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Viewpoint

Distributed assessment systems: an emerging paradigm of research, assessment and decision-making for environmental change☆

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1. Introduction

Global environmental change is increasingly understood to have causes and effects which span multiple levels, from the local to the global (Gibson et al., 1997; Folke et al., 1998; Wilbanks and Kates, 1999; Cash and Moser, 2000). Traditional centralized assessment efforts used to address global change, however, are generally insensitive to the multi-level nature of environmental problems. These efforts forego an opportunity to engage and inform regional and local researchers and decision-makers, increasingly important players in the science and politics of climate change, biodiversity loss, and other large-scale problems.

In response to this shortcoming, a new paradigm for environmental assessment and management has begun to emerge, paralleling and complementing the centralized committee-and-report approach: *distributed assessment systems*. These integrated networks of research, assessment, and management bridge numerous levels, and include sustained, long-term interactions between scientists, decision-makers, and stakeholders. This paper identifies such innovative systems in several issue-areas, outlines characteristics that contribute to their success, and argues that, given the increasing *local* sensitivity to *global* environmental problems, adoption of such systems are urgently needed.

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2. Global assessments of "global" problems?

To address a vast array of environmental problems, numerous international and regional environmental treaties have been initiated in the last 30 years. Almost all require scientific assessment and monitoring to support decision-making. The institutional structure of these assessment has historically been top–down, centralized, and primarily focused on producing written reports. Familiar examples include the Intergovernmental Panel on Climate Change (Intergovernmental Panel on Climate Change, 1996), or the World Meteorological Organization Ozone Assessment of the mid-1980s (World Meteorological Organization, 1985). This structure can be relatively efficient and has worked well for probing questions about large-scale phenomena and informing the agenda for international negotiations. However, it has been poorly suited for identifying and describing regional and local vulnerabilities to these large-scale phenomena, integrating and synthesizing data collected at multiple scales, identifying and assessing interactive environmental stresses, and producing policy-relevant information for sub-national decision-makers (Jasanoff and Wynne, 1998). In so doing, traditional centralized assessments have failed in assisting local decision-makers in taking actions to help prevent global environmental problems, or in implementing responses to adapt to local impacts of global change (Wilbanks and Kates, 1999).

However, two trends indicate an increasing understanding of both these shortcomings and, more generally, in the multi-level nature of "global" problems. The first is a growing recognition in the scientific community that data and knowledge about fine-scale structures are necessary for understanding large-scale systems (Ayensu et al., 1999). This is seen, for example, in the attempt by climate modelers to produce more accurate and predictive *global* climate models by incorporating greater *local* specificity of climate parameters (Harvey, 2000).

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Second, subnational decision-makers are demanding high-resolution information about the implications of global phenomena at the local level (Lins et al., 1997). Heterogeneity of local impacts and vulnerabilities, the interactions of multiple environmental stresses, and large geographic variance in costs and benefits highlight the potential pitfalls of centralized assessment systems which are poorly linked to decision-makers at multiple levels. *Global* mean temperature change, while perhaps spurring international action, is irrelevant to *local* emergency relief managers in Bangladesh or farmers in Nebraska.

3. An outline of distributed assessment systems

While traditional assessment processes dominate the landscape of large-scale environmental problems, several recent efforts illustrate some of the characteristics of *distributed* information decision-support systems which effectively address the multi-level nature of these kinds of problems. Three such examples include: The Pacific ENSO Applications Center (PEAC) — a partnership between the US National Oceanic and Atmospheric Administration (NOAA), research centers throughout the Pacific, and the Pacific Basin Development Council (an association of US-affiliated Pacific Islands) created to provide El Niño/Southern Oscillation (ENSO) forecasting products to varied decision-makers in the Pacific; the assessment efforts under the Convention on Long-Range Transboundary Air Pollution (LRTAP) in Europe, a treaty designed to address regional transport of air pollutants; and the Cooperative State Research Education and Extension Service (CSREES) in the US, a system which coordinates state and federal research for the agricultural sector. While these and other examples of distributed assessment systems vary in a number of dimensions, they share at least two common institutionalized features: (1) multiple connections between researchers and decision-makers which cut across various levels (polycentric networks); and (2) sustained and adaptive organizations which allow for iterated interactions between scientists and decision-makers.

3.1. Polycentric networks

Two fundamental and related attributes of successful distributed assessment systems include institutionalized links between scientists and decision-makers, and links between these players across multiple levels. Two-way communication pathways form the backbone of these kinds of linkages allowing: research to be targeted at those questions that matter most to decision-makers; the strengths and limitations of current scientific knowledge to be communicated to decision-makers; and research findings to be packaged in the most useful ways by scientists.

Linkages across levels provide an avenue to accomplish the parallel goals of providing local-scale data for the understanding of large-scale phenomena, while meaningfully rendering the implications of large-scale events for local conditions. For example, over the 80-plus years of the CSREES, institutionalized linkages (formal relationships, legislated duties, contracts, etc.) have evolved which connect, in a dense network: farmers; county extension agents; scientists at state land-grant colleges; local, state, and federal legislators, managers, and regulators; and US Department of Agriculture scientists at federal, regional, and state offices. The result is a dynamic and flexible system that provides timely, useful and credible information to a wide array of decision-makers at multiple levels (Rasmussen, 1989; National Research Council, 1996).

An institutional structure that supports such linkages can be conceived of as a polycentric network of semi-autonomous research nodes spanning multiple levels and supporting decision-making at these multiple levels. The notion of a "polycentric network of semi-autonomous research nodes" captures the importance of balancing: (1) coordinated scientific efforts which capitalize on the scientific comparative advantages at different nodes, and which provide coherence of data and methods across levels (Easterling, 1997; Ayensu et al. 1999) (e.g., the computing and modeling resources of a national weather agency complementing the site-specific knowledge and monitoring ability of a local resource management entity, neither of which could individually undertake a globally complete and locally relevant assessment effort); and (2) autonomous efforts by local scientists and managers to address important local environmental issues, and tap into local and indigenous knowledge sources and knowledge production processes.

For example, the PEAC network is coordinated by NOAA, and integrates the research and forecasting at the National Weather Service Pacific Region, National Centers for Environmental Prediction, the International Research Institute for Climate Prediction at Columbia University, the University of Hawaii's Social Science Research Institute and School of Ocean and Earth Science and Technology, and the University of Guam's Water and Environmental Research Institute. These research nodes integrate their assessment and forecasting efforts, exploiting comparative advantages and specialized strengths of the different institutions. As such, each institution does what it does best, but does so in the context of a larger collaborative effort, tailoring specific information products to specific needs (Office of Global Programs and US Department of Commerce, 1999).

While successful distributed assessment systems take advantage of specialization, they also depend on duplicate or parallel sub-systems within the system as a whole. At first, these two efforts (specialization and duplication) seem mutually exclusive, but successful systems find a balance, using multiple and linked pathways to derive complementary benefits of both. Thus, in addition to tapping into the advantages of specialization (as outlined above), such a structure exploits several advantages of duplication.

First, it allows for redundancy, protecting the system as a whole from failures in one part. In this sense, such a multi-linked network constitutes a robust system that is more likely to weather disruptions.

Second, and related to such protections spawned by multiple pathways, is the encouragement of innovation and flexibility. Multiple nodes where researchers and decision-makers are assessing and addressing similar issues provide multiple crucibles for solving assessment and management problems, and thus numerous potential solutions. Such a phenomenon was seen in Europe in the mid-1980s as three teams of modelers working under LRTAP produced a variety of different innovative ways of conceptualizing the problem of transboundary air pollution. One model was ultimately found to be the most useful and credible by the negotiators of the convention, while the other two were used for back-up comparisons (Tuinstra et al., 1999). The drawback of a system built for redundancies and innovation is inefficient repetition. Efforts such as those under LRTAP, however, demonstrate that the heterogeneity and complexity of the biogeophysical and human systems demands corresponding complexity, and that the benefits of some level of duplication outweigh the costs (Ostrom, 1998; Gibbons, 1999).

Third, a network comprised of multiple nodes and entry points facilitates the ability to incorporate stakeholder and non-governmental organization involvement in assessment and management activities, a trend that is increasingly embraced for environmental problem-solving at all levels. One advantage of such stakeholder involvement is that it fosters greater linkage of emerging *global* problems to pre-existing *local* environmental concerns, thus increasing the relevance and legitimacy of an assessment (Cohen, 1997).

Finally, a well-integrated network fosters capacity building both horizontally (e.g., nation to nation) and vertically (e.g., nation to locale, and vice verse). For example, the capacity to contribute to and utilize complex large-scale hydrogeologic models has been successfully built in local water management districts in the US Great Plains through their coordinated networking with state and federal agencies (e.g., Kansas Geologic Survey and US Geologic Survey) (Cash, 1998).

3.2. *Long-term adaptive institutions*

Another suite of features of distributed assessment systems addresses the importance of building *sustained* and *adaptive* networked relationships between science and decision-making and across levels. Long-term institutionalized relationships allow trust and credibility to accrue over time, especially critical in an information/decision system which addresses contested and controversial issues. Iterative interactions between scientists, decision-makers, and stakeholders, which are only possible in the context of long-term relationships, encourage the fine-tuning of research agendas, of the research process, and of information products over time. Moreover, an iterative process is a necessary component of adaptive assessment and management, in which policy experimentation can be attempted and assessment can consciously evolve to address changes in policy, science, and the natural environment. Long-term flexibility in such a system also allows for the possibility of cross-fertilization of issue areas, and more useful analysis of the interactions between environmental risks (Gunderson et al., 1995). Agriculture research and extension in the US illustrates an enduring and adaptive structure which has been able to address a large variety of emerging issues, to abandon unsuccessful programs, to modify existing programs, and to create new ones, all in the context of building trust and credibility between both the producers and users of information (Rasmussen, 1989; Cash, 1998).

4. Challenges

One of the most significant challenges facing the implementation of distributed assessment systems is the need to marshal the resources to create and sustain such systems. Building institutionalized linkages that currently do not exist, is financially and politically costly, with benefits reaped in the future. Clearly, one way of addressing at least part of this problem is by building on previously existing institutions and networks, as is demonstrated by PEAC or by the agricultural extension system. Such building with existing pieces, or adapting old structures for new functions is not only less costly than constructing from scratch, but it also provides an opportunity to take advantage of pre-existing trust and credibility, and to relate established concerns to emerging and future environmental problems.

Another central challenge is related to the already contested and negotiated boundary between science and decision-making. Distributed assessment systems call for a new way of conceptualizing the boundary between science and decision-making, one that fundamentally acknowledges a shifting and more porous boundary, and attempts to define and craft that boundary to better produce both credible science and useful information (Gibbons, 1999; Jasanoff, 1987). Such a change in the way the science-policy boundary is conceived is likely to be controversial and difficult to propel forward in the face of already existing and entrenched conceptual frameworks, interests and institutions.

Despite these challenges, the growing realization of both the global implications of local actions and the local impacts of global environmental change has pushed both scientists and decision-makers to re-evaluate how research and assessment can effectively support environmental decision-making. The resultant paradigm of distributed assessment systems, while far from being fully understood and specified, offers a powerful and dynamic conception of how science and decision-making at multiple levels are already being effectively integrated.

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