Series on Science for Sustainable Development No. 8

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Making Science for Sustainable Development More Policy Relevant: New Tools for Analysis

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ICSU Series on Science for Sustainable Development

The ICSU Series on Science for Sustainable Development is produced by the International Council for Science in connection with preparations for the 2002 World Summit on Sustainable Development (WSSD). The aim of WSSD is to bring together governments, United Nations agencies and other key stakeholders, including representatives of civil society and the Scientific and Technological Community, to build upon the 1992 United Nations Conference on Environment and Development (UNCED) and to enhance efforts toward the future of sustainable development. The Series includes a set of inter-disciplinary reports focusing on major issues that are relevant to science for sustainable development. The Series is meant to serve as a link between the scientific community and decision-makers, but the reports should also be useful to all others interested in the contribution of science to sustainable development. The Series highlights the fundamental role science has played and will play in finding solutions to the challenges of sustainable development. It examines experiences since UNCED and looks towards the future. It provides up-to-date knowledge, examines lessons learned, successes achieved, and difficulties encountered; while also outlining future research agendas and actions to enhance problem solving and good practices in sustainable development. The Series was made possible due to a generous grant provided by the David and Lucile Packard Foundation.

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Making Science for Sustainable Development More Policy Relevant: New Tools for Analysis

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Preface

At the heart of any efforts to understand the current unsustainable patterns of development and to foster sustainable development lie scientific analysis and the application of scientific knowledge. Enhancing science and technology activities that respond to and anticipate the needs of policy-makers and other stakeholders is essential when addressing issues from the plight of widespread poverty to global climate change. Research and scientific analyses must become more problem-focused, and apply an interdisciplinary approach to sustainable development issues in order for science to become more policy relevant.

The scientific tools of state-of-environment reporting, environmental and sustainable development indicators and indices, as well as geospatial data-based analysis and large-scale assessments are currently undergoing a process of rapid change. In fact, a whole new generation of these scientific tools that renders scientific information truly policy relevant is emerging.

ICSU's Scientific Committee on the Problems on the Environment (SCOPE), in collaboration with the United Nations Environment Programme (UNEP), recently convened a workshop to review the potential of these new-generation scientific tools for analysis. This Report is based on the scientific background papers prepared for this workshop. ICSU is grateful to SCOPE and UNEP for having taken this initiative.

Making science for sustainable development more policy relevant has become a major issue, both for the science and technology community and for policy-makers, during the preparations for the World Summit on Sustainable Development (WSSD). I trust that the ideas presented in this Report on the new tools for scientific analysis will strengthen the further implementation of Agenda 21, aimed at achieving the objectives of sustainable development. Scientists and policy-makers must map out and travel this road hand in hand, together with other stakeholders.

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Executive Summary

There is a clear and vital need for a strong partnership between science and society as we enter the new millennium. Solutions to many of our greatest problems, such as feeding a growing world population that may peak at 9 billion during the second half of the 21st century, will come from this partnership. But at present the partnership is not operating at its full potential because society does not always find science to be policy relevant.

Thus, one of the commitments made by the scientific community for the World Summit on Sustainable Development is to make science more policy relevant. This will require science to deliver usable knowledge, i.e., science that is timely, relevant, and place-based, to policy-makers, decision-makers, stakeholders and citizens. Relevancy can be improved by placing more emphasis on social aspects of sustainability, by addressing the uncertainty of the scientific process, through the use of common languages that are understandable to stakeholders, and by localizing environmental assessments so that they are relevant to the specific geographies of stakeholders.

A new generation of tools for scientific analysis is emerging. These tools will address the policy relevance of science for sustainable development. A list of such improved tools includes:

- conceptual frameworks, which provide powerful insight and organizing qualities for sustainability analyses;
- indicators and indices of development status and environmental change;
- specific forms of analysis–cost burden, cost benefit, risk analysis, and so forth–relying on indicators that are best selected through the use of sound conceptual frameworks; and
- assessments that are carefully constructed and produced to provide policy input.

To date there has been no comprehensive evaluation of the major scientific assessments of the past two decades that addresses the following questions. What topics have been covered? Are there important topic gaps? What are the successes and failures? What aspects of design and process make for successful assessments? Can we combine the successful aspects of design and process into a new assessment framework that makes science highly policy relevant? This report proposes that the relevant international scientific organizations, in co-operation with intergovernmental organizations jointly undertake such a comprehensive evaluation.

Useable knowledge will be attained only when we move to studies that are framed by geographic context–i.e., how and why does place make a difference and how can spatial context be optimised for integrated assessments, including social, economic, and environmental aspects? The consequences of our actions and impact on sustainability are clearly influenced by place and scale. With tools like remote sensing, we can map, measure, and monitor the phenomena that comprehensively form geographic complexity, and we can track, over time, how conditions on the Earth's surface are changing. Through the use of geographic information systems (GIS) and global positioning systems (GPS), we can establish geographic location, define context, and apply spatial models to translate problems into terms associated with the decision-making process for the range of environmental, social, and economic challenges.

However, these tools are not valuable unless we overcome the real limitations associated with the lack of quality data. The availability of data sets at national and regional levels is uneven and any attempt to localize environmental assessments will be limited by the coarsest available indicator data. Crucial needs for environmental data will only be met if data centres and spatial data clearinghouses such as the UNEP-GRID network and the ICSU World Data Centres focus on making the best available spatial data sets accessible to the environmental assessment community.

The use of these tools for developing and analyzing indicators and for use in sustainability assessments is a vital part of a robust state of environment reporting program. State of the environment reports should be balanced, comprehensive, causal, objective, policy-oriented and provide incentive for action. In order to 'breath life' into the existing statistical frameworks, a conscientious effort needs to be made to give equal weight to the biophysical, geographic, socio-economic and human health dimensions.

All future considerations of the science and policy interface should integrate social and health sciences with the natural sciences. Until recently, contributions from these sectors have been underplayed, but great strides have been made in understanding linkages, for example, between human health and ecosystem condition. Once we can clearly demonstrate how all the variables (personal health, economic opportunity, preservation of cultural traditions, social support mechanisms) that people use as yardsticks that matter to humans are interrelated within an ecosystem health context, we may finally begin to foresee more science-based policy that can effectively lead to the long-term sustainability of our environment and our societies.

Introduction

Background

A whole series of initiatives can be characterized by a common cause: making science more policy relevant. This is an important unifying theme for the World Summit on Sustainable Development (WSSD). Here, the science and technology community will demonstrate its readiness and ability to "change course" developing a new role and commitment of science and scientists in the contemporary world, not new science but science in service to society, inclusive rather than exclusive, seeking partnerships, and involving other stakeholders.

The WSSD seeks a greater role for science and scientists. As stated in paragraph 93 of the Draft Plan of Implementation (IVth Session of the Preparatory Committee for the WSSD, Bali, June 12, 2002): "Improve policy and decision making at all levels through, *inter alia*, improved collaboration between natural and social scientists, and between scientists and policy makers:

- Increase the use of scientific knowledge and technology, and increase the beneficial use of local and indigenous knowledge in a manner respectful of the holders of that knowledge and consistent with national law;
- Make greater use of integrated scientific assessments, risk assessments and interdisciplinary and intersectoral approaches;
- Continue to support and collaborate with international scientific assessments supporting decision making, including the Intergovernmental Panel on Climate Change, with the broad participation of developing country experts;
- Assist developing countries in developing and implementing science and technology policies;
- Establish partnerships between scientific, public and private institutions and by integrating scientists' advice into decision making bodies in order to ensure a greater role for science, technology development and engineering sectors."

Furthermore, paragraph 95 calls to: "establish regular channels between policy makers and the scientific community for requesting and receiving science and technology advice for the implementation of Agenda 21, and create and strengthen networks for science and education for sustainable development, at all levels, with the aim of sharing knowledge, experiences and best practices, and building scientific capacities, particularly in developing countries."

Science in service to society means that science must aim for solutions to real world contemporary problems. Such science should move beyond the traditional 'three-pillar' assessment framework (i.e. economic, social and environment), and should seek for true integration among the three elements. The social pillar of sustainability seems to be an especially crucial one, and at the same time the least developed. The science and technology community would like to contribute to the Millennium Declaration goals, a prominent one being the eradication of poverty. But what is poverty? Is the commonly used definition of per capita income below one USD/per day adequate? The answer is probably yes in most countries, especially in the developed world. But what about indigenous subsistence farmers in remote areas? They certainly are vulnerable to the many threats of the globalized world. But is the focus on merely increasing income sufficient? Such questions, among numerous others, are more and more relevant. Indeed, we are not even able to formulate all the relevant questions. A number of issues related to making science more policy relevant include:

- Legitimacy: to be policy relevant, science must be fully legitimate. There are various sources of legitimacy, e.g. at an international level the involvement of governments.
- The "level of precision" could be complemented by the need to address uncertainty in an appropriate manner, preferably in a quantitative way.
- The language in which science-based knowledge is conveyed must be accessible for all stakeholders.

- Localizing assessments: we must move toward local to regional scientific assessments because geographic and cultural settings matter.

The Need

Since the UN Conference on Environment and Development (UNCED), Rio, 1992, much has been learned about what is needed if scientific understanding of the structure and function of global and local ecosystems is to contribute significantly to the on-going policy discourse on global environmental issues. The three successive assessments of the Intergovernmental Panel on Climate Change have moved from a central focus on biophysical issues to a more integrative treatment of environmental and societal questions. This progression in understanding has taught us what is needed for more sophisticated and sensitive assessments. At the same time, emerging studies around issues of vulnerability, sustainability, science, social and ecological resilience, sustainable livelihoods and more policy relevant research all point to the need for a new generation of assessments to inform the policy dialogue.

Assessments to guide, support, monitor and evaluate policies that seek actions supporting sustainable development, management of human needs in response to climate change, and trans-regional equity in distribution of benefits and burdens in use of material and energy resources will require new kinds of scientific approaches. The focus of such approaches will be directed to socio-cultural, economic and biophysical ecological systems. This means that in-depth analyses into both biophysical and human aspects of ecological systems and their interactions will be needed. This new generation of assessments must also recognize that knowledge is plural and that high-quality science is necessary but not exclusive to fully understand patterns and processes at the local level. Those living with the problem have much to contribute to the assessment process.

The next generation of assessments should be collaborative and participatory in assessing causes, and identifying remedies and institutional structures for implementation. International organizations can play a critical role in fostering and supporting the development of these new assessments, promoting the participatory capacity of regions and localities and enhancing their contributions to the policy process, developing a culture of data sharing. They can serve as gatekeeper and facilitator in exchanges between knowledge producers and interpreters, and knowledge users and managers.

This new generation of assessments will need to proceed from well-developed conceptual frameworks rooted in human ecosystem thinking. They will need to consider that:

- Institutional partnerships fill an essential role in structuring relevant assessments;
- Analyses conducted at different scales reveal different aspects of environmental problems, their causes and potential remedies;
- The current global scale assessments will need to be supplemented by assessments at regional and local scales in co-operation with appropriate institutions;
- The new generation of assessments will be multi-layered and therefore methods for integration among such assessments, both horizontally and vertically, will need to be developed;
- The conventional wisdom of the ‘three pillars’ approach linking economic, social and environmental aspects, and its relevance and potential towards the understanding of environmental issues, will need to be revisited;
- The culture of science will need to develop a ‘service’ orientation toward the needs of policy-makers;
- The scientific process must include steps that ensure the relevance, legitimacy and credibility of its findings and analyses;
- Scientific interest in maintaining the biodiversity and health of ecosystems is balanced with similar interest in serving human needs and the diversity of societies.

To become more policy relevant, science and scientists must deliver usable knowledge to policy-makers, other decision-makers, stakeholders and citizens. Useable knowledge in this context presents several characteristics. First, it is timely, delivered at an appropriate point in the decision-making process. Second, it is relevant, providing data and insight appropriate to the specific decision or policy at hand. Third, useable knowledge is delivered at an appropriate level of precision. Fourth, useable knowledge is cost effective. Finally, knowledge should be locally-specific and reflective of geography and culture, rather than generic for a larger area.

Useable knowledge is best provided through state-of-the-art science. State-of-the-art science is based on sound theory, creative application of the scientific method, rigorous analysis and open review. Useable knowledge can then be considered as a "value-added" science tool to assist in making science more policy relevant.

There are four major types of useable knowledge relevant to science for sustainability. The first is conceptual frameworks, which provide powerful insight and organizing qualities. A second kind of useable knowledge is the wide array of indicators and measures available for monitoring development and environmental change. These indicators can and should vary depending upon place and scale. A third kind of useable knowledge results from specific forms of analysis: cost burden, cost benefit, risk analysis, and so forth. Such analytical tools rely on indicators that are best selected through the use of sound conceptual frameworks.

Finally, all these types of useable knowledge contribute to a fourth kind–assessments. Such assessments must be carefully constructed and produced if they are to provide powerful policy input. Issues such as integration, use of common language, regional- and place-based focus, legitimacy, use of both traditional and scientific knowledge, and involvement of citizens must be creatively and effectively addressed.

Numerous delivery systems that include environmental reporting, presentation of issues using maps and graphics, use of public workshops, presentation of modelled simulations and scenario exercises, and communication through the public and professional media, can provide essential usable knowledge to policy-makers, other decision-makers, stakeholders and citizens. These different systems for delivering useable knowledge each have advantages and disadvantages, yet all contribute to making science more policy relevant and improving data sharing between the scientific and policy-making communities.

Furthermore, useable knowledge can be conveyed to decision- and policy-makers through the direct involvement of scientists in the policy making process. Scientists can serve as advisors, they can sit on policy making boards and/or consultative panels, and can provide informal advice through professional networks. Scientists can act as brokers of knowledge delivering crucial insights to decision-makers. Finally, scientists, like other citizens, can elect to run for office and become decision-makers themselves. All these options provide the opportunity to synchronize the cultures of the scientific and policy-making communities.

Frameworks for the State of Environment Reporting

A major impediment to the development of the knowledge base on global environmental change, to the development of more powerful assessment methods, and to the creation of sound indicators and indices has been the lack of a widely agreed upon conceptual framework for assessment that integrates across the human and ecological sciences. However, a number of integrating conceptual frameworks are now beginning to appear. Each of these frameworks is at a different stage of development and reflects different emphases, issues, and scales of use. For example:

- The proposed UNEP Human Environmental Index provides a ranking of nation states based on their response to land, air, and water issues.
- Ostrom et al. examine institutions as regulators of human-nature transactions.
- Holling's panarchy theory emphasizes process.
- The Sustainability Science Initiative outlines an entirely new-edge science.
- The Resilience Alliance and the Millennium Ecosystem Assessment seek measures of pattern and process in both human and biophysical ecosystems.
- Moldan and Billharz (1997) grouped sustainability indicators within large-scale conceptual frameworks.
- Telos developed a stocks and flows "sustainability triangle" that connects ecological capital, social and cultural capital and economic capital.
- Costanza and his colleagues have developed a detailed framework for estimating the economic value of ecological resources.

These families of conceptual approaches all emphasize value and utility for policy applications. The time is opportune for synergy among these frameworks through some form of "model dialogue" aimed at comparing the integrative conceptual frameworks that are emerging, assessing their commonalities and differences, connecting their foci of interest through a more ordered division of labor, and charting the course for the next stage of development.

Connecting the global consequences of human action with the local levels of human interest and management is critically important. The issues of scale have been aptly noted by Vasishth's and Sloane's (2002: 343-365) comment that:

"A central challenge in an ecosystem approach to planning and its concern with managing open systems lies in this seeking out and questioning traditionally accepted definitions in our conceptions of organization, boundaries and scale-definitions that, in the absence of careful attention, inevitably permeate the descriptions we make of the natural and social world we seek to control. In such cases, the idea that we should 'think globally and act locally' becomes less than adequate, and we may need to settle for some less catchy but more pragmatic version–perhaps one that says this: Think at the scales that matter, and act at levels that count."

A framework that integrates a variety of these emergent approaches so that they might help us to "think at the scales that matter and to act at levels that count" could be, for example, the Human Ecosystem Model (HEM) that has been in process and testing since 1984 (Burch and DeLuca). It was reconfigured in 1997 by Machlis et al. and then expanded by Pickett et al. in 1997 to guide a Long-Term Ecosystem Study in the Baltimore, Maryland, USA Urban Region. A recent review by Luzadis et al. (2002: 93) suggests:

"The HEM provides a strong conceptual basis as a social science framework for an integrated social and biophysical model. This foundation allows examination of broad temporal and spatial scales, and the ability to relate biophysical and social patterns and processes. Its primary weakness is in its lack of specification of process. Additional improvements could be made by specifying the processes in terms of energy transformation and flow to more fully allow linkages with systems ecology models. These weaknesses provide opportunity for productive future research to aid in understanding ecosystems and sustainability."

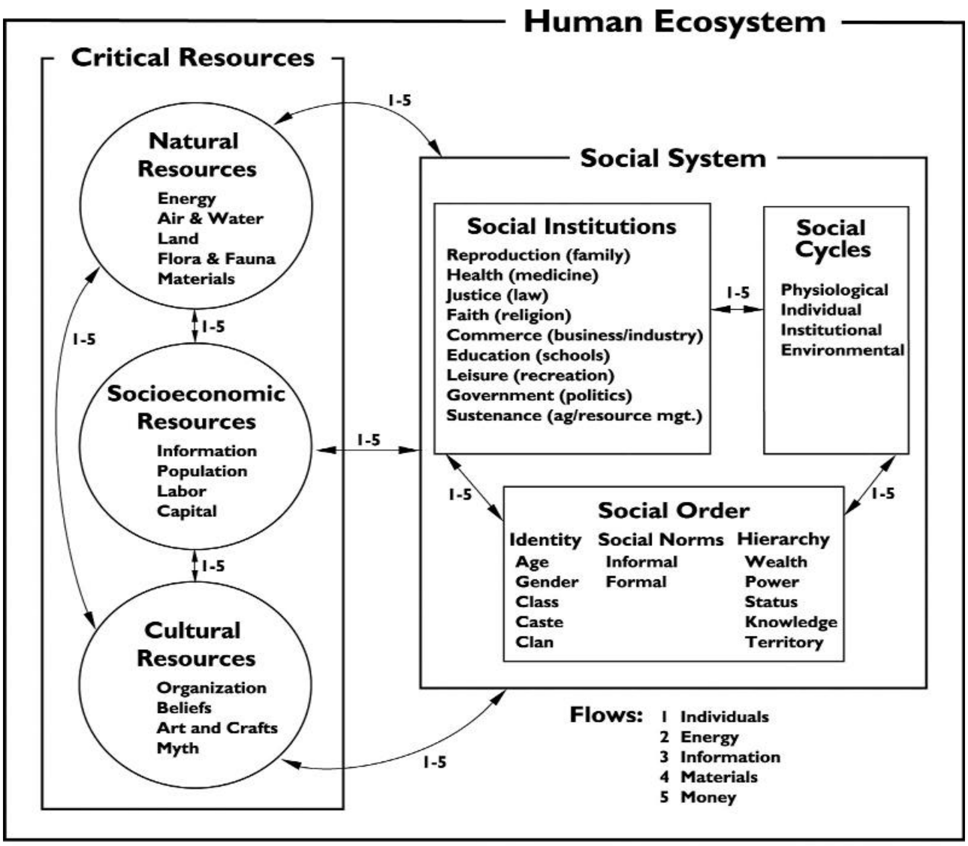
These weaknesses are currently being corrected, and an operational manual is being developed with a full array of indicator measures and data from case studies conducted over nearly three decades of exploration.

The Human Ecosystem Model

The human ecosystem is defined as *a coherent system of biophysical and social factors capable of adaptation and sustainability over time.* Human ecosystems rest upon a foundation of abiotic and biotic biophysical factors taken as base conditions, including (1) a solar-driven energy system obeying thermodynamic properties, (2) biogeochemical cycles, (3) landforms and geological variation of great complexity, and (4) the full genetic structure of life including biophysical properties of *homo sapiens.* The base conditions limit, constrain, influence and occasionally direct many human ecosystem processes, and affect all realistic efforts to understand the structure of human ecosystems. Boundaries can be spatially identified through ecological transition zones, administrative and/or political boundaries, or more fine-scaled analysis of sharp perturbations in system flows. (See Figure 1.)

The social system is composed of three subsystems. The first subsystem is a set of social institutions, defined as collective solutions to universal challenges, wants and needs. The second subsystem is a series of social cycles, i.e. temporal patterns for allocating human activity. The third subsystem is the social order, which is a set of cultural patterns for organizing interaction among people and groups, and people and nature. Taken together, these three subsystems constitute the social system. Combined with the flow of resources, this creates the human ecosystem.

Within this structure, key flows transfer individuals (of varying species), information (from genetic to cultural), energy, materials (here including natural resources such as water, and man-made goods as well), nutrients and money. These flows–within human ecosystems and between them as well–vary by rate, intensity, duration, frequency, and distribu-



The Structure of Human Ecosystems, Machlis et al (2002)

Figure 1. *The Human Ecosystem Framework (Machlis et al. 2002). Within any particular human ecosystem, a set of critical resources is required in order to provide the system with necessary supplies. The flow and use of these critical resources are regulated by the social system, the set of general social structures (including institutions, patterns and processes) that guide much of human behavior.*

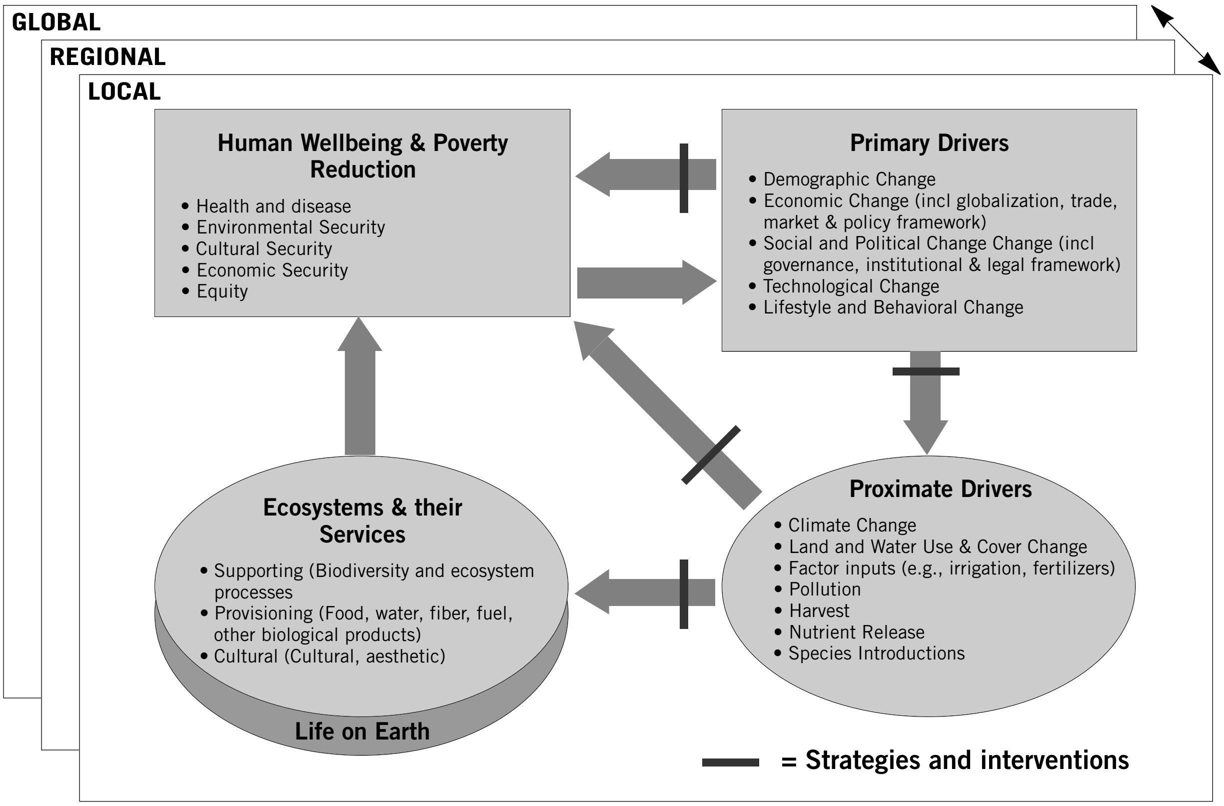


Figure 2. *Conceptual Framework of the Millennium Ecosystem Assessment (redrawn from http://www.millenniumassessment.org).*

tion. Flows between structural components of human ecosystems indicate most biophysical and socio-cultural processes.

A primary objective is meeting human needs and wants at the levels of individuals, social groups, and organizations. Efficacy in achieving advantageous adaptation is based on social power (broadly defined to include social, cultural, political, economic and military forms). It is important to recognize that human ecosystems are hierarchically nested at different scales, and linked through shared base conditions, structures, flows, adaptive mechanisms and the agency of human needs and wants.

Conceptual Framework of the Millennium Ecosystem Assessment

The recently launched Millennium Ecosystem Assessment (MA) has adopted a framework with an integrated ecosystem assessment approach that includes an analysis of the capacity of an ecosystem to provide goods and services important for human development. (See Figure 2.) The MA includes both ecological and economic analysis and considers both the current state of the ecosystem and its future potential. Two fundamental features of an ecosystem assessment are:

- The assessment is place-based; the focus is on a specific ecosystem in a particular location, recognizing that the factors influencing that system may be either local (e.g., farming) or remote (e.g., change in atmospheric CO_2);
- The assessment is multi-sectoral in order to take into account how a suite of factors interact to influence the ecosystem and how an entire array of goods and services are affected by changes in the ecosystem.

An advantage of the integrated ecosystem assessment strategy is that it provides the information necessary to consider various levels of goods and services and to identify opportunities to increase the level of benefits obtained from ecosystem goods and services. It is expected that the multi-sectoral assessment approach, considering water, food production, carbon sequestration, timber, and other ecosystems uses will provide decision makers with trade-off information needed to promote realistic management strategies.

Ecosystem Health Approach

Definitions of ecosystem health are often couched in terms of the absence of signs of pathology. For example, a lake is deemed "healthy" if it shows none of the obvious signs of pathology such as contamination, algal blooms, loss of fish species, and the like. However, this is only part of the story. A focus on ecosystem health must also examine the capacity for maintaining or restoring biological and social organization on the one hand, and the ability to meet reasonable and sustainable human goals on the other. From this perspective, ecosystem health is as much about sustaining human communities, cultural and linguistic diversity, economic opportunity, and human and animal health, as it is about sustaining the biological functions of ecosystems.

Looking further into the properties of ecosystem health, three major attributes emerge as measures of health: (1) vigor (productivity), (2) organization (including the diversity of biota and their interactions) and (3) resilience. Vigor or productivity refers to the capacity of the system to sustain growth and transmission (reproduction) of biological, linguistic and cultural components. Organization refers to the capacity of the system to support biological and cultural diversity. Resilience refers to the capacity of the system to buffer perturbations, and is also the capacity to rebound after social, political, or natural disturbances and reestablish vigor and organization.

While the attributes of vigor, organization, and resilience have been assessed from an ecological perspective, these concepts are equally applicable to the socio-economic, human health and bio-cultural dimensions. For example, in a healthy ecosystem, economic activity is buffered against the vagaries of market forces, for the system can support a variety of alternative human activities that can be brought into play to maintain a source of income for the human communities within the system.

As ecosystems are inclusive of human communities and associated cultural/linguistic attributes within this model, the evolving definitions of ecosystem health will need to account for the social, economic and cultural components as much as the biophysical aspects. It follows that ecosystem health is as much mirrored in socio-economic and cultural attributes as it is in biophysical attributes. For example, economic manifestations of ecosystem health are found in indicators of sustainability livelihoods (with both rural and urban components). Inevitably, ecosystem degradation is reflected in the loss of opportunities for sustainable livelihoods. Furthermore, as epidemiological studies suggest that human illnesses are in many cases stimulated by ecological imbalance, the health status of populations reflects or mirrors ecosystem health. For example, cholera, malaria, dengue fever, Ross River virus, Lyme disease, cryptosporidosis, to name but a few, are all enhanced by degraded environments. When it comes to linguistic and cultural diversity, the key nuance lies in the interplay with biodiversity. Loss in one component of diversity impacts the other components (Rapport and Singh 2002).

Environmental Reporting

A number of reports are regularly published by international organizations and NGOs utilizing existing environmental data and indicators to evaluate current conditions and trends to provide information on the state of the environment. There are four frameworks that shape most state of the environment reporting:

- *An environmental issues framework* with focus on indicators of specific environmental problems such as waste management, climate change or biodiversity.
- *A resource framework* that considers indicators of natural resource use, such as forestry, fisheries or energy.
- *An environmental media framework* with focus on indicators that measure impacts of various activities on the different environmental elements, such as air, water, land or biota.
- *An environmental process framework* that focuses beyond previous frameworks and identifies not only the individual indicators within each of those areas, but furthermore attempts to combine and link them to human activities responsible for the changes in environmental conditions (CEC 1996).

A detailed discussion on various frameworks for state of environment reporting is given in Moldan and Billharz (1997) and Rump (1996). Almost all international organizations are using a similar framework for indicator typology. In the early 1990s, the Organisation for Economic Co-operation and Development adopted a model called the *Pressure-State-Response* (PSR) framework (OECD 1998) for international comparability. The PSR framework was initially proposed by Rapport and Friend (1979) as the "stress-response" model. It provided a means for assessing the interactions between environmental pressures, the state of the environment, and environmental responses (OECD 2001). However, the PSR framework does not attempt to specify the nature or form of the interactions between human activities and the state of the environment. The PSR framework was then extended to cover the environmental/social interface of sustainable development in order to better track the course toward a sustainable future. As a result the framework provided a baseline for the evolution of the *Driving Force-State-Response* (DSR) and the *Pressure-State-Impact-Response* (PSIR) or *Driving Force-Pressure-State-Impact-Response* (DPSIR). In 1995, in the context of Agenda 21, the United Nations Commission on Sustainable Development (UNCSD) adopted a world programme targeted at generating and using sustainable development indicators. In 1996 the UNCSD identified a core set of 134 indicators grouped in categories covering the economic, social, institutional and environmental aspects of sustainable development. The core set of indicators has been presented in a *Driving Force-State-Response* framework, which is analogous to the *Pressure-State-Response* model.

The European Environment Agency is using the *Driving Forces-Pressure-State-Impact-Response (DPSIR)* framework. The DPSIR provides an overall mechanism for analyzing environmental problems (Livestock and Environment Toolbox 2001). Canada uses a modified PSR framework for indicators; that is, stress, condition, effect and response (Rutherford, in CEC 1996).

State of environment reporting should be balanced, comprehensive, causal, objective, policy-oriented and provide incentive for action. In other words, state of environment reporting must strive to provide analysis within the dynamics of the human ecosystem model. The assessment should be based on sound scientific methodology, and data should be carried out to answer policy-relevant questions such as:

- What is the state of the environment?
- What are the trends?
- What are the causes inducing these trends?
- What are both the harmful and beneficial consequences to people? This is particularly important as the public is not interested, for example, in the level of nitrogen dioxide in the atmosphere. But people do want to know how it might affect them.

In this context there is a need for an enlarged framework, which takes into account the interaction between human and ecological systems, and its consequences for human well-being. One way to make reporting more policy relevant would be to focus on human concerns.

Human Vulnerability to Environmental Change

The increasing vulnerability of humans to environmental change is a major concern. In fact, the World Commission on Environment and Development (WCED 1987) stressed the needs for:

- Identifying critical threats to the survival security or well-being of all or the majority of people, globally and regionally;
- Assessing the causes and likely human, economic, and ecological consequences of those threats, and reporting regularly and publicly on their findings.

The United Nations Conference on Environment and Development, which adopted Agenda 21 in 1992, proclaimed that "Human beings are at the center of concerns for sustainable development. They are entitled to a healthy and productive life in harmony with nature." (United Nations 1993).

Environmental insecurity is defined as the vulnerability of people to the effects of environmental degradation (Barnett 2001). It implies the way environmental degradation affects the welfare of human beings or threatens the security of people.

However, the majority of scientific assessments of global environmental change mostly pays attention to the analysis of environmental changes, but is less able to quantify the impact these changes might have on societies, including socio-economic impacts and deterioration in cultural and linguistic diversity. As our understanding of environmental change throughout the world grows, it is increasingly clear that highly vulnerable regions, peoples, and ecosystems will bear much of the burden of current patterns of unsustainable human activities. Hence issues related to the vulnerability of social and ecological systems are emerging as a central focus of policy-driven assessments of global environmental change (Belfer Center for Science and International Affairs 2000).

The human impact on the environment should not be seen as a one-way street; it goes in both directions. Changes in the environment have an impact on human welfare, can make major contributions to pathology in the human social system, and can lead to significant loss of bio-cultural diversity. Thus, degradation in ecosystems should stimulate a human adaptive response to reduce the direct and indirect human impacts of such degradation. (Harrison and Pearce 2000). An evolving model, taking full account of such bio-cultural complexity, would seek to (1) quantify human impact on environment; (2) quantify how changes in environment would increase human vulnerability; and (3) quantify how perceived (and actual) losses in socio-economic health and bio-cultural diversity stimulate adaptive response. As we look ahead, we can anticipate that the exploration of these complex feed-back loops could be one of the important pathways through which science can enhance its relevance to public policy in the environmental arena. (See Figure 3.)

Human welfare affected by environmental degradation can easily be depicted through a number of diverse topics, including health, economic losses, poverty, food security, equity (intra and intergenerational), loss of natural heritage and experiences (i.e. cultural and linguistic diversity), loss of intellectual property rights, conflict, exposure to extreme events and climate change impacts. If vulnerability were described under these themes rather than those of state variables (i.e. resources or pressure variables), enhanced public attention and concern would result. It is also essential to differentiate scientific results from the policy significance of those results (Pielke 2002). It follows that environmental assessment processes and policy assessments should be dealt with on separate bases.

In order to 'breathe life' into existing statistical frameworks, a conscientious effort needs to be made to widen their purview by giving equal weight to the biophysical, geographic, socio-economic and human health dimensions. Existing environmental frameworks for statistical purposes are not sufficient by themselves to analyze causality and trends. For sure, assessments must be more local in order to be more relevant. That part of the picture is emerging from detailed and synoptic studies of many case histories, seeking common patterns (Rapport and Whitford 1999).

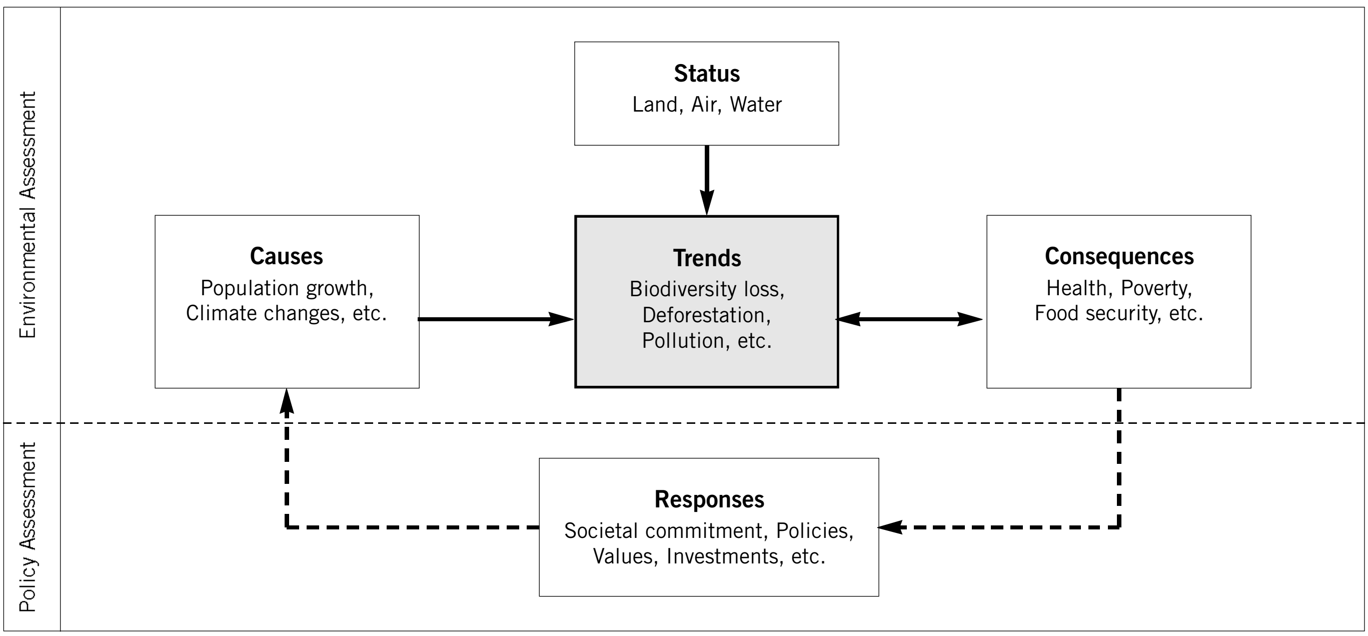


Figure 3. *Human vulnerability to environmental changes framework (Rapport and Singh 2002).*

Environmental Indicators and Indices

The packaging of data into indicators is a way of simplifying complex and detailed information. Indicators should be designed in a way that helps decision-makers to set precise goals for future action and enables interested parties to monitor progress toward the desired goals. An index is a composite of several indicators. Combining relevant indicators from a vast array of environmental data into a composite index reveals the available evidence in a much more convincing fashion than would individual indicators. Normally, indices grab the headlines in the mass media, attract public opinion, and mobilize actions from political leadership. For example, economic indicators like the Gross Domestic Product (GDP) show the power of a single number whose significance is widely comprehended. However, public interest tends to focus more on relative ranking than on absolute score. The relative ranking provides context and perspective, allowing the public to compare each country or theme on the same scale using similar measures and criteria. Such ranking can stimulate discussions for change.

Environmental indicators are relatively under-developed compared to economic and social indicators. No popular environmental index aggregated in a way that provides a sense of the big picture of environmental performance, equivalent to GDP or the Human Development Index (HDI), exists to facilitate comparative ranking of countries based on analogous information and consistent criteria.

Environmental Indices, Indicators and Data: A Review

There have already been attempts to develop composite indices related to various aspects of the environment within the framework of sustainable development. Hammond et al. (1995) discussed a systematic approach to measure and report on environmental policy performance in the context of sustainable development, and provided a conceptual framework (Pressure-State-Impact-Response) for developing composite indices for pollution/emissions, resource depletion, biodiversity, and human impact/exposure. Chambers et al. (2000) have given a lucid description of the advantages and disadvantages of numerous frameworks on sustainability indicators such as ‘Environmental Space’, ‘System Models’, ‘Environmental Impact Assessment and Critical Loads’, ‘Corporate Environmental Performance Evaluation’, ‘Life Cycle Analysis’, ‘Metabolic Studies and Material Accounts’ and ‘Energy and Energy Analysis’.

A number of composite indices have been proposed such as the Environmental Sustainability Index (ESI) by the World Economic Forum (2001 & 2002), the Sustainable Development Index and Environmental Policy Index (Thomas et al. 2000), the Living Planet Index (WWF 2000), the Environmental Quality Index “Dashboard Sustainability Concept” (IISD 2000), the Ecological Footprint (Wackernagel and Rees 1996), and the Ecosystem Well-being Index (EWI) (Prescott-Allen 2001).

A summary review of available indices reveals several shortcomings. Some indices deal with only a few environmental challenges (e.g. the Living Planet Index focuses on biodiversity loss) or rely on a particular pattern of human activities (e.g. Ecological Footprint is an index of consumption pressure of societies). Others try to cover environmental goals by involving too many variables, but become too complex for future follow-up and public understanding (e.g. ESI or EWI). In fact, Esty and Porter (2000) observed that the ESI includes theoretically-derived variables, but the methodology does not validate a relationship between these variables and environmental outcomes.

Numerous international, regional organizations, governmental agencies and scientific bodies have launched a variety of environmental indicator initiatives encompassing different areas of the environment. Some of the major initiatives at the global, regional and national levels are summarized by Singh and Moldan (2002).

Recently, the UN General Assembly adopted the United Nations Millennium Declaration (resolution 55/2) which was signed by 145 heads of state and government. The General Assembly thereby requested regular assessments of progress towards the implementation of the goals defined in the Millennium Declaration (http://www.un.org:E/CN.3/2002/25). A framework of eight goals, 18 targets and 48 indicators was included in the report of the Secretary-General on a road map towards the implementation of the Declaration (http://www.un.org: A/56/362). "Goal 7, To ensure environmental sustainability" sets forth the following targets and indicators:

- *Target 9.* Integrate the principles of sustainable development into countries policies and programmes and reverse the loss of environmental resources.
  Indicators:
  Proportion of land area covered by forest
  Land area protected to maintain biological diversity
  GDP per unit of energy use (as proxy for energy efficiency)
  Carbon dioxide emissions (per capita) [Plus two figures of global atmospheric pollution: ozone depletion and the accumulation of global warming gases]
- *Target 10.* Halve by 2015 the proportion of people without sustainable access to safe drinking water
  Indicator:
  Proportion of population with sustainable access to improved water source (data on quality water not available)
- *Target 11.* By 2020 to have achieved a significant improvement in the lives of at least 100 million slum dwellers
  Indicators:
  Proportion of people with access to improved sanitation
  Proportion of people with access to secure tenure

Obviously, many of these indicators attempt to describe particular realms of the environment in detail. Another interesting feature is that too many criteria and indicators are being proposed. As described below, there are more indicators proposed than the number of data variables being normally measured (Singh and Moldan 2002).

There is a need for greatly improved, coherent and compatible baseline data and data systems available to all potential users. The prevalent gap between theory and reality related to the current data and indicators development paradigm is illustrated in Figure 4. The deficiencies in international databases and indicators are in most instances a direct consequence of the lack of basic environmental data at country levels. The only way to ensure the provision of environmental information on a routine basis is to build and enhance national capacities for collection, compilation, and analysis of environmental data.

Criteria for Indicators (based on OECD 2002)

No country, at this point in time, has officially developed one single index of sustainability. Instead, countries are developing sets of indicators. In many cases, the criteria for determining what is a "good" indicator depend on and reflect the users of that indicator. It is extremely difficult to identify indicators that are understandable and useful for all users. This is one reason underlying the need for a number of different sets of indicators. Detailed indicators are often best suited for experts, whereas so-called "headline" indicators are often best for communicating with a wider audience.

The Bellagio report (Hardi and Zdan 1997) suggested that the following points are important as selection criteria: policy relevance; simplicity; validity; availability of time-series data; good quality, affordable data; ability to aggregate information; sensitivity to small changes; reliability.

The OECD established the following set of criteria for indicator selection in the field of environmental indicators (OECD 1998):
Policy relevance and utility for users:

- Provide a representative picture of environmental conditions, pressures on the environment and society's responses;
- Be simple, easy to interpret and be able to show trends over time;
- Be responsive to changes in the environment and related human activities;
- Provide a basis for international comparisons;
- Be either national in scope or applicable to regional environmental issues of national significance;
- Have a threshold or reference value against which to compare it so that users are able to assess the significance of the values associated with it.

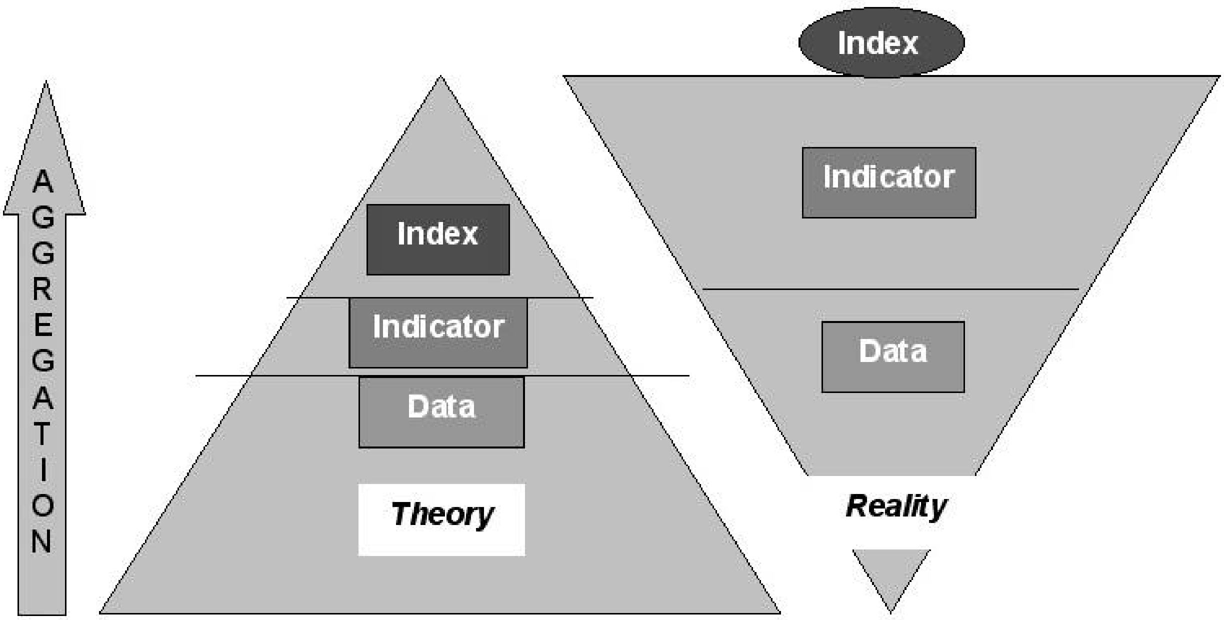


Figure 4. *The Information Pyramid: Theory and Reality (Singh and Moldan 2002).*

Analytical soundness:
- Be theoretically well-founded in technical and scientific terms;
- Be based on international standards and international consensus about its validity;
- Lend itself to being linked to economic models, forecasting and information systems.

Measurability:
- Readily available or made available at a reasonable cost/benefit ratio;
- Adequately documented and of known quality;
- Updated at regular intervals in accordance with reliable procedures.

For policy development, OECD (2002) calls for indicators that are few in number, clear, concise, and analytically robust. In addition, they need to highlight unambiguous "good" and "bad" directions of movement.

A number of other criteria considered to be important include the need to have (1) a close connection between the indicators and quantitative targets, (2) stated objectives, and (3) policy intentions or public expectations. In addition, indicators should be able to differentiate human interference from natural variability, and they must give societies enough time to act to avoid crossing a critical threshold. It would be desirable to include the concept of a critical threshold in an indicator, but it has been noted that this is very difficult.

In conclusion, the power of an indicator lies not only in characterizing the issue but also in providing guidance towards dealing with the issue. At stake is not only our ability to identify indicators, but more concretely to make these indicators accessible and understandable to policy makers and the general public. Until this objective is attained, there will always be too many indicators and very little action. Since the 1992 Rio UN Conference on Environment and Development, there has been a proliferation of activities related to the development of sustainable indicators and, as mentioned earlier, too many indicators have been proposed. However, in recent years, the trend seems to be shifting towards development of fewer indicators as reflected by the *10 Indicators for Environment* by OECD

(2001) and Headline Indicators by the European Environment Agency (EEA) in *Environmental Signals* (2001).

The review by Singh and Moldan (2002) highlighted that there is no composite index widely used to capture progress made towards environmental goals. It affirmed a need for the introduction of a composite index, similar to GNP for economy and HDI for human development, that can be used to track the progress towards environmental protection with a greater degree of simplification, and to facilitate communication. Such a composite index would solicit wider public attention, bring transparency and accountability to policy making, and create a basis for fine-tuning policies for maximum effectiveness.

Geospatial-Based Analysis and New Tools for Assessment

The previous section noted that clarity, relevance, and simplicity were valuable traits for indicators. The nature of problems and the value of assessments vary from place to place. The local interplay of environmental and socio-economic characteristics influences the ways we use available resources and administer human activities. The consequences of our actions and their impact on sustainability are therefore influenced by place.

Closely related are issues associated with the scale of the assessment, the scale of the problem, and the scale at which decisions are made. Regardless of the scale of an assessment, to be policy relevant and provide meaningful input to the decision making process, we must be able to localize problems (Balling 2000). All environmental issues and processes have scale-dependent connections (Bailey 1987). Some environmental problems have specific local origins, such as the soil erosion associated with inappropriate soil management practices. The consequences occur both at the site where there is lower productivity, as well as downstream and regionally because transported sediments impact water quality and aquatic resources. From the opposite vantage point, climate change is a fluid global process with very local implications.

The tools needed to factor in place and scale for collecting the environmental indicators required for environmental assessments are now available, affordable, and explainable. With tools like remote sensing, we can map, measure, and monitor the phenomena that comprehensively form geographic complexity, and we can track, over time, how conditions on the Earth's surface are changing. Through the use of geographic information systems (GIS) and global positioning systems (GPS), we can establish geographic location and define context. A GIS enables use of spatial statistics, spatial data integration, and spatial models to analyze the effects of place and scale, and to translate those effects in terms associated with the decision-making process for a range of environmental, social, and economic challenges.

Spatial Analysis and the Assessment Continuum

Environmental assessments must (1) be appropriate for replicable and applicable implementation in a variety of environs, (2) follow scientifically valid methods that can be harmonized with other assessments, and (3) provide meaningful and relevant products that can be used by non-specialists to usefully serve the sustainable development decision-making process.

The assessment process follows a continuum that involves determining the baseline *rates* or levels of various phenomena or indicators, establishing the *trends* in these measurements or conditions, identifying the *causes* of the indicator rates and trends, and finally, determining what the *consequences* are of the rates and trends. An additional element, *mitigation*, is increasingly important and represents the follow-on actions required such as the establishment of new policies and directives and implementing remedial management activities.

The assessment sequence can be affected by the analytical functions associated with the spatial analysis tools employed. There are four key functions that form the process needed to assess the rates (and initial conditions), trends, causes, consequences, and assess mitigation:

- *Mapping* and *measuring* involve the collection of thematic and quantitative baseline data in a geographic format. The baseline data can be either contemporary or historical and are typically gathered either in situ using a GPS or interpreted using remotely sensed data.
- *Modelling* involves the process of using precise and typically mathematical descriptions of the system inputs, outputs, and processes under study to simulate the present, past or future aspects of the described model based on established scenarios. With GIS, modelling can be done in a spatial context.
- *Monitoring* involves the regular assessment of the condi-

tions and recording the shifts or changes in conditions of the Earth surface and human activities. Using continuous remote sensing inputs, the thresholds for changes can be deployed to identify risk or vulnerability.

The geospatial technologies that support mapping and measuring, modelling, and monitoring must be durable and available to a broad audience. Remote sensing and GPS serve data collection functions associated with mapping, measuring, and monitoring, while GIS offers exceptional versatility as it provides a full set of capabilities for collecting, organizing, comparing, and communicating geographic information. In addition, GIS greatly enhances communication and decision support. Finally, the visualization aspects of geospatial technologies facilitate the decision-making process while enabling community interaction for wide audiences and discussion.

Mapping and Measuring via Remote Sensing and GPS

There is a gradual trend toward the collection of geographically-based indicator data for environmental assessment. However, the associated mapping and measuring tasks require a substantial level-of-effort (including high-level staff training and facilities), leaving the development of spatial indicators to organizations with the charter and infrastructure necessary to complete the work. Commonly, national mapping agencies produce the bulk of these data.

Virtually all modern map products derive considerable information from remotely sensed data. Remote sensing provides a means to document "what is where" at a particular point in time. From an environmental assessment perspective, this is essential for establishing the rates of various dynamic resource parameters.

Remotely sensed data can be acquired both from Earth orbiting satellites and from low flying aerial aircraft. This results in data spanning a wide range of spatial scales and resolutions from one-meter to 1000 m^2. A common mistake when considering image requirements is that higher resolution data is always better. While very detailed landscape characteristics may be mapped or measured with sub-metre images, there is a very high cost associated with using such data. For example, a 60 km by 60 km SPOT scene with 20 m and 10 m resolution channels has a cost of $1500. In comparison, equivalent geographic coverage using 1 m IKONOS is $64,800. Table 1. shows the increased costs of higher resolution data.

In addition to data acquisition costs, there are also costs associated with conversion of images to orthorectified (distortion-free and geo-referenced to a coordinate system such as latitude and longitude), interpretation of information using either manual or statistical means, and verification of results. Most products interpreted from remotely sensed data use field observations for classification and validation calibration purposes.

Satellite	Resolution of Example	Geographic Coverage	Cost Per Scene	Cost Per Kilometer^2
MODIS	1000 m^2	1200 km by 1200 km	No Cost	$0.0
SPOT VEGETATION	1000 m^2	1,000,000 km^2	$144	$0.00014
Landsat TM, ETM+	30 m^2	185 km by 185 km	$600	$0.02
SPOT Multispectral, Pan	20 m^2, 10 m^2	60 km by 60 km	$1500	$0.42
IKONOS	1 m^2	1 km by 1 km and larger	$18/$km^2$	$18.00

Table 1. *Geographic extent and current prices (US Dollars) for common sources of current remotely sensed data. Prices are for current data. Older data are often available at a reduced cost. Currently, NASA's policy is to provide the research community free access to MODIS data sets (Loveland and Foresman 2002).*

In general, the approximate cost of producing either thematic or quantitative information breaks down in the following way:

- Cost of remotely sensed data – 10%
- Cost of orthorectifying and georeferencing data – 10%
- Cost of interpretation and analysis – 40%
- Cost of validation and documentation – 40%

The cost of verifying the accuracy of maps is often alarming. However, science quality data (i.e., maps with known and traceable lineage and where the errors inherent in the overall production of the maps have been documented) are essential if large-area environmental assessments are to provide the ability to separate subtle changes from background noise (Estes and Mooneyhan 1994). Accuracy of environmental assessments will have an inherent impact on a litany of conventions and treaties as harmonized and standardized assessments become accepted by all nations including the Kyoto Protocol, as well as the international conventions on biodiversity (CBD), wetlands (Ramsar), and desertification (CCD).

The cost borne by these processes can be lowered through the adoption of international data standards. FAO and UNEP recently launched the first operational standards for a Global Land Cover Network ((FAO/UNEP 2002) using the UN Land Cover Classification System (FAO 2000), in cooperation with experts from over 20 nations and multiple research and government institutions. This represents a major milestone in the standardization and harmonization of land cover mapping activities throughout the globe, and is a fundamental improvement in the environmental assessment process.

GIS and Spatial Data Analysis and Modelling

GIS technology has revolutionized most aspects of spatial data collection and analysis, and has provided breakthroughs that foster examination of environment issues in a geographic context (Foresman 1998). As GIS are capable of assembling, storing, manipulating, and displaying geographically referenced information (i.e. data identified according to their locations), which provides a means to investigate problems in a place-based context, they enable complex, integrated assessments from local to global scales.

Three functional capabilities of geographic information systems are particularly relevant to the environmental assessment process: (1) integration of geospatial technology, (2) linking or integrating information that is difficult to associate through other means, and (3) manipulating and analyzing two- and three-dimensional characteristics of the Earth's surface, subsurface, and atmosphere using mathematical and statistical formulae that model relationships between different environmental variables. Virtually any environmental model, whether dealing with groundwater withdrawal, soil loss, ecosystem productivity, carbon sources/sinks, air quality characteristics and dispersion, or land use change forecasts, etc. can be implemented in a GIS.

Spatial Data

The real limitation of the environmental assessment process results from the availability of quality indicator data. The UNEP Global Environment Outlook (GEO-3) report has demonstrated to a global audience the limitations of data availability in global and regional assessments (UNEP 2002). Depending upon scale, thematic content, and timeliness, this is equally true for both the developed and developing world (Estes and Mooneyhan 1994). While there are now global maps of many land variables, the availability of land data sets at national and regional levels is uneven (Loveland et al. 2000). Any attempt to localize environmental assessments will be limited by the coarsest available indicator data.

Crucial needs for environmental data will only be met if data centers and spatial data clearinghouses such as the UNEP-GRID network and the ICSU World Data Centres focus on making the best available spatial data sets accessible to the environmental assessment community. Progress is being made within the international community towards the harmonization of global environmental assessments (GEAs) with the explicit goal of using these networks and clearinghouse nodes. Such GEAs include the Global International Waters Assessment, Global Environment Outlook, Forest Resources Assessment, World Waters Assessment Programme, Dryland Degradation Assessment, and the Millennium Ecosystem Assessment.

Geospatial Issues and Challenges

While geospatial technologies and strategies are rapidly being incorporated into environmental programs throughout the world, there are still many problems to be considered, for example:

- Geographic data standards are essential elements of environmental assessments. Committees such as the Global Spatial Data Infrastructure (GSDI) are making consequential progress in issues such as compatibility of data and information, interoperability, harmonization and protocols.
- Data quality, including accuracy and precision, must be understood and translated into contexts relevant to the decision-making process.
- Equitable access to data, technology, and other required resources is critical if regional to global understanding of environmental conditions is to be forthcoming.

Given these issues, it is still clear that geospatial tools will help improve the specificity, relevance, and quality of environmental assessments. We are on the verge of significant strides in localizing and integrating environmental assessments across the range of scales that are relevant to the rates, trends, causes, consequences, and mitigation assessment process. However, the primary challenges are not technological, but include data limitations and inadequate institutional infrastructure (Loveland and Foresman 2002).

Conclusions

A strong partnership between society and the science and technology community is the foundation for the development of sound policy options and opportunities for equitable sustainable development. We are looking for a new interface to meet the challenges at this threshold of the 21st century.

Assessments have been used as one of the primary tools for making science accessible and useful to society. Over the past two decades there have been many scientific assessments on a range of topics including stratospheric ozone, climate change and biodiversity. The assessment process continues with activities such as the Millennium Ecosystem Assessment, a combined diagnostic and prognostic assessment of human impacts on ecosystem services. Ecosystem services include provisioning services, such as the supply of food and fiber, and supporting services, *i.a.*, the purification of air and water, and the stabilization of landscapes against wind and water erosion.

There has been no comprehensive evaluation of the major scientific assessments of the past two decades that has addressed the following important questions. What topics have been covered? Are there important topic gaps? What are the successes and failures? What aspects of design and process make for successful assessments? Can we combine the successful aspects of design and process into a new assessment framework? If yes, does the new framework yield an assessment that makes science highly policy relevant?

It is important to construct a new framework for assessments that builds on lessons learned from evaluations of extant and ongoing assessments and related work. It is also important to focus on testing the new framework, *i.a.*, by

- cataloguing the major environmental assessments of the past two decades and identifying critical topics in need of scientific assessment;
- studying the design and process aspects of these major assessments;
- exploring a range of issues, including scale (global, regional, local), language, legitimacy, and stakeholder involvement; and
- constructing a new assessment framework to yield scientific information that is maximally policy relevant.

Over the past decade, science has primarily flourished using the narrowing-in approach, breaking down fields to smaller and smaller entities. The pendulum is now swinging in the direction of holistic synthesis, and greater understanding of bio-complexity, not as an alternative but as a complement to the prevailing model.

We believe that this is a more appropriate approach, and one which can cope with the integration of humans, cultures, ecologies and health. Its very complexity is its strength. Should we persist in fragmented thinking, managing resources without cognizance of the ecosystem properties and functions in which they are embedded, we will continue to lose ground, that is we will continue to face a more impoverished world–both biologically and culturally.

All future considerations of the science and policy interface should integrate social and health sciences with the natural sciences. Until recently, contributions from these sectors have been underplayed but great strides have been made in understanding linkages, for example, between human health and ecosystem condition. Once we can clearly demonstrate how all the variables (personal health, economic opportunity, preservation of cultural traditions, social support mechanisms) that people use as yardsticks that matter to humans are interrelated within an ecosystem health context, we may finally begin to foresee more science-based policy that can effectively lead to long-term sustainability of our environment.

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Annexes

Acronyms

CBD	Convention on Biological Diversity
CCD	Convention to Combat Desertification
CEC	Commission for Environmental Cooperation
DPSIR	Driving Force-Pressure-State-Impact-Response
DSR	Driving Force-State-Response
EEA	European Environment Agency
ESI	Environment Sustainability Index
EWI	Ecosystem Well-being Index
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GEA	Global Environmental Assessment
GEO	Global Environment Outlook
GIS	Geographic Information System
GPS	Global Positioning System
GRID	Global Resource Information Database
GSDI	Global Spatial Data Infrastructure
HDI	Human Development Index
HEM	Human Ecosystem Model
ICSU	International Council for Science
IKONOS	High resolution satellite sensor by Space Imaging Corp.
MA	Millennium Ecosystem Assessment
MODIS	Moderate Resolution Imaging Spectroradiometer
NASA	National Aeronautics and Space Administration
OECD	Organisation for Economic Co-operation and Development
PSIR	Pressure-State-Impact-Response
SCOPE	Scientific Committee on Problems of the Environment
SPOT	Système Pour l'Observation de la Terre
TM	Thematic Mapper
UNCED	United Nations Conference on Environment and Development
UNCSD	United Nations Commission on Sustainable Development
UNEP	United Nations Environment Programme
WCED	World Commission on Environment and Development
WSSD	World Summit on Sustainable Development

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