schneider (1990) also present case studies that use these principles to compare different systems. A comparison of a healthy and a degraded ecosystem that are otherwise similar shows several changes, including significant drops in total energy flows and throughput, biomass, lengths of food chains, resource consumption, ability to dissipate incoming energy, response to stress, and the overall measure of ascendancy. In other words, the impacted ecosystem was shown to be "smaller, recycle less, and leak."

The **Ecological Footprint** (Rees and Wackernagel 1992) is an indicator that recognizes that regions can no longer be recognized as independent units because of integration through trade. Therefore it asks how much land and water is needed to support the resource flows or consumption by the population of a particular region. This information provides a physical measure of demand on natural capital or appropriated carrying capacity. Dependence on imported carrying capacity may also provide a basis for anticipating international conflicts. For example, the authors show that to support the lifestyle of the population (1.7 million) of the Vancouver-Lower Fraser Valley Region of British Columbia in Canada, which has a land area of 400,000 ha, a land area of 8.7 million ha is required, or twenty-two times the amount of land actually occupied. Factors considered include land for food, forest products, fossil energy consumption, assuming an average Canadian diet and current management practices. Fossil fuel consumption is based either on the amount of land required to produce the biomass energy (ethanol) equivalent, or a comparable area of temperate forest that would be devoted to assimilation of per capital CO2 emission. The Netherlands was shown to require fourteen times its land area.

"**Critical loads**" are based on identification of what are considered to be the critical deposition levels that can have significant long-term impacts. Standards are thus related to actual environmental quality, to appropriate spatial and temporal scales, and consideration of all ecological functions, as well as impacts of structural (land use) changes. The objective is to not jeopardize the environment's assimilative capacity. In some cases, particular species have been found to provide indicators of the critical threshold. Reduction targets necessary to keep depositions under the critical level are then identified, in contrast with the practice of making decisions based on costs of abatement (Rennings and Wiggering 1997).

One of the more ambitious initiatives for monitoring biodiversity is **Gap analysis** (Scott et al. 1993), which has the objective of determining whether areas of high biodiversity are adequately represented in protected areas, by overlaying maps of vegetation and species distribution on land use maps. Vegetation, vertebrate, and butterfly distribution are used as indicators of overall biodiversity. In a recent evaluation, Flather et al. (1997) find that it is difficult to test whether these are adequate indicators because biotic inventories are inadequate even for small areas, which is the reason indicators are used. Other test measures of such indicators are correlated species counts, coincidence of species "hot spots" and representativeness of species composition. However, species counts may covary for other reasons such as changes in latitude and areas of similar richness may vary substantially in composition—it may be more useful to look at the extent to which regional species are represented in a regional pool. The objective of Gap analysis, to determine minimum area needed to protect maximum number, can exclude important species. Among the authors' conclusions is that, to ensure conservation over time, prediction of species distribution based on

habitat associations would need to be complemented by an understanding of ecological processes generating the patterns. Given the dynamic nature of landscapes, this should include those processes operating at a broader scale, outside the pattern-defined boundary.

The **Index of Biological Integrity (IBI)** (Karr 1991; Karr 1993), in which integrity is defined as the "ability to sustain a balanced biological community," seeks a multiparameter approach because it recognizes that "no single biological or chemical attribute is sufficient to evaluate ecological conditions and complexity." IBI also recognizes that "a diversity of approaches are needed to make informed decisions." It contrasts with the practice of monitoring water quality based on limited concepts of factors responsible for degradation, for example, using only chemical criteria. Variables considered in the IBI may include: water quality, habitat structure, flow regime, energy source, and biotic interactions-and are evaluated against a reference condition. Emphasis is on relative vs. numerical abundances. Among the strengths of IBI is that it is composed of diverse independent evaluations that can provide mutual validation.

A collection of papers on a broad range of **biogeophysical indicators** of sustainability, from a conference sponsored by UNU and the World Bank in 1992, is found in a review by Munasinghe and Shearer (Munasinghe and Shearer 1995). A synthesis paper identifies key parameters and associated indicators for diverse ecosystems.

Of particular interest for land management are **situational indicators** (Gallopin, in press). These indicators are applicable to land use in situations in which suitability for different uses can be defined because impacts depend on the type of landscape or socioecological system as well as on the causal factors. A global monitoring system based on these concepts could also preserve local specificities. This system consists of a three-tiered approach:

1) A coarse level in which landscape units are classified based on coarse characteristics (such as soil type, floodplain) regarding which information may be obtainable from secondary sources (such as remote sensing, GIS and groundtruthing). The units are classified as: "no problem," "danger" or "opportunity."
2) For danger or opportunity: medium level monitoring is applied (such as Rapid Rural Appraisal, field surveys, and local expert consultations) to determine the actual existence and magnitude of the problem.
3) If necessary, fine level monitoring is conducted (such as field measurements and experiments).

### 3.7.2 Socioeconomic Frameworks: Measuring Social Capital

Given the importance of interpretation and perception in the identification of appropriate indicators, and the importance of social discourse in establishing objectives, there may be little in the vast literature of the social sciences that is not relevant to the topic of indicators, which could be broadly construed as consisting of whatever information is actually relied upon for decision-making. As pointed out in a report of the Interorganizational Committee on Guidelines and Principles for

Social Impact Assessment (1994), a key factor to be considered is that "humans are affected [also] by changes in the distinctly human environment," related to the social construction of reality. According to the Committee, "the social construction of reality is characteristic of all social groups, including the agencies attempting to implement changes," and cannot be dismissed as "mere perception or emotions to be distinguished from reality." The Committee report also provides an overview of key principles of social impact assessment, processes of conducting it, and identification of important and accessible literature.

It has also been suggested that the barrier to collaboration between natural and social sciences may well fade. According to Arizpe (1996), the interest of the natural and exact sciences in "nonlinear, irreversible, and unstable phenomena ... will draw them closer to the social sciences, whose focus has always included these features." The World Bank report (1995) goes so far as to suggest that, given the link between poverty and environment, indicators for one could be used for the other as well. This section will not attempt an exhaustive review of the social science literature but will instead consider how the social sciences frame environmental problems and identify some relevant themes.

Within the PSR framework, according to a recent review by Bakkes et al. (1994), explicit indicators of social response to environmental pressures and changes have been limited to expenditures for environmental protection. However, increasing attention is being devoted to finding ways of measuring and developing what is coming to be known as **social capital**, which is recognized as accounting for differences in wealth (Putnam 1993; The World Bank 1995). At present, indicators of social capital, such as civic participation, appear primarily in local indicator initiatives, such as (Sustainable Seattle 1995) and are associated with concern for establishing or restoring a sense of community.

**Statistical socioeconomic indicators**, also relevant to environmental concerns, and various approaches to its measurement are found in the development literature—in the yearly reports of multilateral organizations such as the United Nations Development Programme (UNDP) Human Development Report (UNDP 1993); in reports of the International Fund for Agricultural Development (IFAD 1992), the World Bank (The World Bank 1990; The World Bank 1993), The World Health Organization (WHO Commission on Health and Environment 1992); and domestically, in reports of government agencies and NGOs, such as the Children's Defense Fund and the Center on Budget and Policy Priorities (Center on Budget and Policy Priorities 1991; Children's Defense Fund 1994). An overview is provided in the UNEP Environment and Poverty Report (1995b).

Most well known among the statistical indicators is the **Human Development Index (HDI)**, compiled by UNDP, which ranks countries according to their progress towards the maximum attainable values for life expectancy, education, and income indicators. It is assumed that nutritional status and child mortality are reflected in life expectancy, and that employment rates are reflected in real income. The regular HDI does not reveal disparities among different social economic or regional groups, although a separate HDI was calculated for thirty-three countries for which data was available, based on gender, income, and regional differences, to illustrate disparities within countries. India as a whole, for example, ranks 121, while its most populous state, Uttar Pradesh, ranks 147. Male and female disparities are widest in the developing countries. In Canada, for example,

the female HDI is 86% of the male HDI; in Costa Rica, it is two thirds; and in Kenya, it is one half (UNDP 1992). Little if any relationship was found between a country's GNP and HDI rank.

Also worth mentioning is the **disaggregated approach**, adopted by the International Fund for Agricultural Development (IFAD 1992), which better illustrates the variation in conditions of poverty that need to be understood for addressing the problem. These indices illustrate a general decline in food security between the mid-1960s and mid-1980s, particularly in sub-Saharan Africa, and increasing severity of poverty. Inconsistency in the relationship between GNP per capita and the extent to which basic needs are being met demonstrates the importance of considering how budget resources are allocated and the cost-effectiveness of the delivery of services. The twenty lowest-ranking countries on the combined index of relative welfare were also consistent with those considered the most vulnerable based on the HDI ranking method of UNDP.

Poverty in rural areas is characterized using four macro-level indices that measure food security; the depth of poverty; the extent to which basic needs are being met; and relative welfare, which consists of an average of the first three indices. At the household level, the primary consideration is the ability to meet minimum consumption needs during periods of economic difficulty and calamity. Poverty at the household level is characterized by the extent of material deprivation, isolation, alienation, dominance and dependence, lack of participation and freedom of choice, lack of assets, vulnerability, and insecurity. In addition to providing some measure of the quality of life, these factors serve to illustrate some of the social conditions that prevent an escape from poverty. The IFAD report uses a broad set of indicators to illustrate conditions of poverty in several different circumstances and by different social groups, also characterizing different survival strategies and the kinds of conflicts that are inherent in these different conditions.

One of the difficulties in measurement of poverty and quality of life in general concerns is the definition of human needs, which cannot be defined simply in terms of material subsistence factors such as food and shelter. Satisfying basic subsistence needs depends also on networks of social relationships, and institutions that govern access to resources. **Consumption** issues are starting to receive more attention. Summaries of key literature on the topic can be found in Goodwin et al. (1997). In a proposed method for Human Scale Development, Max-Neef (1992) makes a useful **distinction between human needs and satisfiers of needs** (Max-Neef 1992). Human needs are characterized as a system of interrelated factors which are limited in number and the same for everyone, across cultures: Subsistence, Protection, Affection, Understanding, Participation, Creation, Leisure, Identity, and Freedom. These needs can be satisfied in different ways by different people, particularly across cultures—from this perspective, food and shelter are ways that the subsistence need is satisfied. The inability to satisfy any particular need is seen as a different kind of poverty or pathology. For example, a poverty of participation is related to marginalization and discrimination; a poverty of protection is related to violence, and bad health care systems. The basic needs are seen as equally important—inability to meet a particular need, such as subsistence, blocks the ability to meet others. For example, total lack of affection or loss of identity can lead to self-destructive behavior. Disproportionate emphasis on any particular one is also seen as a pathology.

"**Cultural capital**" (Berkes and Folke 1994) is an important prerequisite for sustainable development because it shapes perceptions and mediates human and environmental relationships.

Cultural capital includes world views; values; local and traditional knowledge; and institutions, particularly those that have evolved for management of natural resources, and insure long-term access to those resources by controlling access and preventing unlimited consumption. An extensive literature review on this is classified under the topic of **"Common Property Resource Management"** (see Gupta 1992; Netting 1993; Ostrom 1990; Ostrom et al. 1993) in addition to the above references of Berkes.

A relevant indicator of community integrity suggested by Gupta (1992) might be what a particular community has done collectively without any outside assistance rather than simply trying to increase public participation in externally designed programs and projects. According to Gupta, an organization evolves into an institution when people behave in the collective interest in response to internal commands rather than to external demands made by the organization in which they work (Gupta 1985a; Gupta 1985b). The challenge for development organizations is to also see themselves as participants as well as to be a link between local and national or global systems. Ostrom (1993) examines institutional indicators and shows that institutions account for success or failure of infrastructural development projects.

Two qualitative indicators of social capital that merit extended discussion are equity and trust.

**Equity**

Equity meets the criteria of being useful to a wide range of models because it is related to many different problems, domestically as well as internationally. For example, recent studies have suggested that the degree of inequity or size of the gap between rich and poor is a more important factor than absolute levels of poverty in explaining the health and mortality rates of the poor. States with greater inequality also spent less on education, and had poorer educational performance, more babies born with low birth weight, higher rates of homicide and violent crime, more disabilities, more smokers, more sedentary population, and higher costs for medical care and police protection (Kaplan et al. 1996). Although the studies did not examine environmental issues, they may be relevant because the poor are known to bear a disproportionate burden of the costs of environmental degradation. Life expectancy is also thought to reflect environmental conditions broadly defined.

One way in which these problems are linked is in the disproportionate impacts of environmental degradation on those who are marginal or external to the decision-making process. This is the rationale behind the now infamous statement of former World Bank Chief Economist Lawrence Summers that "the economic logic behind dumping a load of toxic waste in the lowest-wage country is impeccable" (The Economist 1992), and other statements in The Economist magazine (1994) that to put environmental and labor issues on the table in negotiations of international trade agreements is to remove comparative advantage, considered the axiom of free trade theory, before the negotiations even begin.

In other words, our economic system is driven by inequity, which suggests that, to address either environment or development issues, there needs to be a bottom line, particularly if sustainable development is defined as meeting human needs over the long term. A key criterion for sustainable

development would then be to consider whether the needs of the least advantaged and most vulnerable members of society are being met, as well as the most vulnerable ecosystems. Although development projects are normally accompanied by social costs, if the objectives of development are long-term sustainability and poverty alleviation, this criterion suggests a threshold beyond which the costs of development are too high.

Equity is also important because, when uncertainties and stakes are high, decision-making is dominated by the competing world views of people involved who may have different and incompatible notions of what is fair, and of what they are entitled to, as well as of their obligations as humans towards other species (Rayner 1994). According to Rayner, the key challenge in problems such as negotiating the reduction of greenhouse gas emissions is to design a process that is able to engage and retain participation of parties upholding incommensurable preferences rather than to find a single principle of distribution on which all can agree.

Rayner also outlines a framework for understanding these different rationalities with respect to equity. A key distinction is between **distributional and procedural justice**. Procedural justice may be "universalist," which involves generalization and applying the same rules to everyone regardless of differences in context, or "contextual," which considers unique situations. Another concept of fairness is a technical one, based on the economic theory of Pareto optimality, which defines a fair outcome as not leaving any party worse off, and is derived from prescriptive value placed on efficiency in theoretical economics. However, it is rarely if ever achieved, and, if it were valued, no one would give up their life for family, faith or country (Rayner 1994). Universalism has been said to eliminate the rational basis for choosing among rival theories. But "other than subjective individual taste, there is no way to pick and choose among rival moral theories until we begin to apply their principles to see how they affect human relations in real societies." Objective criteria would then be compatibility with preferred and diverse modes of maintaining social solidarity or kinds of social bonding, as well as meeting basic social needs which cannot be universally defined. The demand for fairness arises because of the existence of community, and is based on shared expectations for conduct of community relations or procedural equity, and distribution of rights over resources within and among communities (distributional equity). In one of the classics of economic anthropology, Marcel Mauss (1967) suggested that maintenance of social relations may depend very largely on keeping a running balance of unfairness in transactions because the obligation this creates for future reciprocity is actually the glue that holds human societies together. According to Rayner, methodological individualism is particularly poor at handling intergenerational issues because individual motivations die with individuals. Families, corporations and nation states are institutions that create solidarity within and across generations.

**Trust and Social Solidarity**

There is growing literature on the factors that create social solidarity, that underlie community cohesion, and their relationship to environmental problems. Trust is receiving increasing attention in the literature as a variable that accounts for differences in wealth, for institutional success or failure and as a key ingredient of democracy (Putnam 1993). Putnam also notes that, social trust, norms of reciprocity, networks of civic engagement and successful cooperation, or the lack of these characteristics, tend to be mutually reinforcing. We might also characterize this mutual reinforcement

as an upward or downward spiral—in the upward spiral, trust provides the basis for successful cooperation which leads to greater prosperity than could be achieved by individuals, which leads to greater trust. Conversely, the loss of trust leads to non-cooperation, which leads to the breakdown of social institutions that control access to resources—providing a strong incentive for individuals to consume as much of the resource base as possible before someone else does, and impoverishment—which further reduces trust. This theory is consistent with the interpretation of Ben Abdallah and Englehard (1993), that the unrestricted maximization of individual interests and the externalities associated with it can lead only to an unsustainable society, in which humans and ecosystems are impoverished as a result of the breakdown of economic, demographic, ecological, cultural and social systems.

Erikson (1994) presents several case studies on the effects of human-induced environmental disasters, the most insidious of which he finds to be the deterioration of communities, evidenced by the loss of reciprocity among community members, a process in which "in effect, people put their own individual resources at the disposal of the group—placing them in the communal store, as it were—and then draw on that reserve supply for the demands of everyday life." Unlike the rekindling of community ties through mutual assistance normally experienced after natural disasters, communities traumatized by human-induced environmental disasters were characterized instead by divisiveness between those affected and not affected, and the loss of trust, respect, decency, charity and concern that normally bind human communities in times of crisis. They may be drawn together instead by a shared pessimism. Erikson notes:

> *Human beings are surrounded by layers of trust, radiating out in concentric circles like the ripples in a pond. The experience of trauma, at its worst, can mean not only a loss of confidence in the self but a loss of confidence in the scaffolding of family and community, in the structures of human government, in the larger logics by which humankind lives, and in the ways of nature itself.*

Part of what appears to set these disasters apart is the denial of responsibility by those in charge and the absence of apology. According to Erikson, "the real problem in the long run is that the inhumanity people experience comes to be seen as a natural feature of human life rather than as the bad manners of a particular corporation. They think their eyes are being opened to a larger and profoundly unsettling truth: that human institutions cannot be relied on" (Erikson 1994).

The kinds of trauma described above are similar to those that result from long-term chronic conditions as well as from sudden events, such as is seen in groups of people who have been relocated or who have suffered from plague, famine, spoilage of natural resources, and chronic poverty. The symptoms of trauma found in these situations include "a numbness of spirit, a susceptibility to anxiety and rage and depression, a sense of helplessness, an inability to concentrate, a loss of various motor skills, a heightened apprehension about the physical and social environment, a preoccupation with death, a retreat into dependency, and a general loss of ego functions." These symptoms are found "wherever people feel left out of things, abandoned, separated from the life around them" (Erikson 1994).

One particularly vivid example of community trauma is found in the description of the native community in Grassy Narrow, Canada (Shkilnyk 1985), home to a band of Ojibwa who had suffered from many layers of trauma. These included the diseases resulting from contact with Europeans in the early part of the century, forced acculturation, relocation in 1963, and mercury poisoning of their river system, discovered in 1970, which destroyed their economic base. This was a community that had begun to self-destruct, in which "death from old age had become a rarity...infants died from neglect and outright abuse; older children killed one another and themselves with apparent abandon." According to Anastasia Shkilnyk, who was sent there in 1976 to advise the Canadian government on programs to alleviate the economic disruption caused by the mercury pollution:

> *It did not take me long to recognize that the situation in the community was far more complex and much less amenable to a technical solution than I had envisaged. All the indications of material poverty were there—substandard housing, the absence of running water and sewage connections, poor health, mass unemployment, low income, and welfare dependency—but something more fundamental seemed amiss. Its manifest symptom was widespread alcohol abuse, in the form of prolonged and frequent periods of spree drinking. In the day-care center where I lived, I could not help but be exposed to the difficulties this caused, because battered women and abandoned children came there to seek warmth, refuge, and food....I could never escape the feeling that I had been parachuted into a void—a drab and lifeless place in which the vital spark of life had gone out. It wasn't just the poverty of the place, the isolation, or even the lack of a decent bed that depressed me. I had seen worse material deprivation when I was working in squatter settlements around Santiago, Chile. And I had been in worse physical surroundings while working in war-devastated Ismailia on the project for reconstruction of the Suez Canal. What struck me about Grassy Narrows was the numbness in the human spirit. There was an indifference, a listlessness, a total passivity that I could neither understand nor seem to do anything about. I had never seen such hopelessness anywhere in the Third World (Shkilnyk 1985).*

According to Arizpe (1996), it has been shown that all societies share the desire to prevail as an identity group even after the deaths of its individual members, and, until now, no historical or anthropological evidence has been found of any society that has consciously and deliberately walked to its death. In light of this, "the collective suicide of a religious sect, involving almost seven hundred people in Georgetown, Guyana, in the 1970s, seems to have been an alarm for civilization...," to which we might add incidents like what occurred at Grassy Narrows, described above. According to Erikson these kinds of disasters "serve as a reminder that the preservation (or restoration) of communal forms of life must become a lasting concern, not only for those charged with healing the wounds of acute disaster but for those charged with planning a truly human future" (Erikson 1994).

## 3.8 Indicator Programs

### 3.8.1 Local Initiatives

Local initiatives have always had a greater focus on participatory processes because it is at the local level that impacts at all levels are originated, experienced and responded to. However, the relevant literature has received less attention in national and global level research agendas because the emphasis on complexity and variation in human motivation produces highly disaggregated data and analyses that is context-specific and does not always fit into established conceptual frameworks. The tendency of experts to look for broad and general conclusions also tends to discount the local knowledge and experience of stakeholders found in context-specific cases (Bradbury and Rayner 1995). But even at the local level, indicators mask an enormous amount of complexity. As is pointed out in the report of the Sustainable Seattle initiative:

> *It is significant to remember that just as "the map is not the territory," the indicators are not the same thing as the systems they attempt to measure. These numbers, charts, and graphs represent, in very simple terms, a much more complex reality. Reflected here are the individual lives of thousands of people, animals, and other living things; a complicated economic system; and all the conflicts and commonalties that are expressed in community and political life. The indicators, taken together, provide us with a snapshot of our community, though there is no set of data or comprehensive theory that can take the place of people's direct experiences. (Sustainable Seattle 1995)*

The objective of indicators then, is to find those areas in which the multitude of interests has some degree of overlap, however small. We could usefully conceptualize the local as context for the global—to the extent that local and experiential knowledge is not somehow reflected in globally aggregated understandings of the problem of sustainability, it may constrain actions that can be taken at the global level, which will be seen as irrelevant.

An inventory of local indicator initiatives and references is provided by Corson (1995). A report of the Community Environmental Council (CEC 1994) reviews and compares the experience in three prominent local initiatives: **Sustainable Seattle**, the **Cambridge Civic Forum**, and the **Santa Monica Sustainable City** program. All three used the process of developing indicators as a way to stimulate community dialogue regarding goals for a sustainable future and action to achieve them, but they illustrate three different approaches to the process itself.

In Seattle, a voluntary civic form was initiated by a group of individuals who then conducted research on indicators identified by participants, which they saw as the beginning of a long-term effort to determine the health of the community and find integrated solutions to community problems. Some key principles upon which the **Sustainable Seattle** initiative were based are:

- To use existing data, but recognizing its limitations and re-evaluating its underlying assumptions

- To integrate long-term and short-term concerns—short-term indicators are those that could show results within a one-year period
- To relate them to the concerns of individuals
- To indicate direction of change—toward or away from sustainability, rather than setting specific targets
- To present individual indicators in context of the whole system, and showing links between them, rather than in isolation

The actual indicators address concerns in four areas: environment, population and resources, economy and culture, and society. A master list of the Seattle 1995 indicators is contained in Appendix B. Most of the indicators are surrogates for a broader range of concerns. For example, in addition to level of resource consumption and related air and water pollution, "Vehicle Miles Traveled and Fuel Consumption" is also an indicator of whether people are able to work, live and participate in the neighborhood or local community, whether there is a sense of community, and pressures on open space and wildlife habitat. In addition to confidence in the democratic system, "Voter Participation" is linked to poverty levels and social problems. Likewise, "Children Living in Poverty" is linked with risk for substance abuse; educational opportunities; juvenile crime; and effects of poor health care, such as low birth weights, malnutrition and unwanted pregnancies. "Air Quality" is related to transportation methods, population patterns, economic development, health care costs, social stress and acid rain.

The **Santa Monica Sustainable City** effort, initiated by the city government as a way to develop criteria for incorporating environmental objectives into local government decisions, placed less emphasis on community dialogue. Specific goals and targets were set for resource conservation policy, transportation policy, pollution prevention and public health protection policy, and community and economic development policy (see Appendix C). Special emphasis was on what could be done within existing programs and could be demonstrated to the community.

The **Cambridge Civic Forum** was intended to identify the needs of the community and develop projects that address them and that can be immediately implemented. The indicators are based on characteristics of a sustainable community identified in an applied policy research report prepared by the Tufts University Consortium for Regional Sustainability (CRS): economic security, ecological integrity, quality of life, and empowerment with responsibility. Recognizing the limitations of large community meetings focused on what is largely seen as an abstract concept, the core group used what came to be referred to as a "reaching in" approach. This approach consisted of core members going to other community meetings to learn the immediate day-to-day needs and more tangible community concerns, which broadened the base of participants and facilitated the inclusion of more diverse perspectives. The results were used to frame topics for community forums.

The CEC report also includes discussion of what motivates participation. Key factors in whether individuals, community organizations and businesses commit volunteer time is the ability to connect their personal concerns with larger issues "such as clean air, water quality, adequate housing, fear of crime, quality of education for children, availability of recreational open space,

local jobs and business investment." For local governments, a key factor is the potential to apply the process to planning efforts and community programs. Another key factor is the high level of commitment and amount of time required for either outreach or "reaching in."

### 3.8.2 Grassroots Indicators

"**Grassroots indicators**" is a term used to distinguish indicators that most directly reflect local and indigenous knowledge. Key issues are discussed in an International Development Research Center (IDRC) report (Hambly and Angura 1996) based on a conference on the topic, which also presents several examples. Among the key issues are: the interface between the indigenous and exogenous knowledge system, integrating policy, research and action—referred to as "the three solitudes"—and supporting local knowledge and innovation. Indicators are explicitly seen as a focus for community participation. One paper proposes that indicators of natural resource degradation and desertification be linked to food insecurity because doing so pressures people into unsustainable practices in addition to its effects on health and nutrition (Mwadime 1996). Another paper links health and environmental indicators by demonstrating links between human and livestock health with ecological diversity and conservation in Maasailand (Kipuri 1996).

According to Ugandan Minister of Karamoja, the Honourable David Pulkol, much of the motivation for exploring this approach came from the failure of remote sensing and agricultural forecasting to predict famine in the region. The famine had been anticipated by the local populations based on local knowledge, and their observations of changes in vegetation and rainfall patterns, but they were not heard in the policy process (Hambly and Angura 1996). Similar experiences have been reported elsewhere regarding the crash of the cod fishery in Newfoundland—that scientific research was biased towards offshore data collection and treated the knowledge of the small-scale and near shore fishermen, who anticipated the crash, as anecdotal (McCay and Finlayson 1995).

Gupta proposes a classification of grassroots indicators according to type:

- Biological—Ecological
- Institutional
- Technological
- Social—Cultural

Gupta also proposes a classification according to whether they are used by individuals or groups, and the relevant time dimension:

- Contingent (ecospecific)
- Concurrent (durable, longer-term)
- Cyclical (repetitive at certain intervals)

An initiative to document these kinds of indicators and local innovations more systematically is the **HoneyBee network**, which, in addition to gathering the information, also makes it available in several local languages. One example of a grassroots ecological indicator in India is the flowering

of the neem tree. According to Gupta, "it indicates the nature of the coming monsoon before the rains begin. Ants collect their pupae (eggs) three or four days before the monsoon rains arrive, and snakes move into treetops three days ahead of the monsoon. These local indicators can be compared to the best satellite data which give only forty-eight hours advance warning. These biological and ecological examples of grassroots indicators can also be classified as individual and concurrent (durable)." In other cases, local community residents act as monitors and report on occurrences of scientifically defined indicators, such as cottagers in the Great Lakes region reporting blooms of blue-green algae to monitor water pollution (Hambly and Angura 1996).

However, to be available, such knowledge also needs to be valued. As stated by one participant in the IDRC conference, Mararike (1996), just as the land deteriorates, so too the local knowledge base and the existence of grassroots indicators based on it, which also need to be protected and shared if they are to persist. Gupta (1991; 1996), suggests it is no coincidence that biodiversity is most abundant in the most impoverished regions and reviews some of the reasons why this is so. Much of the reason has to do with the biases inherent in using prices as indicators and as the basis for establishing the "correct" allocation of resources. Also, areas of high biodiversity are often high risk, marginal areas (in contrast with the requirements for uniformity in the marketplace) whose inhabitants are less well represented politically. Gupta proposes using indigenous knowledge systems as the basis for assigning weights to decision-making criteria in that it represents experience in making ecological and economic trade-offs over time.

Niamir-Fuller (1995) examines the kind of **indicators needed for monitoring non-equilibrium ecosystems with high variability**. Because of this variability in rainfall and the patchiness of resources, monitoring requires more frequent measurements both spatially and temporally, more emphasis on groundtruthing than remote sensing, and more emphasis on soil and climate than on vegetation. There is also more emphasis on disaggregated measures, such as density of key species rather than total density, and minimum and maximum ranges of biomass and interannual variation rather than averages. This more extensive approach to monitoring suggests the importance of decentralized institutional arrangements that involve local people and that incorporates their traditional knowledge, even if only for reasons of cost. A collection of papers by Moran (1995) reviews the kinds of data needed to understand human and environment relationships and that could be used to corroborate local knowledge. Moran suggests that more disaggregated measures are also more useful for understanding how decisions are made.

The Mackenzie Basin Impact Study (MBIS) (Cohen 1997) was an integrated assessment of climate change impacts that had an explicit objective of **scientist and stakeholder** collaboration in a region where there is a rich base of traditional ecological knowledge. A set of related studies were conducted to anticipate the effects of climate change and their implications for different stakeholder groups. For example, the participants sought to anticipate potential land use conflicts between agricultural, forestry, and subsistence economies resulting from changes in landcover. In a study of economic impacts in the traditional economies, qualitative information provided the basis for interpreting and determining the implications of quantitative results (Lonergan et al. 1995). The final workshop led to recommendations that scientists develop a framework for explicitly incorporating traditional knowledge into scientific work and to proposals for developing a collaborative monitoring system. Representatives of native communities emphasized the dynamic

nature of traditional knowledge, which exists as part of a tradition of community deliberation and sharing of knowledge in which the historical knowledge of the older people is reconciled with changes observed by the younger people. As stated by Joe Benoit, a representative of the Gwich'in Land Administration, traditional knowledge exists because their lives depend on it—research should be conducted that way also (Cohen 1997).

A set of indicators that integrates qualitative and quantitative factors in evaluating project success is found in the "**Grassroots Development Framework**" of the Inter-American Foundation (IAF) (Ritchey-Vance 1996) (see Figure 3). Noting that project emphasis and reporting was on implementation of project activities and immediate tangible rather than lasting results, and that seemingly successful projects were often abandoned, IAF sought measures that also reflected project sustainability over time. The framework breaks down the broad objectives of participation, empowerment, and sustainability into twenty-two variables in six categories that reflect both tangible and intangible results at different levels, in an interconnected upward spiral ranging from individuals and families to grassroots organizations, NGOs and networks, to society at local, regional and national levels. Categories of variables that reflect tangible results are standard of living, organizational capability, and policy environment. Intangible results are reflected in qualitative indicators of personal capacity, organizational culture, and community norms. Inherent in the framework also is a recognition of the need for balance among these factors (that is, capability for strategic planning without a vision of organizational direction is a sterile exercise). use of this framework for reporting also had the effect of helping grassroots organizations to improve their performance. In that the framework has also been adopted by other foundations and NGOs, it meets its own criteria for success. According to Ritchey-Vance, "what the development assistance community chooses to measure is what [they] will ultimately get from grassroots development" and "cost/efficiency measures will produce bricks and mortar, but at the expense of less visible, less marketable efforts to build human capacity and social capital."

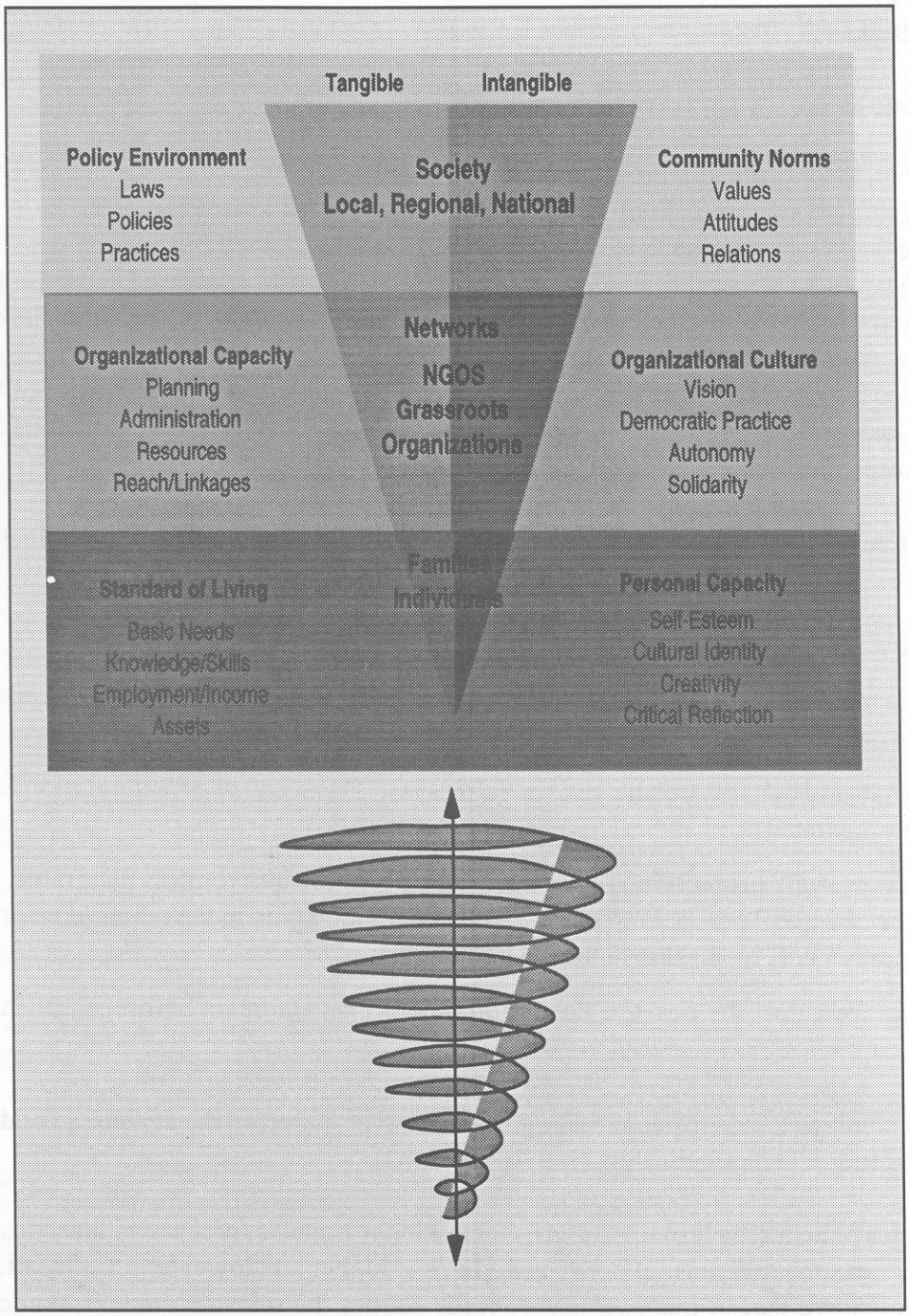


**Fig. 3. The Inter-American Foundation Grassroots Development Framework**
**Source: Ritchey-Vance (1996)**

### 3.8.3 Regional Initiatives

**State-of-the-Lakes**

The Great Lakes indicator program, as described in a report of the Indicators for Evaluation Task Force of the International Joint Commission on the Great Lakes (IJC 1996), is part of a comprehensive ecosystem approach to management of the Great Lakes Basin, in which "**State-of-the-Lake**" indicators are derived from a vision of ecosystem integrity expressed in relevant policies. The indicators are intended to communicate progress toward the goals of the Great Lakes Water Quality agreement, and follow the Pressure-State-Response model. The vision is expressed in the Great Lakes Ecosystem Charter of the Great Lakes Commission, vision statements of the Great Lakes Water Quality Board and Fishery Commission, and an ecosystem model of the Council of Great Lakes Research Managers.

In reference to the goals of the Water Quality agreement, the key questions addressed in the report are:

- How clean is the environment; i.e. what are present ambient conditions?
- Are trends in the right direction? How quickly are we making progress toward achieving the desired outcome?
- What and where are the causes (stresses)? Have cause-effect relationships been demonstrated?
- Are present protection, restoration and pollution prevention programs, policies, processes, and practices working? Are humans engaging in the required environmental actions? Will they achieve the desired outcomes?
- Can we detect the onset of deleterious conditions and react before significant impact occurs?

The IJC report also identifies specific goals and targets based on the agreement and scientific criteria for selecting relevant indicators (see Appendix D).

Principles of hierarchy provide the basis for linking regional to local and global considerations because it illustrates the relationship between systems at higher and lower levels of spatiotemporal scale. The level above that of management concern defines the relevant context, while the level below defines relevant mechanisms. Recognizing that there is no single generic ecosystem because it can be examined from a multitude of perspectives, each of which will affect the observation criteria and the relevant spatial and temporal boundaries, four different ecological perspectives are explicitly recognized:

- Community ecology—in which the focus is on interactions among multiple species, and in which the temporal component is important for considering past processes that led to the current condition. Community ecology is also seen as a way of linking the

concerns of human health, socio-economic infrastructure, and ethics inherent in the Water Quality Agreement.

- Process function ecology—in which exchanges of matter, energy and information show process pathways. From this perspective, it is the pathways that are important, rather than the organisms themselves. These are interlinked processes across relevant scales that are spatially diffuse and best defined in turnover times.
- Landscape ecology—pertains to geographically defined areas, consisting of clusters of sites embedded in a landscape, which is embedded in the land and water system and in the larger region. Landscape ecology also provides a spatial matrix for considering communities and process functions, and is the basis for defining the Great Lakes Basin Ecosystem.
- Population ecology—populations are seen as spatially and temporally well-defined groups of individuals in the same species, although they may be embedded in larger groups.

The ecosystem approach is also explicitly defined to include human needs and the economic system. Under the Agreement, progress is to be assessed "in the light of present and future socio-economic imperatives." The report acknowledges that:

> *Despite societal experience with economic indicators as measures of national economic performance, there is but a rudimentary understanding of how to measure desirable economic states and progress therein, in a sustainable development paradigm.... In part, the answer to the conundrum lies in the realization that the true measure of human welfare, classically assumed to be economic in its essence, is in fact much broader. It is now generally held to include social, cultural and human health (physical and mental) dimensions. Some of these issues are reflected in other desired outcomes in this report, particularly the human health desired outcome, which is determined by critical social and economic dimensions as well as the presence or absence of physical disease.*

A comprehensive analyses of the ecosystem approach and the experience of implementing it in the Great Lakes is provided in MacKenzie (1996).

**State of the Chesapeake Bay**

The State of the Bay report (Magnien et al. 1995) highlights the role of citizen involvement in monitoring, and is based on indicators important to the Bay region, described in a report by the Chesapeake Bay Program Office (1994). The Bay is also receiving special attention as part of an inter-agency regional effort described below.

**Other References to Regional Initiatives**

The Oregon benchmark process, known for innovative approaches to controlling sprawl, is described in a report by the Oregon Progress Board (1994).

### 3.8.4 National Initiatives

**The United States**

The EPA Environmental Monitoring and Assessment Program (EMAP) began with the intention of being a comprehensive, integrated, nationwide monitoring system but, realizing that this scope was beyond the ability of a single agency, has redirected its efforts towards research needs for ecological indicators and integrated assessment. The broader vision has instead become the goal of an inter-agency program under the direction of the President's Committee on the Environment and Natural Resources (CENR). A **multi-tiered monitoring strategy** developed by EMAP is being tested in the mid-Atlantic region. An annotated bibliography of literature on monitoring and indicators related to the EMAP program is provided in Griffith (1994). The EMAP indicator development strategy is presented in Barber (1994). A scientific review of EMAP was also conducted by the National Research Council (1995) which, in addition to recommending more explicit links between models and indicators, also found the sampling scale to be too coarse to detect important changes, and recommended developing a reliable scientific index of ecosystem health, as well as giving more attention to the information management system. Current information, with links to regional efforts, can be found on the world wide web: <URL: http://www.epa.gov/emap>.

In the **Mid-Atlantic Integrated Assessment** (MAIA), an initiative of EPA's Office of Research and Development and Region III, in collaboration with other agencies, special consideration is being given to **place-based research** and to measures that integrate land cover information with other measures of stress. Key questions guiding the program are:

- Is there a problem?
- Where is the problem?
- What is the cause of the problem?
- Are things changing?
- What does it mean to a community?
- What can we do about it?

The **CENR** effort National Science and Technology Council (NSTC 1997) is looking to better integrate thirty government programs identified as conducting activities relevant to environmental monitoring, who have a combined budget of $500 million a year. The goal is also to create a **network of monitoring sites**, primarily from these existing programs, that integrate regional information and that are also complementary to international monitoring efforts. An overall objective is to generate standard and compatible data needed for integrated modeling and assessment

intended to support decision making through better understanding of ecosystem processes, and anticipation of changing conditions. However, the scope appears to be limited to physical and biological parameters. The full report is available on the web via the White House Office of Science and Technology Policy (OSTP): <http://www.whitehouse.gov/WH/EOP/OSTP/html/OSTP_Home.html>.

The President's Council on Sustainable Development (PCSD 1996) identified some indicators of progress for the ten broad goals that were agreed upon. That report is also available in full on the web: <http://www.whitehouse.gov/PCSD>.

**Canada**

Environment Canada's "State of the Environment Reporting" (1991; 1995) was designed to measure progress towards Canada's Green Plan and consists of priority objectives and targets that can be applied at different scales and in different sectors (such as national, regional, municipal, watershed, parks). The initiative is based on a condition-stress-response framework. It is also described by Kerr (1994), and is accessible on the web at: <http://www.doe.ca/envhome.html>.

### 3.8.5 International Initiatives

International indicator initiatives are primarily oriented towards providing information necessary for monitoring compliance with international environmental treaties, which include the Nations Framework Convention on Climate Change, UN-Economic Commission for Europe Convention on Long-range Transboundary Air Pollution (LRTAP), and the Montreal Protocol on Chloro-Fluorocarbons (CFCs). Indicators related to international treaties, as well as all the international indicator sets reviewed in the World Bank report from the different sources, are available for interactive querying on the world wide web at CIESIN <http://www.ciesin.org>, which also has links to several regional initiatives. International indicators are compiled in a joint publication of the World Resources Institute, UNEP, United Nations Development Programme (UNDP), and the World Bank (1996), which also features a special section on urban indicators. Another important compendium of data regarding international indicators is in the UNEP Environmental Data Report, produced by the United Nations Development Programme and Global Resource Information Database (UNEP GRID) program (UNEP 1993). National and international level indicators are also the subject of a separate SCOPE project on Indicators for Sustainable Development for which publications are forthcoming.

A review and comparison of international initiatives is provided by Bakkes et al. (1994). These initiatives are primarily based on the pressure-state-response framework originally developed by Rapport and Friend (Rapport and Friend 1979). The report reviews indicators, key references, and data collection efforts for air pollution, stratospheric ozone depletion, climate change, freshwater and marine resources, natural resources, biodiversity, and socioeconomic environmental indicators. The natural resources category includes soils, desertification, landcover/land use, forests, agriculture, fisheries, irrigation, and agro-ecological zones. Socioeconomic environmental indicators include public health, and wastes as measures of effects of human activities on the environment. Overall conclusions are that there is a bias towards priorities of industrialized countries. The framework is

also described as static in that it is not designed to show cross linkages between different aspects of environmental quality, impacts, and driving forces. Incorporation of modeling and systems analysis is recommended.

The OECD indicators (OECD 1993; OECD 1994), based on the Pressure-State-Response framework, are grouped in nine categories of environmental issues that reflect major environmental concerns in OECD countries and allow for comparison. The categories are: climate change and ozone layer depletion, eutrophication, acidification, toxic contamination, urban environmental quality, biodiversity and landscapes, waste, natural resources, and general indicators. Indicators are used to measure environmental performance, and to integrate environmental concerns into sectorial as well as overall economic policies (for example, in satellites to national accounts and natural resource accounts—so far done only for water, use has been calculated as a fraction of gross annual amount available by country, and pollution costs for abatement and control). Sectorial indicators are not yet available. Key criteria for their selection have to do with policy relevance, usefulness to users, analytical soundness, and measurability.

An international/regional indicator initiative that reflects developing country concerns is a United Nations Development Programme and Centro Internacional de Argricultura Tropical (International Center for Tropical Agriculture) (UNEP/CIAT) program that has an emphasis on spatial indicators and detailed aspects of land and resource use, as well as community health (Winograd 1995). These indicators are described and listed in a website: <http://www.ciat.cgiar.ag/land/indicators>, and are included in Appendix F as an example of indicators that express developing country concerns. Land Quality Indicators are also expected to be available through the CIESIN website: <http://www.ciesin.org>.

## 3.9 Conclusion

This review has sought to characterize and contrast two key perspectives regarding models and sustainable development indicators: that of trying to consider diverse environmental concerns using narrow indices upon which most decision-making is presently based (that is, attempting to somehow fit scientific considerations into a cost benefit analysis framework); and that of instead altering the decision process and institutional relationships to consider more diverse and interrelated criteria for sustainable development. Adopting the broader, systems approach implies that ethical and cultural criteria are given as much consideration as scientific and technical, and that the decision-making process itself is part of the system. Indicators of success depend on how success is defined and cannot be defined outside the context of policy objectives and visions of the future.

Although there is a bias in this review towards the systems approach, these two overall approaches need not be seen as mutually exclusive. Aggregated indicators may be useful for comparing overall trends, just as cost-benefit analysis may be appropriate for well defined and uncontroversial problems. However, aggregated indicators do not provide the detail relevant to management concerns, and needed for determining a course of action to address specific problems in specific circumstances. They also make their inherent biases less transparent (as is discussed in the section on distributional issues). If we instead recognize complex environmental problems as sociopolitical conflicts regarding the disproportionate distribution of risks and benefits, then these

habitat associations would need to be complemented by an understanding of ecological processes generating the patterns. Given the dynamic nature of landscapes, this should include those processes operating at a broader scale, outside the pattern-defined boundary.

The **Index of Biological Integrity (IBI)** (Karr 1991; Karr 1993), in which integrity is defined as the "ability to sustain a balanced biological community," seeks a multiparameter approach because it recognizes that "no single biological or chemical attribute is sufficient to evaluate ecological conditions and complexity." IBI also recognizes that "a diversity of approaches are needed to make informed decisions." It contrasts with the practice of monitoring water quality based on limited concepts of factors responsible for degradation, for example, using only chemical criteria. Variables considered in the IBI may include: water quality, habitat structure, flow regime, energy source, and biotic interactions-and are evaluated against a reference condition. Emphasis is on relative vs. numerical abundances. Among the strengths of IBI is that it is composed of diverse independent evaluations that can provide mutual validation.

A collection of papers on a broad range of **biogeophysical indicators** of sustainability, from a conference sponsored by UNU and the World Bank in 1992, is found in a review by Munasinghe and Shearer (Munasinghe and Shearer 1995). A synthesis paper identifies key parameters and associated indicators for diverse ecosystems.

Of particular interest for land management are **situational indicators** (Gallopin, in press). These indicators are applicable to land use in situations in which suitability for different uses can be defined because impacts depend on the type of landscape or socioecological system as well as on the causal factors. A global monitoring system based on these concepts could also preserve local specificities. This system consists of a three-tiered approach:

1) A coarse level in which landscape units are classified based on coarse characteristics (such as soil type, floodplain) regarding which information may be obtainable from secondary sources (such as remote sensing, GIS and groundtruthing). The units are classified as: "no problem," "danger" or "opportunity."
2) For danger or opportunity: medium level monitoring is applied (such as Rapid Rural Appraisal, field surveys, and local expert consultations) to determine the actual existence and magnitude of the problem.
3) If necessary, fine level monitoring is conducted (such as field measurements and experiments).

### 3.7.2 Socioeconomic Frameworks: Measuring Social Capital

Given the importance of interpretation and perception in the identification of appropriate indicators, and the importance of social discourse in establishing objectives, there may be little in the vast literature of the social sciences that is not relevant to the topic of indicators, which could be broadly construed as consisting of whatever information is actually relied upon for decision-making. As pointed out in a report of the Interorganizational Committee on Guidelines and Principles for

Social Impact Assessment (1994), a key factor to be considered is that "humans are affected [also] by changes in the distinctly human environment," related to the social construction of reality. According to the Committee, "the social construction of reality is characteristic of all social groups, including the agencies attempting to implement changes," and cannot be dismissed as "mere perception or emotions to be distinguished from reality." The Committee report also provides an overview of key principles of social impact assessment, processes of conducting it, and identification of important and accessible literature.

It has also been suggested that the barrier to collaboration between natural and social sciences may well fade. According to Arizpe (1996), the interest of the natural and exact sciences in "nonlinear, irreversible, and unstable phenomena ... will draw them closer to the social sciences, whose focus has always included these features." The World Bank report (1995) goes so far as to suggest that, given the link between poverty and environment, indicators for one could be used for the other as well. This section will not attempt an exhaustive review of the social science literature but will instead consider how the social sciences frame environmental problems and identify some relevant themes.

Within the PSR framework, according to a recent review by Bakkes et al. (1994), explicit indicators of social response to environmental pressures and changes have been limited to expenditures for environmental protection. However, increasing attention is being devoted to finding ways of measuring and developing what is coming to be known as **social capital**, which is recognized as accounting for differences in wealth (Putnam 1993; The World Bank 1995). At present, indicators of social capital, such as civic participation, appear primarily in local indicator initiatives, such as (Sustainable Seattle 1995) and are associated with concern for establishing or restoring a sense of community.

**Statistical socioeconomic indicators**, also relevant to environmental concerns, and various approaches to its measurement are found in the development literature—in the yearly reports of multilateral organizations such as the United Nations Development Programme (UNDP) Human Development Report (UNDP 1993); in reports of the International Fund for Agricultural Development (IFAD 1992), the World Bank (The World Bank 1990; The World Bank 1993), The World Health Organization (WHO Commission on Health and Environment 1992); and domestically, in reports of government agencies and NGOs, such as the Children's Defense Fund and the Center on Budget and Policy Priorities (Center on Budget and Policy Priorities 1991; Children's Defense Fund 1994). An overview is provided in the UNEP Environment and Poverty Report (1995b).

Most well known among the statistical indicators is the **Human Development Index (HDI)**, compiled by UNDP, which ranks countries according to their progress towards the maximum attainable values for life expectancy, education, and income indicators. It is assumed that nutritional status and child mortality are reflected in life expectancy, and that employment rates are reflected in real income. The regular HDI does not reveal disparities among different social economic or regional groups, although a separate HDI was calculated for thirty-three countries for which data was available, based on gender, income, and regional differences, to illustrate disparities within countries. India as a whole, for example, ranks 121, while its most populous state, Uttar Pradesh, ranks 147. Male and female disparities are widest in the developing countries. In Canada, for example,

the female HDI is 86% of the male HDI; in Costa Rica, it is two thirds; and in Kenya, it is one half (UNDP 1992). Little if any relationship was found between a country's GNP and HDI rank.

Also worth mentioning is the **disaggregated approach**, adopted by the International Fund for Agricultural Development (IFAD 1992), which better illustrates the variation in conditions of poverty that need to be understood for addressing the problem. These indices illustrate a general decline in food security between the mid-1960s and mid-1980s, particularly in sub-Saharan Africa, and increasing severity of poverty. Inconsistency in the relationship between GNP per capita and the extent to which basic needs are being met demonstrates the importance of considering how budget resources are allocated and the cost-effectiveness of the delivery of services. The twenty lowest-ranking countries on the combined index of relative welfare were also consistent with those considered the most vulnerable based on the HDI ranking method of UNDP.

Poverty in rural areas is characterized using four macro-level indices that measure food security; the depth of poverty; the extent to which basic needs are being met; and relative welfare, which consists of an average of the first three indices. At the household level, the primary consideration is the ability to meet minimum consumption needs during periods of economic difficulty and calamity. Poverty at the household level is characterized by the extent of material deprivation, isolation, alienation, dominance and dependence, lack of participation and freedom of choice, lack of assets, vulnerability, and insecurity. In addition to providing some measure of the quality of life, these factors serve to illustrate some of the social conditions that prevent an escape from poverty. The IFAD report uses a broad set of indicators to illustrate conditions of poverty in several different circumstances and by different social groups, also characterizing different survival strategies and the kinds of conflicts that are inherent in these different conditions.

One of the difficulties in measurement of poverty and quality of life in general concerns is the definition of human needs, which cannot be defined simply in terms of material subsistence factors such as food and shelter. Satisfying basic subsistence needs depends also on networks of social relationships, and institutions that govern access to resources. **Consumption** issues are starting to receive more attention. Summaries of key literature on the topic can be found in Goodwin et al. (1997). In a proposed method for Human Scale Development, Max-Neef (1992) makes a useful **distinction between human needs and satisfiers of needs** (Max-Neef 1992). Human needs are characterized as a system of interrelated factors which are limited in number and the same for everyone, across cultures: Subsistence, Protection, Affection, Understanding, Participation, Creation, Leisure, Identity, and Freedom. These needs can be satisfied in different ways by different people, particularly across cultures—from this perspective, food and shelter are ways that the subsistence need is satisfied. The inability to satisfy any particular need is seen as a different kind of poverty or pathology. For example, a poverty of participation is related to marginalization and discrimination; a poverty of protection is related to violence, and bad health care systems. The basic needs are seen as equally important—inability to meet a particular need, such as subsistence, blocks the ability to meet others. For example, total lack of affection or loss of identity can lead to self-destructive behavior. Disproportionate emphasis on any particular one is also seen as a pathology.

"**Cultural capital**" (Berkes and Folke 1994) is an important prerequisite for sustainable development because it shapes perceptions and mediates human and environmental relationships.

Cultural capital includes world views; values; local and traditional knowledge; and institutions, particularly those that have evolved for management of natural resources, and insure long-term access to those resources by controlling access and preventing unlimited consumption. An extensive literature review on this is classified under the topic of **"Common Property Resource Management"** (see Gupta 1992; Netting 1993; Ostrom 1990; Ostrom et al. 1993) in addition to the above references of Berkes.

A relevant indicator of community integrity suggested by Gupta (1992) might be what a particular community has done collectively without any outside assistance rather than simply trying to increase public participation in externally designed programs and projects. According to Gupta, an organization evolves into an institution when people behave in the collective interest in response to internal commands rather than to external demands made by the organization in which they work (Gupta 1985a; Gupta 1985b). The challenge for development organizations is to also see themselves as participants as well as to be a link between local and national or global systems. Ostrom (1993) examines institutional indicators and shows that institutions account for success or failure of infrastructural development projects.

Two qualitative indicators of social capital that merit extended discussion are equity and trust.

**Equity**

Equity meets the criteria of being useful to a wide range of models because it is related to many different problems, domestically as well as internationally. For example, recent studies have suggested that the degree of inequity or size of the gap between rich and poor is a more important factor than absolute levels of poverty in explaining the health and mortality rates of the poor. States with greater inequality also spent less on education, and had poorer educational performance, more babies born with low birth weight, higher rates of homicide and violent crime, more disabilities, more smokers, more sedentary population, and higher costs for medical care and police protection (Kaplan et al. 1996). Although the studies did not examine environmental issues, they may be relevant because the poor are known to bear a disproportionate burden of the costs of environmental degradation. Life expectancy is also thought to reflect environmental conditions broadly defined.

One way in which these problems are linked is in the disproportionate impacts of environmental degradation on those who are marginal or external to the decision-making process. This is the rationale behind the now infamous statement of former World Bank Chief Economist Lawrence Summers that "the economic logic behind dumping a load of toxic waste in the lowest-wage country is impeccable" (The Economist 1992), and other statements in The Economist magazine (1994) that to put environmental and labor issues on the table in negotiations of international trade agreements is to remove comparative advantage, considered the axiom of free trade theory, before the negotiations even begin.

In other words, our economic system is driven by inequity, which suggests that, to address either environment or development issues, there needs to be a bottom line, particularly if sustainable development is defined as meeting human needs over the long term. A key criterion for sustainable

development would then be to consider whether the needs of the least advantaged and most vulnerable members of society are being met, as well as the most vulnerable ecosystems. Although development projects are normally accompanied by social costs, if the objectives of development are long-term sustainability and poverty alleviation, this criterion suggests a threshold beyond which the costs of development are too high.

Equity is also important because, when uncertainties and stakes are high, decision-making is dominated by the competing world views of people involved who may have different and incompatible notions of what is fair, and of what they are entitled to, as well as of their obligations as humans towards other species (Rayner 1994). According to Rayner, the key challenge in problems such as negotiating the reduction of greenhouse gas emissions is to design a process that is able to engage and retain participation of parties upholding incommensurable preferences rather than to find a single principle of distribution on which all can agree.

Rayner also outlines a framework for understanding these different rationalities with respect to equity. A key distinction is between **distributional and procedural justice**. Procedural justice may be "universalist," which involves generalization and applying the same rules to everyone regardless of differences in context, or "contextual," which considers unique situations. Another concept of fairness is a technical one, based on the economic theory of Pareto optimality, which defines a fair outcome as not leaving any party worse off, and is derived from prescriptive value placed on efficiency in theoretical economics. However, it is rarely if ever achieved, and, if it were valued, no one would give up their life for family, faith or country (Rayner 1994). Universalism has been said to eliminate the rational basis for choosing among rival theories. But "other than subjective individual taste, there is no way to pick and choose among rival moral theories until we begin to apply their principles to see how they affect human relations in real societies." Objective criteria would then be compatibility with preferred and diverse modes of maintaining social solidarity or kinds of social bonding, as well as meeting basic social needs which cannot be universally defined. The demand for fairness arises because of the existence of community, and is based on shared expectations for conduct of community relations or procedural equity, and distribution of rights over resources within and among communities (distributional equity). In one of the classics of economic anthropology, Marcel Mauss (1967) suggested that maintenance of social relations may depend very largely on keeping a running balance of unfairness in transactions because the obligation this creates for future reciprocity is actually the glue that holds human societies together. According to Rayner, methodological individualism is particularly poor at handling intergenerational issues because individual motivations die with individuals. Families, corporations and nation states are institutions that create solidarity within and across generations.

**Trust and Social Solidarity**

There is growing literature on the factors that create social solidarity, that underlie community cohesion, and their relationship to environmental problems. Trust is receiving increasing attention in the literature as a variable that accounts for differences in wealth, for institutional success or failure and as a key ingredient of democracy (Putnam 1993). Putnam also notes that, social trust, norms of reciprocity, networks of civic engagement and successful cooperation, or the lack of these characteristics, tend to be mutually reinforcing. We might also characterize this mutual reinforcement

as an upward or downward spiral—in the upward spiral, trust provides the basis for successful cooperation which leads to greater prosperity than could be achieved by individuals, which leads to greater trust. Conversely, the loss of trust leads to non-cooperation, which leads to the breakdown of social institutions that control access to resources—providing a strong incentive for individuals to consume as much of the resource base as possible before someone else does, and impoverishment—which further reduces trust. This theory is consistent with the interpretation of Ben Abdallah and Englehard (1993), that the unrestricted maximization of individual interests and the externalities associated with it can lead only to an unsustainable society, in which humans and ecosystems are impoverished as a result of the breakdown of economic, demographic, ecological, cultural and social systems.

Erikson (1994) presents several case studies on the effects of human-induced environmental disasters, the most insidious of which he finds to be the deterioration of communities, evidenced by the loss of reciprocity among community members, a process in which "in effect, people put their own individual resources at the disposal of the group—placing them in the communal store, as it were—and then draw on that reserve supply for the demands of everyday life." Unlike the rekindling of community ties through mutual assistance normally experienced after natural disasters, communities traumatized by human-induced environmental disasters were characterized instead by divisiveness between those affected and not affected, and the loss of trust, respect, decency, charity and concern that normally bind human communities in times of crisis. They may be drawn together instead by a shared pessimism. Erikson notes:

> *Human beings are surrounded by layers of trust, radiating out in concentric circles like the ripples in a pond. The experience of trauma, at its worst, can mean not only a loss of confidence in the self but a loss of confidence in the scaffolding of family and community, in the structures of human government, in the larger logics by which humankind lives, and in the ways of nature itself.*

Part of what appears to set these disasters apart is the denial of responsibility by those in charge and the absence of apology. According to Erikson, "the real problem in the long run is that the inhumanity people experience comes to be seen as a natural feature of human life rather than as the bad manners of a particular corporation. They think their eyes are being opened to a larger and profoundly unsettling truth: that human institutions cannot be relied on" (Erikson 1994).

The kinds of trauma described above are similar to those that result from long-term chronic conditions as well as from sudden events, such as is seen in groups of people who have been relocated or who have suffered from plague, famine, spoilage of natural resources, and chronic poverty. The symptoms of trauma found in these situations include "a numbness of spirit, a susceptibility to anxiety and rage and depression, a sense of helplessness, an inability to concentrate, a loss of various motor skills, a heightened apprehension about the physical and social environment, a preoccupation with death, a retreat into dependency, and a general loss of ego functions." These symptoms are found "wherever people feel left out of things, abandoned, separated from the life around them" (Erikson 1994).

One particularly vivid example of community trauma is found in the description of the native community in Grassy Narrow, Canada (Shkilnyk 1985), home to a band of Ojibwa who had suffered from many layers of trauma. These included the diseases resulting from contact with Europeans in the early part of the century, forced acculturation, relocation in 1963, and mercury poisoning of their river system, discovered in 1970, which destroyed their economic base. This was a community that had begun to self-destruct, in which "death from old age had become a rarity...infants died from neglect and outright abuse; older children killed one another and themselves with apparent abandon." According to Anastasia Shkilnyk, who was sent there in 1976 to advise the Canadian government on programs to alleviate the economic disruption caused by the mercury pollution:

> *It did not take me long to recognize that the situation in the community was far more complex and much less amenable to a technical solution than I had envisaged. All the indications of material poverty were there—substandard housing, the absence of running water and sewage connections, poor health, mass unemployment, low income, and welfare dependency—but something more fundamental seemed amiss. Its manifest symptom was widespread alcohol abuse, in the form of prolonged and frequent periods of spree drinking. In the day-care center where I lived, I could not help but be exposed to the difficulties this caused, because battered women and abandoned children came there to seek warmth, refuge, and food....I could never escape the feeling that I had been parachuted into a void—a drab and lifeless place in which the vital spark of life had gone out. It wasn't just the poverty of the place, the isolation, or even the lack of a decent bed that depressed me. I had seen worse material deprivation when I was working in squatter settlements around Santiago, Chile. And I had been in worse physical surroundings while working in war-devastated Ismailia on the project for reconstruction of the Suez Canal. What struck me about Grassy Narrows was the numbness in the human spirit. There was an indifference, a listlessness, a total passivity that I could neither understand nor seem to do anything about. I had never seen such hopelessness anywhere in the Third World (Shkilnyk 1985).*

According to Arizpe (1996), it has been shown that all societies share the desire to prevail as an identity group even after the deaths of its individual members, and, until now, no historical or anthropological evidence has been found of any society that has consciously and deliberately walked to its death. In light of this, "the collective suicide of a religious sect, involving almost seven hundred people in Georgetown, Guyana, in the 1970s, seems to have been an alarm for civilization...," to which we might add incidents like what occurred at Grassy Narrows, described above. According to Erikson these kinds of disasters "serve as a reminder that the preservation (or restoration) of communal forms of life must become a lasting concern, not only for those charged with healing the wounds of acute disaster but for those charged with planning a truly human future" (Erikson 1994).

## 3.8 Indicator Programs

### 3.8.1 Local Initiatives

Local initiatives have always had a greater focus on participatory processes because it is at the local level that impacts at all levels are originated, experienced and responded to. However, the relevant literature has received less attention in national and global level research agendas because the emphasis on complexity and variation in human motivation produces highly disaggregated data and analyses that is context-specific and does not always fit into established conceptual frameworks. The tendency of experts to look for broad and general conclusions also tends to discount the local knowledge and experience of stakeholders found in context-specific cases (Bradbury and Rayner 1995). But even at the local level, indicators mask an enormous amount of complexity. As is pointed out in the report of the Sustainable Seattle initiative:

> *It is significant to remember that just as "the map is not the territory," the indicators are not the same thing as the systems they attempt to measure. These numbers, charts, and graphs represent, in very simple terms, a much more complex reality. Reflected here are the individual lives of thousands of people, animals, and other living things; a complicated economic system; and all the conflicts and commonalties that are expressed in community and political life. The indicators, taken together, provide us with a snapshot of our community, though there is no set of data or comprehensive theory that can take the place of people's direct experiences. (Sustainable Seattle 1995)*

The objective of indicators then, is to find those areas in which the multitude of interests has some degree of overlap, however small. We could usefully conceptualize the local as context for the global—to the extent that local and experiential knowledge is not somehow reflected in globally aggregated understandings of the problem of sustainability, it may constrain actions that can be taken at the global level, which will be seen as irrelevant.

An inventory of local indicator initiatives and references is provided by Corson (1995). A report of the Community Environmental Council (CEC 1994) reviews and compares the experience in three prominent local initiatives: **Sustainable Seattle**, the **Cambridge Civic Forum**, and the **Santa Monica Sustainable City** program. All three used the process of developing indicators as a way to stimulate community dialogue regarding goals for a sustainable future and action to achieve them, but they illustrate three different approaches to the process itself.

In Seattle, a voluntary civic form was initiated by a group of individuals who then conducted research on indicators identified by participants, which they saw as the beginning of a long-term effort to determine the health of the community and find integrated solutions to community problems. Some key principles upon which the **Sustainable Seattle** initiative were based are:

- To use existing data, but recognizing its limitations and re-evaluating its underlying assumptions

- To integrate long-term and short-term concerns—short-term indicators are those that could show results within a one-year period
- To relate them to the concerns of individuals
- To indicate direction of change—toward or away from sustainability, rather than setting specific targets
- To present individual indicators in context of the whole system, and showing links between them, rather than in isolation

The actual indicators address concerns in four areas: environment, population and resources, economy and culture, and society. A master list of the Seattle 1995 indicators is contained in Appendix B. Most of the indicators are surrogates for a broader range of concerns. For example, in addition to level of resource consumption and related air and water pollution, "Vehicle Miles Traveled and Fuel Consumption" is also an indicator of whether people are able to work, live and participate in the neighborhood or local community, whether there is a sense of community, and pressures on open space and wildlife habitat. In addition to confidence in the democratic system, "Voter Participation" is linked to poverty levels and social problems. Likewise, "Children Living in Poverty" is linked with risk for substance abuse; educational opportunities; juvenile crime; and effects of poor health care, such as low birth weights, malnutrition and unwanted pregnancies. "Air Quality" is related to transportation methods, population patterns, economic development, health care costs, social stress and acid rain.

The **Santa Monica Sustainable City** effort, initiated by the city government as a way to develop criteria for incorporating environmental objectives into local government decisions, placed less emphasis on community dialogue. Specific goals and targets were set for resource conservation policy, transportation policy, pollution prevention and public health protection policy, and community and economic development policy (see Appendix C). Special emphasis was on what could be done within existing programs and could be demonstrated to the community.

The **Cambridge Civic Forum** was intended to identify the needs of the community and develop projects that address them and that can be immediately implemented. The indicators are based on characteristics of a sustainable community identified in an applied policy research report prepared by the Tufts University Consortium for Regional Sustainability (CRS): economic security, ecological integrity, quality of life, and empowerment with responsibility. Recognizing the limitations of large community meetings focused on what is largely seen as an abstract concept, the core group used what came to be referred to as a "reaching in" approach. This approach consisted of core members going to other community meetings to learn the immediate day-to-day needs and more tangible community concerns, which broadened the base of participants and facilitated the inclusion of more diverse perspectives. The results were used to frame topics for community forums.

The CEC report also includes discussion of what motivates participation. Key factors in whether individuals, community organizations and businesses commit volunteer time is the ability to connect their personal concerns with larger issues "such as clean air, water quality, adequate housing, fear of crime, quality of education for children, availability of recreational open space,

local jobs and business investment." For local governments, a key factor is the potential to apply the process to planning efforts and community programs. Another key factor is the high level of commitment and amount of time required for either outreach or "reaching in."

### 3.8.2 Grassroots Indicators

"**Grassroots indicators**" is a term used to distinguish indicators that most directly reflect local and indigenous knowledge. Key issues are discussed in an International Development Research Center (IDRC) report (Hambly and Angura 1996) based on a conference on the topic, which also presents several examples. Among the key issues are: the interface between the indigenous and exogenous knowledge system, integrating policy, research and action—referred to as "the three solitudes"—and supporting local knowledge and innovation. Indicators are explicitly seen as a focus for community participation. One paper proposes that indicators of natural resource degradation and desertification be linked to food insecurity because doing so pressures people into unsustainable practices in addition to its effects on health and nutrition (Mwadime 1996). Another paper links health and environmental indicators by demonstrating links between human and livestock health with ecological diversity and conservation in Maasailand (Kipuri 1996).

According to Ugandan Minister of Karamoja, the Honourable David Pulkol, much of the motivation for exploring this approach came from the failure of remote sensing and agricultural forecasting to predict famine in the region. The famine had been anticipated by the local populations based on local knowledge, and their observations of changes in vegetation and rainfall patterns, but they were not heard in the policy process (Hambly and Angura 1996). Similar experiences have been reported elsewhere regarding the crash of the cod fishery in Newfoundland—that scientific research was biased towards offshore data collection and treated the knowledge of the small-scale and near shore fishermen, who anticipated the crash, as anecdotal (McCay and Finlayson 1995).

Gupta proposes a classification of grassroots indicators according to type:

- Biological—Ecological
- Institutional
- Technological
- Social—Cultural

Gupta also proposes a classification according to whether they are used by individuals or groups, and the relevant time dimension:

- Contingent (ecospecific)
- Concurrent (durable, longer-term)
- Cyclical (repetitive at certain intervals)

An initiative to document these kinds of indicators and local innovations more systematically is the **HoneyBee network**, which, in addition to gathering the information, also makes it available in several local languages. One example of a grassroots ecological indicator in India is the flowering

of the neem tree. According to Gupta, "it indicates the nature of the coming monsoon before the rains begin. Ants collect their pupae (eggs) three or four days before the monsoon rains arrive, and snakes move into treetops three days ahead of the monsoon. These local indicators can be compared to the best satellite data which give only forty-eight hours advance warning. These biological and ecological examples of grassroots indicators can also be classified as individual and concurrent (durable)." In other cases, local community residents act as monitors and report on occurrences of scientifically defined indicators, such as cottagers in the Great Lakes region reporting blooms of blue-green algae to monitor water pollution (Hambly and Angura 1996).

However, to be available, such knowledge also needs to be valued. As stated by one participant in the IDRC conference, Mararike (1996), just as the land deteriorates, so too the local knowledge base and the existence of grassroots indicators based on it, which also need to be protected and shared if they are to persist. Gupta (1991; 1996), suggests it is no coincidence that biodiversity is most abundant in the most impoverished regions and reviews some of the reasons why this is so. Much of the reason has to do with the biases inherent in using prices as indicators and as the basis for establishing the "correct" allocation of resources. Also, areas of high biodiversity are often high risk, marginal areas (in contrast with the requirements for uniformity in the marketplace) whose inhabitants are less well represented politically. Gupta proposes using indigenous knowledge systems as the basis for assigning weights to decision-making criteria in that it represents experience in making ecological and economic trade-offs over time.

Niamir-Fuller (1995) examines the kind of **indicators needed for monitoring non-equilibrium ecosystems with high variability**. Because of this variability in rainfall and the patchiness of resources, monitoring requires more frequent measurements both spatially and temporally, more emphasis on groundtruthing than remote sensing, and more emphasis on soil and climate than on vegetation. There is also more emphasis on disaggregated measures, such as density of key species rather than total density, and minimum and maximum ranges of biomass and interannual variation rather than averages. This more extensive approach to monitoring suggests the importance of decentralized institutional arrangements that involve local people and that incorporates their traditional knowledge, even if only for reasons of cost. A collection of papers by Moran (1995) reviews the kinds of data needed to understand human and environment relationships and that could be used to corroborate local knowledge. Moran suggests that more disaggregated measures are also more useful for understanding how decisions are made.

The Mackenzie Basin Impact Study (MBIS) (Cohen 1997) was an integrated assessment of climate change impacts that had an explicit objective of **scientist and stakeholder** collaboration in a region where there is a rich base of traditional ecological knowledge. A set of related studies were conducted to anticipate the effects of climate change and their implications for different stakeholder groups. For example, the participants sought to anticipate potential land use conflicts between agricultural, forestry, and subsistence economies resulting from changes in landcover. In a study of economic impacts in the traditional economies, qualitative information provided the basis for interpreting and determining the implications of quantitative results (Lonergan et al. 1995). The final workshop led to recommendations that scientists develop a framework for explicitly incorporating traditional knowledge into scientific work and to proposals for developing a collaborative monitoring system. Representatives of native communities emphasized the dynamic

nature of traditional knowledge, which exists as part of a tradition of community deliberation and sharing of knowledge in which the historical knowledge of the older people is reconciled with changes observed by the younger people. As stated by Joe Benoit, a representative of the Gwich'in Land Administration, traditional knowledge exists because their lives depend on it—research should be conducted that way also (Cohen 1997).

A set of indicators that integrates qualitative and quantitative factors in evaluating project success is found in the "**Grassroots Development Framework**" of the Inter-American Foundation (IAF) (Ritchey-Vance 1996) (see Figure 3). Noting that project emphasis and reporting was on implementation of project activities and immediate tangible rather than lasting results, and that seemingly successful projects were often abandoned, IAF sought measures that also reflected project sustainability over time. The framework breaks down the broad objectives of participation, empowerment, and sustainability into twenty-two variables in six categories that reflect both tangible and intangible results at different levels, in an interconnected upward spiral ranging from individuals and families to grassroots organizations, NGOs and networks, to society at local, regional and national levels. Categories of variables that reflect tangible results are standard of living, organizational capability, and policy environment. Intangible results are reflected in qualitative indicators of personal capacity, organizational culture, and community norms. Inherent in the framework also is a recognition of the need for balance among these factors (that is, capability for strategic planning without a vision of organizational direction is a sterile exercise). use of this framework for reporting also had the effect of helping grassroots organizations to improve their performance. In that the framework has also been adopted by other foundations and NGOs, it meets its own criteria for success. According to Ritchey-Vance, "what the development assistance community chooses to measure is what [they] will ultimately get from grassroots development" and "cost/efficiency measures will produce bricks and mortar, but at the expense of less visible, less marketable efforts to build human capacity and social capital."

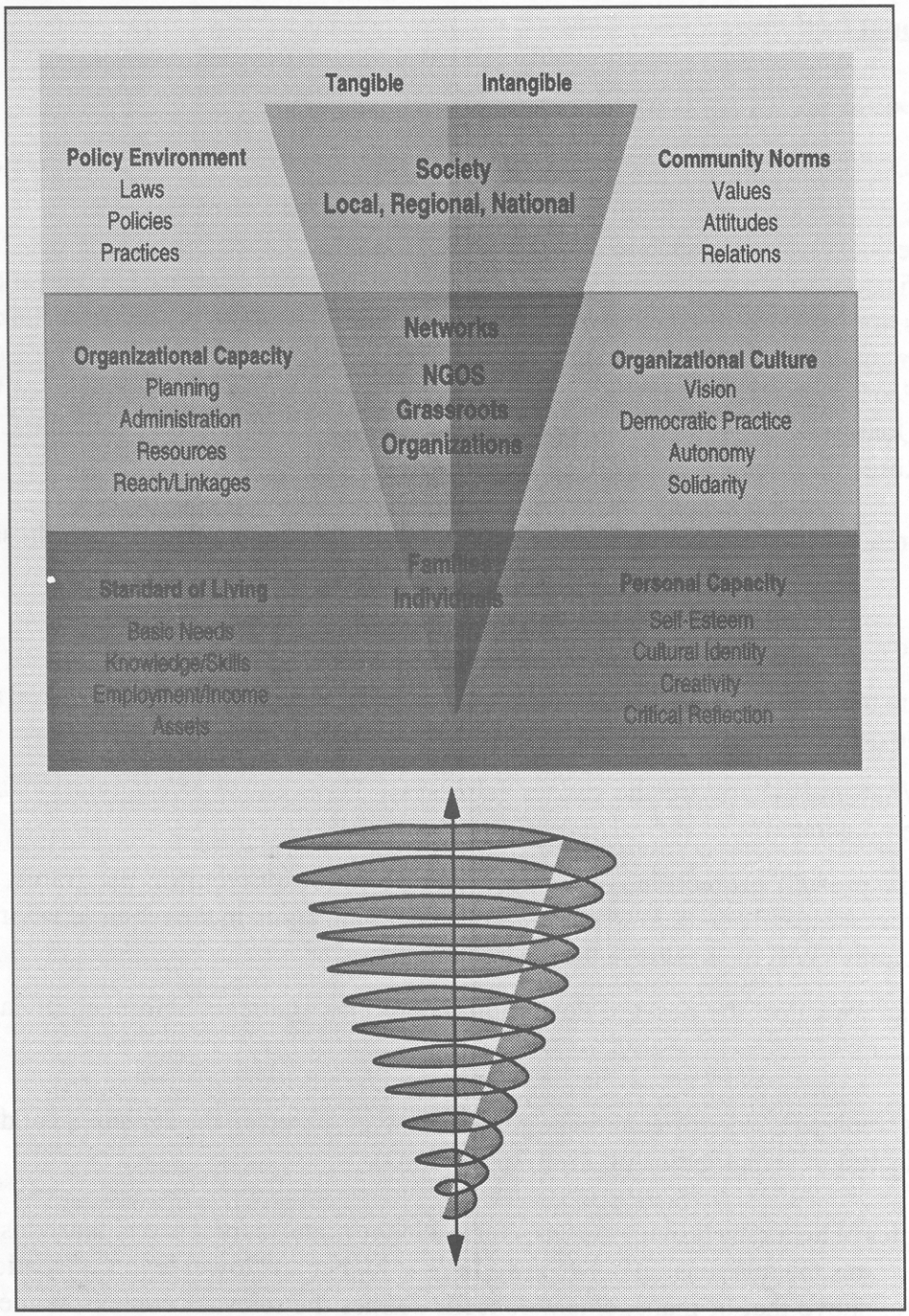


**Fig. 3. The Inter-American Foundation Grassroots Development Framework**
**Source: Ritchey-Vance (1996)**

### 3.8.3 Regional Initiatives

**State-of-the-Lakes**

The Great Lakes indicator program, as described in a report of the Indicators for Evaluation Task Force of the International Joint Commission on the Great Lakes (IJC 1996), is part of a comprehensive ecosystem approach to management of the Great Lakes Basin, in which "**State-of-the-Lake**" indicators are derived from a vision of ecosystem integrity expressed in relevant policies. The indicators are intended to communicate progress toward the goals of the Great Lakes Water Quality agreement, and follow the Pressure-State-Response model. The vision is expressed in the Great Lakes Ecosystem Charter of the Great Lakes Commission, vision statements of the Great Lakes Water Quality Board and Fishery Commission, and an ecosystem model of the Council of Great Lakes Research Managers.

In reference to the goals of the Water Quality agreement, the key questions addressed in the report are:

- How clean is the environment; i.e. what are present ambient conditions?
- Are trends in the right direction? How quickly are we making progress toward achieving the desired outcome?
- What and where are the causes (stresses)? Have cause-effect relationships been demonstrated?
- Are present protection, restoration and pollution prevention programs, policies, processes, and practices working? Are humans engaging in the required environmental actions? Will they achieve the desired outcomes?
- Can we detect the onset of deleterious conditions and react before significant impact occurs?

The IJC report also identifies specific goals and targets based on the agreement and scientific criteria for selecting relevant indicators (see Appendix D).

Principles of hierarchy provide the basis for linking regional to local and global considerations because it illustrates the relationship between systems at higher and lower levels of spatiotemporal scale. The level above that of management concern defines the relevant context, while the level below defines relevant mechanisms. Recognizing that there is no single generic ecosystem because it can be examined from a multitude of perspectives, each of which will affect the observation criteria and the relevant spatial and temporal boundaries, four different ecological perspectives are explicitly recognized:

- Community ecology—in which the focus is on interactions among multiple species, and in which the temporal component is important for considering past processes that led to the current condition. Community ecology is also seen as a way of linking the

concerns of human health, socio-economic infrastructure, and ethics inherent in the Water Quality Agreement.

- Process function ecology—in which exchanges of matter, energy and information show process pathways. From this perspective, it is the pathways that are important, rather than the organisms themselves. These are interlinked processes across relevant scales that are spatially diffuse and best defined in turnover times.
- Landscape ecology—pertains to geographically defined areas, consisting of clusters of sites embedded in a landscape, which is embedded in the land and water system and in the larger region. Landscape ecology also provides a spatial matrix for considering communities and process functions, and is the basis for defining the Great Lakes Basin Ecosystem.
- Population ecology—populations are seen as spatially and temporally well-defined groups of individuals in the same species, although they may be embedded in larger groups.

The ecosystem approach is also explicitly defined to include human needs and the economic system. Under the Agreement, progress is to be assessed "in the light of present and future socio-economic imperatives." The report acknowledges that:

> *Despite societal experience with economic indicators as measures of national economic performance, there is but a rudimentary understanding of how to measure desirable economic states and progress therein, in a sustainable development paradigm.... In part, the answer to the conundrum lies in the realization that the true measure of human welfare, classically assumed to be economic in its essence, is in fact much broader. It is now generally held to include social, cultural and human health (physical and mental) dimensions. Some of these issues are reflected in other desired outcomes in this report, particularly the human health desired outcome, which is determined by critical social and economic dimensions as well as the presence or absence of physical disease.*

A comprehensive analyses of the ecosystem approach and the experience of implementing it in the Great Lakes is provided in MacKenzie (1996).

**State of the Chesapeake Bay**

The State of the Bay report (Magnien et al. 1995) highlights the role of citizen involvement in monitoring, and is based on indicators important to the Bay region, described in a report by the Chesapeake Bay Program Office (1994). The Bay is also receiving special attention as part of an inter-agency regional effort described below.

**Other References to Regional Initiatives**

The Oregon benchmark process, known for innovative approaches to controlling sprawl, is described in a report by the Oregon Progress Board (1994).

### 3.8.4 National Initiatives

**The United States**

The EPA Environmental Monitoring and Assessment Program (EMAP) began with the intention of being a comprehensive, integrated, nationwide monitoring system but, realizing that this scope was beyond the ability of a single agency, has redirected its efforts towards research needs for ecological indicators and integrated assessment. The broader vision has instead become the goal of an inter-agency program under the direction of the President's Committee on the Environment and Natural Resources (CENR). A **multi-tiered monitoring strategy** developed by EMAP is being tested in the mid-Atlantic region. An annotated bibliography of literature on monitoring and indicators related to the EMAP program is provided in Griffith (1994). The EMAP indicator development strategy is presented in Barber (1994). A scientific review of EMAP was also conducted by the National Research Council (1995) which, in addition to recommending more explicit links between models and indicators, also found the sampling scale to be too coarse to detect important changes, and recommended developing a reliable scientific index of ecosystem health, as well as giving more attention to the information management system. Current information, with links to regional efforts, can be found on the world wide web: <URL: http://www.epa.gov/emap>.

In the **Mid-Atlantic Integrated Assessment** (MAIA), an initiative of EPA's Office of Research and Development and Region III, in collaboration with other agencies, special consideration is being given to **place-based research** and to measures that integrate land cover information with other measures of stress. Key questions guiding the program are:

- Is there a problem?
- Where is the problem?
- What is the cause of the problem?
- Are things changing?
- What does it mean to a community?
- What can we do about it?

The **CENR** effort National Science and Technology Council (NSTC 1997) is looking to better integrate thirty government programs identified as conducting activities relevant to environmental monitoring, who have a combined budget of $500 million a year. The goal is also to create a **network of monitoring sites**, primarily from these existing programs, that integrate regional information and that are also complementary to international monitoring efforts. An overall objective is to generate standard and compatible data needed for integrated modeling and assessment

intended to support decision making through better understanding of ecosystem processes, and anticipation of changing conditions. However, the scope appears to be limited to physical and biological parameters. The full report is available on the web via the White House Office of Science and Technology Policy (OSTP): <http://www.whitehouse.gov/WH/EOP/OSTP/html/OSTP_Home.html>.

The President's Council on Sustainable Development (PCSD 1996) identified some indicators of progress for the ten broad goals that were agreed upon. That report is also available in full on the web: <http://www.whitehouse.gov/PCSD>.

**Canada**

Environment Canada's "State of the Environment Reporting" (1991; 1995) was designed to measure progress towards Canada's Green Plan and consists of priority objectives and targets that can be applied at different scales and in different sectors (such as national, regional, municipal, watershed, parks). The initiative is based on a condition-stress-response framework. It is also described by Kerr (1994), and is accessible on the web at: <http://www.doe.ca/envhome.html>.

### 3.8.5 International Initiatives

International indicator initiatives are primarily oriented towards providing information necessary for monitoring compliance with international environmental treaties, which include the Nations Framework Convention on Climate Change, UN-Economic Commission for Europe Convention on Long-range Transboundary Air Pollution (LRTAP), and the Montreal Protocol on Chloro-Fluorocarbons (CFCs). Indicators related to international treaties, as well as all the international indicator sets reviewed in the World Bank report from the different sources, are available for interactive querying on the world wide web at CIESIN <http://www.ciesin.org>, which also has links to several regional initiatives. International indicators are compiled in a joint publication of the World Resources Institute, UNEP, United Nations Development Programme (UNDP), and the World Bank (1996), which also features a special section on urban indicators. Another important compendium of data regarding international indicators is in the UNEP Environmental Data Report, produced by the United Nations Development Programme and Global Resource Information Database (UNEP GRID) program (UNEP 1993). National and international level indicators are also the subject of a separate SCOPE project on Indicators for Sustainable Development for which publications are forthcoming.

A review and comparison of international initiatives is provided by Bakkes et al. (1994). These initiatives are primarily based on the pressure-state-response framework originally developed by Rapport and Friend (Rapport and Friend 1979). The report reviews indicators, key references, and data collection efforts for air pollution, stratospheric ozone depletion, climate change, freshwater and marine resources, natural resources, biodiversity, and socioeconomic environmental indicators. The natural resources category includes soils, desertification, landcover/land use, forests, agriculture, fisheries, irrigation, and agro-ecological zones. Socioeconomic environmental indicators include public health, and wastes as measures of effects of human activities on the environment. Overall conclusions are that there is a bias towards priorities of industrialized countries. The framework is

also described as static in that it is not designed to show cross linkages between different aspects of environmental quality, impacts, and driving forces. Incorporation of modeling and systems analysis is recommended.

The OECD indicators (OECD 1993; OECD 1994), based on the Pressure-State-Response framework, are grouped in nine categories of environmental issues that reflect major environmental concerns in OECD countries and allow for comparison. The categories are: climate change and ozone layer depletion, eutrophication, acidification, toxic contamination, urban environmental quality, biodiversity and landscapes, waste, natural resources, and general indicators. Indicators are used to measure environmental performance, and to integrate environmental concerns into sectorial as well as overall economic policies (for example, in satellites to national accounts and natural resource accounts—so far done only for water, use has been calculated as a fraction of gross annual amount available by country, and pollution costs for abatement and control). Sectorial indicators are not yet available. Key criteria for their selection have to do with policy relevance, usefulness to users, analytical soundness, and measurability.

An international/regional indicator initiative that reflects developing country concerns is a United Nations Development Programme and Centro Internacional de Argricultura Tropical (International Center for Tropical Agriculture) (UNEP/CIAT) program that has an emphasis on spatial indicators and detailed aspects of land and resource use, as well as community health (Winograd 1995). These indicators are described and listed in a website: <http://www.ciat.cgiar.ag/land/indicators>, and are included in Appendix F as an example of indicators that express developing country concerns. Land Quality Indicators are also expected to be available through the CIESIN website: <http://www.ciesin.org>.

## 3.9 Conclusion

This review has sought to characterize and contrast two key perspectives regarding models and sustainable development indicators: that of trying to consider diverse environmental concerns using narrow indices upon which most decision-making is presently based (that is, attempting to somehow fit scientific considerations into a cost benefit analysis framework); and that of instead altering the decision process and institutional relationships to consider more diverse and interrelated criteria for sustainable development. Adopting the broader, systems approach implies that ethical and cultural criteria are given as much consideration as scientific and technical, and that the decision-making process itself is part of the system. Indicators of success depend on how success is defined and cannot be defined outside the context of policy objectives and visions of the future.

Although there is a bias in this review towards the systems approach, these two overall approaches need not be seen as mutually exclusive. Aggregated indicators may be useful for comparing overall trends, just as cost-benefit analysis may be appropriate for well defined and uncontroversial problems. However, aggregated indicators do not provide the detail relevant to management concerns, and needed for determining a course of action to address specific problems in specific circumstances. They also make their inherent biases less transparent (as is discussed in the section on distributional issues). If we instead recognize complex environmental problems as sociopolitical conflicts regarding the disproportionate distribution of risks and benefits, then these

problems need to be addressed through negotiation, in a conflict resolution framework. Appropriate indicators would reflect what is important to stakeholders and allow the decision-maker to anticipate conflicts. These indicators would also be the decision points and can be broken down into as much detail as is necessary to the situation.

In what is described as a coevolutionary approach (Norgaard 1994), diversity becomes the key criterion for sustainability because it implies more choices. The objective is to look for elements that provide mutual reinforcement for what is to be sustained—an economic system cannot be sustained without the support of ecosystem services, appropriate knowledge, institutions that govern access to resources (such as enforcing property rights), appropriate technology, and values through which the desired endpoint is decided. The economy and the ecosystem are not tangible entities that can be universally defined—any order we experience is merely the outcome of networks of recursive relationships that reflect goal-directed behavior, as is described for social systems by Law (1994), for ecosystems by Ulanowicz (in press), and for both, as a seamless web, by Murdoch (1994). Values and preferences are constructed through deliberative processes and depend also on how choices are framed by institutions. We can also find mutual construction between science and policy-for example, Darwin found support for his theory of evolution in the ideas of political economists of his time (Smith and Malthus). Darwin's ideas were in turn used to validate ideas about social Darwinism (Mirowski 1994). More recently, ecological ideas about non-equilibrium systems has provided reinforcement for the development of ecological economics (Perrings et al. 1995b).

Scientific methods in general, like political institutions, have been biased towards finding things that fit into established conceptual frameworks, in the process externalizing complexity. Diversity—or things that don't fit—are often dismissed as errors or outliers if they are perceived at all. As described by Wynne (1992), while this tendency is normal for basic and reductionist scientific research, characterizing risk in this way leads to this leads to suppression of uncertainty by political institutions, and to tendencies to control the social world to correspond with this knowledge. As described by Holling (1978; 1986), characterizing risk in this way also leads to attempts to control rather than adapt to ecosystem processes through management practices (such as fire suppression), which leads to more catastrophic consequences later.

A variety of approaches are also presented because, in complex problems, as is characteristic of environmental issues, there is no single correct approach and different perspectives are illustrative of factors that may need to be considered in different situations. As is suggested by the "garbage can model" (Warglien and Masuch 1996), rigid and sequential procedures and dominance of a single perspective can kill the most creative solutions, which are more likely to arise through interaction among different perspectives. A world that values diversity, and life itself, is a prerequisite.

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## Appendix A: The Bellagio Principles

(Developed at a workshop organized by the International Institute for Sustainable Development, Winnipeg Canada <http://iisd1.iisd.ca/>)

***Background***

In 1987, the World Commission on Environment and Development (Brundtland Commission) called for the development of new ways to measure and assess progress toward sustainable development. This call has been subsequently echoed in Agenda 21 of the 1992 Earth Summit and through activities that range from local to global in scale. In response, significant efforts to assess performance have been made by corporations, non-government organizations, academics, communities, nations, and international organizations.

***Who Developed the Principles?***

In November 1996, an international group of measurement practitioners and researchers from five continents came together at the Rockefeller Foundation's Study and Conference Center in Bellagio, Italy, to review progress to date and to synthesize insights from practical ongoing efforts. The following principles resulted and were unanimously endorsed.

***What is Their use and Who are the users?***

These principles serve as guidelines for the whole of the assessment process including the choice and design of indicators, their interpretation and communication of the result. They are interrelated and should be applied as a complete set. The principles are intended for use in starting and improving assessment activities of community groups, non-government organizations, corporations, national governments, and international institutions.

***Overview***

These principles deal with four aspects of assessing progress toward sustainable development. Principle 1 deals with the starting point of any assessment—establishing a vision of sustainable development and clear goals that provide a practical definition of that vision in terms that are meaningful for the decision-making unit in question. Principles 2 through 5 deal with the content of any assessment and the need to merge a sense of the overall system with a practical focus on current priority issues. Principles 6 through 8 deal with key issues of the process of assessment, while Principles 9 and 10 deal with the necessity for establishing a continuing capacity for assessment.

**Principle 1. Guiding Vision and Goals**

Assessment of progress toward sustainable development should be guided by a clear vision of sustainable development and goals that define that vision.

**Principle 2. Holistic Perspective**

Assessment of progress toward sustainable development should:

- Include review of the whole system as well as its parts
- Consider the well-being of social, ecological, and economic sub-systems, their state as well as the direction and rate of change of that state, of their component parts, and the interaction between parts

- Consider both positive and negative consequences of human activity, in a way that reflects the costs and benefits for human and ecological systems, in monetary and non-monetary terms

**Principle 3. Essential Elements**

Assessment of progress toward sustainable development should:

- Consider equity and disparity within the current population and between present and future generations, dealing with such concerns as resource use, over-consumption and poverty, human rights, and access to services, as appropriate
- Consider the ecological conditions on which life depends
- Consider economic development and other, non-market activities that contribute to human/social well-being

**Principle 4. Adequate Scope**

Assessment of progress toward sustainable development should:

- Adopt a time horizon long enough to capture both human and ecosystem time scales, thus responding to needs of future generations as well as those current to short-term decision-making
- Define the space of study large enough to include not only local but also long distance impacts on people and ecosystems
- Build on historic and current conditions to anticipate future conditions—where we want to go, where we could go

**Principle 5. Practical Focus**

Assessment of progress toward sustainable development should be based on:

- An explicit set of categories or an organizing framework that links vision and goals to indicators and assessment criteria
- A limited number of key issues for analysis
- A limited number of indicators or indicator combinations to provide a clearer signal of progress
- Standardizing measurement wherever possible to permit comparison
- Comparing indicator values to targets, reference values, ranges, thresholds, or direction of trends, as appropriate

**Principle 6. Openness**

Assessment of progress toward sustainable development should:

- Make the methods and data that are used accessible to all
- Make explicit all judgments, assumptions, and uncertainties in data and interpretations

**Principle 7. Effective Communication**

Assessment of progress toward sustainable development should:

- Be designed to address the needs of the audience and set of users
- Draw from indicators and other tools that are stimulating and serve to engage decision-makers
- Aim, from the outset, for simplicity in structure and use of clear and plain language

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### Principle 8. Broad Participation

Assessment of progress toward sustainable development should:

- Obtain broad representation of key grass-roots, professional, technical and social groups, including youth, women, and indigenous people—to ensure recognition of diverse and changing values
- Ensure the participation of decision-makers to secure a firm link to adopted policies and resulting action

### Principle 9. Ongoing Assessment

Assessment of progress toward sustainable development should:

- Develop a capacity for repeated measurement to determine trends
- Be iterative, adaptive, and responsive to change and uncertainty because systems are complex and change frequently
- Adjust goals, frameworks, and indicators as new insights are gained
- Promote development of collective learning and feedback to decision-making

### Principle 10. Institutional Capacity

Continuity of assessing progress toward sustainable development should be assured by:

- Clearly assigning responsibility and providing ongoing support in the decision-making process
- Providing institutional capacity for data collection, maintenance, and documentation
- Supporting development of local assessment capacity

## Appendix B: CEC Workshop Discussion of Indicators (CEC, 1995)

*Economic*

- Percent of business locally owned within a gross percentage of sales
- Percent of revenues generated from local population
- Percent of products manufactured locally
- Percent of recyclable resources collected locally with added value or for conversion to new products
- Percent of jobs available to those who want them
- Percent of jobs available with acceptable income levels
- Local training opportunities for local jobs—ability to train throughout life
- Employment security vs. job security
- Sufficient income to afford housing
- Non-financial economic activity—barter or exchange
- Percent of residents using biking, walking and driving for transportation
- Community dependence on physical growth for its economic health
- Economic diversification originating in the community
- Wealth generated from non-building activities

*Environmental*

- Health of human population
- Diversity of wildlife
- Net degradation to wildlife habitat
- Degree to which wildlife habitat is increasing
- Existing indigenous species vs. foreign species
- Percent of new development that reuses or restores existing building
- Development on underutilized land vs. development in open space
- Percent of open space per capita
- Sense of connection to open space
- Access to recreational facilities
- Use and availability of public parks

*Quality of Life*

- Health care costs per capita associated with environmentally related sources
- Access to goods and services and recreational and cultural activities
- Amount of time families spend together
- Pattern of voting, by neighborhoods, in local elections
- Statistics and perception of safety/fear
- Percent of structures that are seismically safe

*Empowerment with Responsibility*

- Degree to which people are listened to and have access to government
- Community issues included in the decision-making process
- Level of alcohol and drug use
- Level of involvement in civic activities

## Appendix C: Sustainable Seattle - The 1995 Master List

*Environment*

- Wild Salmon
- Wetlands
- Biodiversity
- Soil Erosion
- Air Quality
- Pedestrian Friendly Streets
- Open Space in Urban Villages
- Impervious Surfaces

*Population and Resources*

- Population
- Residential Water Consumption
- Solid Waste Generated and Recycled Pollution Prevention and Renewable Resource Use
- Farm Acreage
- Vehicle Miles Traveled and Fuel Consumption
- Renewable and Nonrenewable Energy Use

*Economy*

- Employment Concentration
- Real Unemployment
- Distribution of Personal Income
- Health Care Expenditures
- Work Required for Basic Needs
- Housing Affordability Ratio
- Children Living in Poverty
- Emergency Room use for Non-ER Purposes
- Community Capital

*Youth and Education*

- Adult Literacy
- High School Graduation
- Ethnic Diversity of Teachers
- Arts Instruction
- Volunteer Involvement in Schools
- Juvenile Crime
- Youth Involvement in Community Service

*Health and Community*

- Equity in Justice
- Low Birthweight Infants

- Asthma Hospitalization Rate for Children
- Voter Participation
- Library and Community Center usage
- Public Participation in the Arts
- Gardening Activity
- Neighborliness
- Perceived Quality of Life

# Appendix D: Santa Monica Sustainable City Program

***Summary of Indicators, Baseline Data and Targets (From CEC 1995)***

| SUSTAINABILITY INDICATOR | 1990 (Actual) | 1993 (Actual) | 2000 (Target) |
|---|---|---|---|
| Energy Usage (Btus/year) | 4.0 million | 4.0 million | 3.36 million |
| Water Usage (gallons/day) | 14.3 million | 12.0 million | 11.4 million |
| Landfilled Solid Waste (tons per year) | 107,000 | 105,400 | 62,000 |
| Postconsumer Recycled/Tree-Free Content of City Paper Purchases | Unknown | Unknown | 50% |
| City Fleet Vehicles Using Reduced-Emission Fuels | Unknown | 10% | 75% |
| Wastewater Flows (million gallons/day) | 10.4 | 8.5 | 8.8 |
| Trees in Public Spaces | 28,000 | 28,000 | 28,350 |
| Ridership on Santa Monica Bus Lines (millions) | 19.0 | 18.0 | 20.9 |
| Average Vehicle Ridership (AVR) of Employers with over 50 Employees | N/A | 1.34 | 1.5 |
| Dry Weather Stormdrain Discharges to Ocean (gallon/day) | 500,000 | 350,000 | 200,000 |
| Use of Hazardous Materials | Unknown | Unknown | 15% reduction |
| Known Underground Storage Tank Sites Requiring Cleanup | N/A | 25 | 6 |
| Deed Restricted Afford. Housing Units | 1,172 | 1,313 | 1,922 |
| Community Gardens | 2 | 2 | 5 |
| Create and Implement a Sustainable Schools Program | N/A | N/A | Implemented |
| Public Open Space (acres) | 164 | 164.8 | 180 |

*Santa Monica Sustainable City Program Policy Goals and Targets*

## I. Resource Conservation

**Policy Goals**

Increase the use of Technologies and practices.
Reduce the use of non-renewable resources.
Develop local, non-polluting, renewable energy, water and material resources, and expand recycling technology in these areas.

**Targets**

Reduce energy usage by 16%.
Reduce potable water usage by 20%.
Reduce solid waste volumes by at least 50%.
Achieve 50% average postconsumer recycled and/or tree-free content in all City paper purchases.
Convert 75% of the City vehicle fleet to reduced-emission fuels.
Reduce wastewater flows by 15%.
Increase total number of trees on public property by 350.

## II. Transportation

**Policy Goals**

Maximize the use of alternative forms of transportation, including walking, bicycling, public transit and carpools/ridesharing.
Develop innovative traffic policies that reduce negative impacts from vehicles.
Limit pavement area to the minimum necessary.
Implement work schedules that reduce the number of employee commute days.
Advocate for the regional development of public transportation systems.

**Targets**

Increase ridership on Santa Monica Municipal Bus Lines (including shuttles) by 10%.
Achieve average vehicle ridership of 1.5 for all employers with over 50 employees.

## III. Pollution Prevention and Public Health Protection

**Policy Goals**

Protect and enhance environmental and public health by reducing or eliminating the use of hazardous and toxic materials by residents and businesses.
Minimize the levels of pollutants entering the air, soil and water.
Lessen the risks environmental problems pose to human health.
Ensure that no single geographic or socioeconomic group in the City is being unfairly affected by environmental pollution.

**Targets**

Reduce the total volume of dry weather stormdrain discharges to the ocean by 60%.
Reduce consumption of hazardous materials, including pesticides, by 15%.
Clean up and close 75% of all known underground storage tank contamination sites.

## IV. Community and Economic Development

**Policy Goals**

Encourage compact, mixed-use, pedestrian-oriented projects designed to maximize affordable housing, and encourage walking and bicycling.
Use of existing and future public transit systems.
Create community gardens.
Promote the growth of local businesses that provide employment opportunities to Santa Monica residents, including youth, and have positive environmental and social impacts.
Facilitate education programs that enrich the lives of all members of the community.

**Targets**

Provide 750 additional affordable housing units. Create three new community gardens.
Establish partnerships with local schools to create and implement a Sustainable Schools Program.
Increase total public open space area by fifteen acres.

## Appendix E: Criteria for Evaluating the "State-of-the-Lakes"

Excerpts from the Report of the Indicators for Evaluation Task Force of the International Joint Commission on the Great Lakes (IJC, 1996)

***Selected Targets, Programs and Measures in the Agreement***

- Achievement of general and specific objectives
- Effective standards and other regulatory requirements to achieve them
- Research on identified needs and other priorities
- Mechanisms for international organization
- Control of pollution sources including:
  - Municipal sources (pretreatment, sanitary, storm and combined sewer overflows)
  - Industrial sources (waste treatment and control, substantial elimination of persistent toxics, nutrient, thermal and nuclear inputs)
  - Nonpoint sources (pesticides, animals, land-use planning)
  - Shipping activity (spill prevention, surveillance, contingency plans)
  - Airborne source identification
- Additional programs given specifically in the annexes, notably:
  - Remedial Action Plans, Lakewide Management Plans, and Point Source Impact Zones
  - Virtual elimination and zero discharge of persistent toxic substances
  - Dredging
  - Groundwater
  - Wetlands

***Criteria for Scientific Completeness***

- Is the indicator necessary to characterize the desired outcome properly and to evaluate progress?
- Is the indicator relevant, i.e. important and of value?
- Is the indicator scientifically valid?
- Are historical data and information available to define trends and possibly acceptable and unacceptable conditions, and can measurements be made currently and in the future?
- Can the data and information be interpreted in terms of the desired outcome?
- Can reference or target values be established?
- What are the costs to acquire the data and information, including availability of human and financial resources?
- What is the quality of the data and information, and can confidence be placed in them?
- Is the indicator sensitive, i.e. without an all-or-none response or extreme natural variability?
- Is the indicator timely, i.e. providing data and information quickly enough to initiate effective action?
- Is the indicator anticipatory, i.e. capable of providing early warning, an indication of change before serious harm has occurred?
- Is the indicator integrative, i.e. possessing the capacity to combine a variety of diverse data and information?

- Is the indicator broadly applicable, e.g. to more than one desired outcome?
- Is the suite of identified indicators sufficient to fully characterize the desired outcome and to evaluate Agreement progress?

***Desired Outcomes for the Great Lakes Basin Ecosystem***

- **Fishability**. There shall be no restrictions on the human consumption of fish in the waters of the Great Lakes basin ecosystem as a result of anthropogenic (human) inputs of persistent toxic substances.
- **Swimability**. No public bathing beaches closed as a result of human activities or, conversely, all beaches are open and available for public swimming.
- **Drinkability**. Treated drinking water is safe for human consumption; human activities do not result in application of consumption restrictions.
- **Healthy Human Populations**. Human populations in the Great Lakes basin are healthy and free from acute illness associated with locally high levels of contaminants, or chronic illness associated with long-term exposure to low levels of contaminants.
- **Economic Viability**. A regional economy that is viable, sustainable and provides adequate sustenance and dignity for the human population of the basin.
- **Biological Community Integrity and Diversity**. Maintenance of the ability of biological communities to function normally in the absence of severe environmental stress (ecosystem health) and to cope with changes in environmental conditions which impose stress, i.e. to be able to maintain their processes of self-organization on an ongoing basis (ecological integrity). Maintenance of the diversity of biological communities, species and genetic variation within species.
- **Virtual Elimination of Inputs of Persistent Toxic Substances**. Virtual elimination of inputs of persistent toxic substances to the Great Lakes system.
- **Absence of Excess Phosphorus**. Absence of excess phosphorus entering the water as a result of human activity.
- **Physical Environment Integrity**. Land development and use compatible with maintaining aquatic habitat of a quantity and quality necessary and sufficient to sustain an endemic assemblage of fish and wildlife populations.

# Appendix F: CIAT-UNEP Environmental and Sustainability Indicators; Potential Spatial Indicators for Latin America and the Caribbean

**Table 1. Environmental Pressure Indicators**

| Variable | Indicator |
|---|---|
| Population | Urban population<br>Population density<br>Rural population |
| Socio-Economic | Accessibility (travel time, roads)<br>Accessibility (travel time, rail)<br>Infrastructure development factor<br>Annual growth rate ($)(C)<br>GNP per capita (state-department, major cities)($)(C)<br>GDP per capita (state-department, major cities)($)(C)<br>Percent unemployment (C)<br>External debt and service as Percent of Exports ($)(C)<br>Exchange ratio (C)<br>Human development index<br>Life expectancy at birth and Infant Mortality Rate (C)<br>Percent of children undernourished and calorie supply (C)<br>Percent of adult literacy (C)<br>Percent of poverty incidence (C) |
| Food and Agriculture | Potential cropland<br>Land expansion potential<br>Soils with limitations<br>Sources of foods<br>Population supporting capacity<br>Agricultural land needed Irrigation potential (?)<br>Cultivation intensity<br>Methane emissions from livestock<br>Drug production (Coca cultivation, cocaine processing) ($)<br>Change in production and yields (C)<br>Index of food production<br>Per capita calories available and Percent of calorie intake (C)<br>Annual fertilizer and pesticide use (C)<br>Gini coefficient (C)<br>Percent of grain fed to livestock (C) |
| Energy | Bioenergy potential<br>Installed hydropower capacity<br>Kilowatts generated<br>Fuelwood and charcoal production per capita (C)<br>Traditional fuels as percent of total requirements (C)<br>Hydropower generation as percent of capacity (C)<br>Exploitable hydroelectric potential (C) |

Key: (C) = Country level data (may be difficult to obtain at second and third order administrative level)

($) = Monetary valuation possible

**Table 2. Environmental State Indicators**

| Variable | Indicator |
|---|---|
| Ecosystem and Land Use | Natural and actual primary production<br>Agricultural activities ($)<br>Overgrazing/over exploitation of natural vegetation for domestic use<br>Change in land use annual production and value ($) |
| Forests and Rangelands | Closed and open forest surface<br>Timber reserves ($)<br>Protected forest carbon storage service ($)<br>Soil conservation service ($)<br>Flood control service ($)<br>Tourism value ($)<br>Deforestation changes in pasture land climate regulation service ($)<br>Annual deforestation ($)(C)<br>Annual reforestation reforestation/deforestation ratio (C)<br>Roundwood production per capita (C)<br>Production/reserve ratio (C)<br>Percent of change in livestock population (C)<br>Value of principle agricultural products ($) (C) |
| Biological Diversity | Food/nutritional products ($)<br>Medicinal products ($)<br>Raw materials (timber, rattan) ($)<br>Protected areas existence (aesthetic) value ($)<br>Cultural/heritage value ($)<br>Genetic material ($)<br>Threatened animal species<br>Threatened plant taxa<br>Vegetation use index<br>Species risk index Investment in conservation ($) |
| Freshwater and Coastal Resources | Population in (or near) coastal areas<br>Mangrove areas<br>Protected coastal areas<br>Employment/income in Mangroves ($)<br>Tourism value (for reefs) ($)<br>Storage and recycling organic matter<br>Direct use products (fish) ($)<br>Indirect use products (coastal protection) ($)<br>Tourism value (beaches resorts) ($)<br>Renewable water resources per capita ($)(C)<br>Percent and per capita annual withdrawals ($)(C)<br>Percent of sectorial withdrawals ($)(C) |
| Atmosphere and Climate | Emissions CO2 Emissions<br>CO2 by activity<br>Natural disasters (population affected and economic loss) |

**Table 3. Environmental Impact Indicators**

| Variable | Indicator |
|---|---|
| Water erosion | Loss of topsoil<br>Terrain deformation/mass movement |
| Chemical deterioration | Loss of nutrients/organic matter<br>Salinization<br>Acidification<br>Pollution |
| Physical deterioration | Compaction/crusting<br>Water logging<br>Subsidence of organic soils |
| Wind erosion | Loss of topsoil<br>Terrain deformation<br>Over-blowing |

**Table 4. Environmental Response Indicators**

| Variable | Indicator |
|---|---|
| Information and participation | Number of environmental profiles and assessments (C)<br>Number of NGOs by activity area (C)<br>Public perception of environmental problems (C) |
| Treaties and conventions | Protected areas<br>IUCN sites, world heritage sites, biosphere reserves, RAMSAR sites<br>Signature and ratification of international treaties (C)<br>Funds generated for conservation (C) |
| Projections in land uses | Potential productive land<br>Agricultural land needed in 2030<br>Land use index<br>Deforestation rate and reforestation/deforestation ratio (C)<br>Greenhouse gas emissions (C)<br>Mean annual investment ($)(C)<br>Rehabilitation costs and benefits ($)(C)<br>Carbon absorption by reforestation and agroforestry ($)(C) |

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