
Infrastructure for Monitoring Global Change in Local Places

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1. Introduction

Imagine a world where nature and society co-exist in a healthy symbiosis, where human impacts on the environment are minimal, and where communities are safe from natural and technological hazards. Imagine a time when scientists can monitor such sustainable human-environment interactions, when they can interactively share and compare data, analyses, and ideas about those interactions from their homes and offices, and when they can collaborate with local, regional, and international colleagues and stakeholders in a global network devoted to the environmental sustainability of their communities and of the planet. I believe that the Sustainability Geoscope presents the opportunity to develop such a world and time.

I contend that to build the sustainable world portrayed above, it is first necessary to develop an infrastructure¹ that will support such an edifice. Consequently, this essay will present my ideas about the infrastructure needed to realize a global-change-in-local-places vision of the Sustainability Geoscope. The essay also will describe how the HERO project is attempting to take the initial steps to develop that infrastructure. The essay concludes that the future may be closer than we think.

¹ Infrastructure is the foundation or basic framework of a system or organization. An alternative definition of infrastructure is the resources (such as the rules, software, or personnel) required for an activity.

2. Infrastructure for monitoring global change in local places

To paraphrase the American politician Tip O’Neill,² “all global change is local.” Anthropogenic global environmental change is the accumulated result of billions of individual actions occurring at billions of specific locations. People experience the biophysical and socioeconomic impacts of global environmental change in identifiable places. In addition, implementation efforts to adapt to those impacts, as well as to mitigate greenhouse gas emissions, take place locally. Thus, a critical – but until recently, missing – element of the global change research agenda is the integrated³ study of global change in local places (Kates and Torrie, 1998; Wilbanks and Kates, 1999).

It is the assertion of this essay that to develop sustainable communities and a sustainable Earth, it is essential to monitor global change in local places. Why is it important to conduct such monitoring?⁴ The many sustainability indicator projects underway demonstrate that monitoring helps communities gauge their progress towards (or regression away from) sustainability (e.g., Farrell and Hart 1998). Monitoring shows which ideas are improving the local human-environment dynamic; it points to areas of strength and weakness in local human-environment relations. It identifies emerging vulnerabilities to nature or abuses of nature and how fast they are developing. Moreover, if monitoring detects the source of the vulnerability or abuse, it may suggest ways to diminish or eliminate the problem. Importantly, monitoring enables a community to set goals and to determine how far it is from reaching those goals.

² Tip O’Neill was Speaker of the House of the United States Congress, 1977-1987. His most famous quote was, “all politics is local.”

³ By integrated, I mean studies that include the dynamic interaction of biophysical and socioeconomic processes contributing to global change. Necessarily, such studies require both biophysical and social scientists.

⁴ In this context, monitoring is the act of observing, recording, or keeping track of something in order to set a baseline and to establish variations around that baseline over time.

Scientists should monitor global change for similar reasons. At all human levels – international, national, local – monitoring would help gauge progress on mitigating and adapting to global change. Monitoring would tell scientists what adaptation and mitigation strategies are working and which ones are not working. It would identify when and where global change problems are developing and would suggest how urgently society should address the problems. It would enable international bodies, nations, and communities to set goals and measure advancement towards those goals.

Unfortunately, today’s global change monitoring efforts emphasize the global scale. They tend to be disjointed and piecemeal, especially at local scales. I believe that the Sustainability Geoscope provides an opportunity to promote a coordinated monitoring effort that focuses on global change in local places. It affords the scientific community the chance to implement the infrastructure needed to support effective global change monitoring. What should that infrastructure look like?

The Intergovernmental Panel on Climate Change (IPCC) provides one model of the infrastructure needed to monitor global change – in this case, climate change (*e.g.*, Houghton *et al.*, 2001; McCarthy *et al.*, 2001; Metz *et al.*, 2001). There are problems with this model, however. First, the IPCC provides five-year snapshots of the state of the climate and related environment, but tracks few clearly defined indicators of climate change and even fewer indicators of climate change impacts. Instead, the process relies on a larger suite of unique case studies; in fact, the main job of IPCC scientists is to synthesize diverse case studies and to judge subjectively what they mean *in toto*. The IPCC process does a better job of tracking the socioeconomic activities that cause climate change because national databases of socioeconomic activity tend to be superior to natural science and human-environment databases. Second, the

IPCC focuses on global and continental scales—not on the community scale where people ultimately cause, experience, and respond to climate change. Third, IPCC scientists communicate while compiling the five-year reports, but most agree that communications are slow, cumbersome, and influenced by international politics. Finally, although scientists form formal networks to conduct an IPCC assessment, these networks disperse after each assessment, with scientists going back to their institutions to re-engage in research and with governments reforming the networks with new people and ideas for the next assessment. There is no mechanism to maintain an ongoing network of researchers joined by common interests, collaborating in real time, and free from political constraints.

Thus, science needs an alternative model of the infrastructure to monitor global change. That model must enable scientists to monitor the ongoing causes and consequences of environmental change across a continuum of scales, including – and with special emphasis on – the local scale. It must facilitate convenient real-time sharing of data, analyses, and ideas among scientists working in regions and locales around the planet. It must foster a sense of community, purpose, and intellectual freedom among scientists who study global change and who share the goal of local and, consequently, global sustainability.

One important aspect of this envisioned infrastructure is the development of research protocols⁵ and data standards for scientists working on global change in local places. Such protocols should be flexible, accommodating a broad spectrum of potential users from diverse geographic areas with varying resources and training (Tran and Wu, 2001). The protocols should be dynamic, incorporating new technologies, methodologies, models, data, and intellectual paradigms over time. They should be standardized so that comparisons are possible,

⁵ Research protocols are guidelines that specify how a research process should work or how scientists should apply a methodology or suite of methodologies to a particular problem.

showing how processes influencing global change vary over space and time. In addition, global change research protocols should balance data (*e.g.*, quantitative versus qualitative), models (*e.g.*, deterministic versus stochastic), and scope (*e.g.*, multiple spatial and temporal scales). Clearly, there is a tension among the competing concepts of flexibility, dynamism, standardization, and balance, making the development of research protocols for monitoring global change in local places a non-trivial task.

While protocols have been slow to develop, there has been significant progress on international and national data standards, especially in the realm of geospatial data. Most of these efforts involve governments at international or national levels, such as the European Committee for Standardization (CEN, 2002) or the United States Federal Geographic Data Committee (2002). Taking the lead on geospatial standards for industry, the Open GIS Consortium (OGC) aims at increasing the interoperability of hardware and software involving spatial information and location – that is, OGC facilitates communication among geographic information systems, vendor brands, data sources, and computing platforms (OGC, 2002). Its members include public and private companies, universities, government agencies, and other organizations interested in building geospatial interoperability. Notably, OGC is sponsoring a pilot project to demonstrate how geospatial information standards can enhance sustainable development efforts and to show why such standards are critical at the local level. This pilot is just the beginning – science must go much farther to scale data standards from the global and national levels to the community level. In short, the efforts of governments and industry reduce the need to develop data standards for global change monitoring, providing clear guidelines for data storage.

Understanding global change in local places cannot happen in isolation. Scientists who monitor this problem must share their data, methods, and ideas so that they can build a picture that helps them know which characteristics are local, which are regional, and which are truly global. The World Wide Web has made it possible for scientists around the world to know what other scientists are doing. Yet, even if updated daily, today's Web sites are static and neither promote the intellectual interchange nor capture the excitement of dynamic communication. A collaboratory⁶ uses the interconnectivity of the Web to link scientists in near-real time, if not real time (MacEachren, 2000, 2001). The concept of the collaboratory goes beyond email and instant messaging to include such novel dimensions as Web-based video conferencing, electronic Delphi tools, shared notebooks and databases, and interactive maps and graphs. Pilot collaboratories are being developed around the world, but none have realized their potential because of technical and security issues. Only one, described in the next section, focuses on global change.

Finally, an essential part of infrastructure developed to study and monitor global change in local places is a network of scientists who will adopt research protocols and data standards and who will engage each other in the collaboratory. There are already hundreds of local-area research and monitoring sites around the world that focus on environmental change and issues of sustainability; only a few sites concentrate on global change in local places. In all cases, however, these sites function independently, collecting unique data in unique ways, thus guaranteeing that cross-site comparison is impossible now and in the future. Scientists working at these sites sometimes are aware of the work of colleagues at other research and monitoring sites through Web searches, published papers, and conferences, but often they are unaware of similar efforts. It is critical, therefore, that an international network of researchers develops so

⁶ A collaboratory is a Web-based environment aimed at fostering remote collaboration among scientists.

that science has a consistent, verifiable, and comparable record of global change in local places over time and over space.

3. The HERO project

The goal of the Human-Environment Regional Observatory project (HERO, 2002) is to develop the infrastructure needed to understand and monitor global change in local places. To reach that goal, the project has four strategies. First, HERO is developing research protocols and data standards for collecting human-environment data that will facilitate the studying and monitoring of global change at individual sites and that will enable cross-site comparisons and generalizations. Second, HERO is building a collaboratory that will help investigators share data, analyses, and thoughts from remote locations. Third, HERO is testing these ideas by applying the protocols, standards, and networking environment at four proof-of-concept research sites. Fourth, HERO is trying to organize a network of researchers who are investigating global change in local places and who will use the HERO infrastructure.

The research design comes directly from the strategies outlined above and has three components. The first component is the Web-based HERO intelligent networking environment (HEROINE, located at Penn State University), which has two ongoing tasks. The first is to develop strategies for handling the heterogeneous quantitative and qualitative, biophysical and socioeconomic data generated in local human-environment research. The second is to build a collaboratory where researchers from around the world can share data, can analyze, visualize, and compare those data, and can interact with one another while working at their personal

computers. Approaches currently being developed and tested in the HERO collaboratory include an electronic notebook for posting data of any type (*e.g.*, numbers, words, audio, video) and of any format at a central repository for instant access by all researchers in the network, no matter where they are located. Another is an electronic Delphi tool designed to support remote group decision-making and consensus-building through an anonymous, iterative process. A third approach is Web-based video conferencing so that collaborators can interact by seeing and hearing each other, as well as watching each other's PowerPoint presentations, on their laptop computers.

The second component of the HERO research design consists of proof-of-concept testing. To provide a real-world context for development of the infrastructure, the project is focusing on the question, "How does changing land use affect the vulnerability of people and places to climate variation and change?" HERO is addressing this question at four HERO proof-of-concept testing sites (HEROs) in diverse biophysical and socioeconomic settings. The four HEROs include sites in central Massachusetts (Clark University), central Pennsylvania (Penn State University), southwestern Kansas (Kansas State University), and the United States-Mexico border region (University of Arizona). Researchers from these HEROs are collecting data using the same protocols, storing and sharing their data using the same data standards, and interacting through the HERO collaboratory. A vital part of this interaction involves using the collaboratory to develop the protocols and standards and to improve tools through group interaction.

For the third component of the research design, HERO is striving to build a network of researchers working on the local dimensions of environmental change and sustainability. As a starting point, HERO has developed formal relationships with three consortia of human-environment researchers. One is the international Land Use/Land Cover Change Programme

(LUCC, 2002), an element of the International Human Dimensions Programme (IHDP) and the International Geosphere-Biosphere Programme (IGBP). The second consortium involves the social science component of the United States Long Term Ecological Research Network (LTER, 2002), which is being added to the network's ongoing biophysical research and monitoring. The third is the Sustainability Geoscope (2002). HERO is attempting to link these and other research and monitoring networks through its infrastructure and, iteratively, to work with these sites to develop infrastructure that meets their needs.

4. Conclusions

This essay proposed that a fundamental component of the Sustainability Geoscope is the monitoring of global change in local places. It also argued that successful monitoring of diverse places across the globe requires a specific infrastructure. Scientists working on global change in local places need an infrastructure that provides protocols and data standards for their human-environment research, that supports a collaboratory for sharing data, analyses, and ideas, and that sustains a network of colleagues sharing in this important research enterprise. The essay also described the HERO project, which is trying to build infrastructure for the global change in local places research community. In the end, this vision of infrastructure for the Sustainability Geoscope facilitates the monitoring of the anthropocene – the period of inseparability of nature and society – at all spatial scales, from the global to the local.

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