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Assessing vulnerability to global environmental risks

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The last several years have witnessed a significant evolution in what society wants to know about global environmental risks such as climate change, ozone depletion, and biodiversity loss. Until recently, most scientific assessments of such risks focused on the anatomy of conceivable environmental changes themselves, while devoting relatively little attention to the ecosystems and societies the changes might endanger.[i] Recently, however, questions about the *vulnerability* of social and ecological systems are emerging as a central focus of policy-driven assessments of global environmental risks in arenas as different as the ongoing work of the Intergovernmental Panel on Climate Change (IPCC), the World Economic Forum, and the World Food Programme.[ii]

Initial efforts to shape a useful understanding of vulnerability to global change have found the task difficult, hampered by conflicting conceptual frameworks, unconsolidated data, and inadequate models.[iii] Scholarly research on vulnerability has nonetheless begun to mature and produce cumulative results that are potentially relevant.[iv] Unfortunately, the communities of decision-oriented vulnerability assessors for global environmental change issues, research-oriented vulnerability scholars generally focusing on regional scale human-environment interactions, and those conducting vulnerability assessments that assist in targeting improved intervention and mitigation strategies[v] have operated largely independently. We report here on a recent effort to integrate the insights and experiences of these communities.[vi] This paper presents ideas emerging from the first iteration of what has become an ongoing conversation between the assessment and research communities, and sketches an integrated framework for vulnerability-based assessments of climate and other global changes. By virtue of both concept and design this framework has the potential to improve significantly the production of policy-relevant insights into the social and environmental implications of global environmental change.

Vulnerability assessment differs from traditional approaches to impact assessment in a number of important ways. In essence, impact assessment selects a particular environmental stress of concern (e.g. climate change, a large dam, a new fishing technology) and seeks to identify its most important consequences for a variety of social or ecosystem properties.[vii] Vulnerability assessment, in contrast, selects a particular group or unit of concern (e.g. landless farmers, boreal forest ecosystems, coastal communities) and seeks to determine the risk of specific adverse outcomes for that unit in the face of a variety of stresses and identifies a range of factors that may reduce response capacity and adaptation to stressors. In principle, the same global change phenomena could be assessed from both perspectives. In practice, impact studies have been most helpful where they have been able to focus on a single stress that dominates system response. Policy dialogs and scholarship are increasingly suggesting, however, that some of the greatest

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challenges arising from the interactions between human development and the global environment entail complex system responses to multiple and interacting stresses originating in both the social and environmental realms.[viii] Conventional impact assessment practices have been relatively unhelpful in addressing such challenges, primarily because they provide little strategic guidance on which of these multiple stresses a given analysis should consider. Vulnerability assessment offers a maturing strategy to provide such guidance.

Vulnerability to global environmental change has been conceptualized as the risk of adverse outcomes to receptors or exposure units (human groups, ecosystems, and communities) in the face of relevant changes in climate, other environmental variables, and social conditions. Effective vulnerability assessments recognize that the selection of appropriate receptor or exposure units is of the utmost importance, and needs to reflect both the policy- or decision-defined needs and science-defined understanding of relevant causal relationships and forcing functions. Seldom will a single exposure unit suffice; it is important to ensure that the full range and diversity of exposure units be explicitly addressed.

Vulnerability is emerging as a multidimensional concept involving at least exposure – the degree to which a human group or ecosystem comes into contact with particular stresses; sensitivity – the degree to which an exposure unit is affected by exposure to any set of stresses; and resilience – the ability of the exposure unit to resist or recover from the damage associated with the convergence of multiple stresses. The concepts of preparedness, coping reserve, and adaptive capacity are clearly important – but as yet under-theorized – underlying determinants of the sensitivity and resilience of an exposure unit. Vulnerability can increase through cumulative events or when multiple stresses weaken the ability of a human group or ecosystem to buffer itself against future adverse events, often through the reduction in coping resources and adaptive capacities.[ix] Scholarship tracing the "causal chains" of vulnerability has begun to significantly deepen the understanding of how different components of vulnerability arise, how overall causal structure and systems of vulnerability may be characterized, and what reducing vulnerability and thereby increasing security may entail.[x]

Due to its explicit focus on exposure units, vulnerability is an inherently scale-dependent property of systems. For example, it makes sense to speak of the vulnerability of both a nation's and a community's food systems in the face of climate change. These two scales may nonetheless be characterized by different concerns about outcomes and different causal structures of vulnerability. Community-level stakeholders might focus on how climate change could alter their risk of experiencing (local) hunger, whereas national decision makers might focus on whether such changes could affect (national) economic product or import requirements. These risks are clearly related and assessments of interactions across scales can be important for tracing causal chains of vulnerability. Local vulnerabilities, moreover, cannot be simply "summed" to give meaningful national or global vulnerability estimates. Conversely, low vulnerability at higher levels of organization cannot be taken to indicate low vulnerability for all embedded localities.[xi] This scale-dependence of vulnerability suggests that much of importance for societies' efforts to cope with global environmental change will be missed by assessments focused on a narrow range of scales. In particular, it suggests that strategies for reducing vulnerability to global environmental change will require assessments that go beyond the global or continental analyses adopted for pragmatic reasons in most contemporary work.

How can future assessments of vulnerability determine the scales of exposure units that they most need to address? Answers will have to emerge from a deepened understanding of the scales at which interactions between environment and society become particularly intense and problematical. Recent empirical and conceptual work identifying the scales of "critical zones" and "degradation syndromes" suggests how this task might be approached.[xii] A second consideration in selecting the scale of exposure units for vulnerability assessment is more overtly social, shaped by the institutional arrangements through which decisions for responding to environmental risks are deliberated and implemented. Recent trends towards increased "stakeholder participation" have begun to broaden the focus of global environmental assessments beyond their traditional preoccupation with the needs of international negotiators and national policy makers. However, no inherently superior scale of exposure unit or vulnerability analysis has emerged. It nonetheless appears that many, if not most, useful vulnerability assessments will need to address multiple stresses that interact across a variety scales. This will almost certainly require the development of distributed assessment systems similar in structure to the networks and nested institutions that have evolved to link global research and local decision making in the fields of health and agriculture.[xiii]

A final insight emerging from our juxtaposition of research- and assessment-based perspectives on vulnerability concerns the role of scenarios. Global environmental assessments generally have been performed by specifying several scenarios of plausible futures for a particular global environmental stress and then investigating selected impacts of that stress. Such approaches, carefully executed, have many merits.[xiv] They have had difficulty, however, in dealing with multiple interacting stresses and critical thresholds beyond which the risks associated with global change might rapidly escalate. Here the "inverse" approach of vulnerability analysis shows promise of being particularly useful.[xv] For the exposure unit considered, potential outcomes are classified either as acceptable or adverse. The assessment then focuses on determining the dynamic combination of environmental and social stresses that could significantly enhance the likelihood of adverse outcomes.[xvi] Conceived in this way, vulnerability analysis can address multiple causes of critical outcomes (e.g. dislocation, hunger, HIV/AIDS, conflict) rather than only the multiple outcomes of a single event.[xvii] This in turn leads naturally to an evaluation of alternative mitigation and adaptation strategies that could help to avoid such dangerous combinations. Scenarios tying these pieces of the story together become the central output of the vulnerability assessment rather than a peripheral input. Such vulnerability scenarios tend to have a richer texture than conventional impact or hazard type assessments with more coherent story-lines, greater regional and sectoral specificity, and deeper causal complexity, including variables that characterize human and social systems. They can be generated in a number of ways, including iterative dialogues including experts, stakeholders and facilitators.[xviii] Experience suggests that scenario-generating processes can become vehicles for learning and can encourage assessment participants to create (and to consider legitimate) scenarios that include the full range of values of importance.[xix]

The current states of vulnerability research and vulnerability assessment exhibit both a potential for substantial synergy in addressing global environmental risks, as well as significant weaknesses which undermine that potential. A substantial base of fundamental knowledge has been created. But it is highly fragmentary in nature, with competing paradigms, conflicting theory, empirical results often idiosyncratic and tied to particular approaches, and a lack of comparative analyses and findings. This is not surprising given that research has been almost entirely curiosity-driven, geographically scattered, and inadequately funded. Assessment efforts have increasingly identified vulnerability as a central concern of decision-makers and other interested parties at all

levels of governance. But the politically driven circumstances and short time frames that increasingly characterize global environmental assessments have provided few opportunities for identifying and utilizing the new concepts, methods and data arising from this scholarly research.

Meeting the growing demand for a deeper and more useful understanding of vulnerability to global change will require a dual strategy in which initiatives targeted on immediate assessment needs and research opportunities complement and feed into a longer term program for enhancing relevant knowledge bases, assessment practices, and institutional capacities. The design of such a strategy merits a broad and deliberate discussion. However, the initial workshop upon which this note is based, recommended early and parallel efforts including:

- Initiating a Task Force on Vulnerability Research that drafts a "White Paper" on the state-of-the-art of relevant research, begins to shape a common conceptual framework for interdisciplinary vulnerability analysis[xx] and provides guidance on the design of a geographically dispersed ensemble of place-based assessments that reflect the global problematique;[xxi]
- Developing a suite of stylized integrated assessment models that suit the conceptual framework noted above and can be refined into dynamic stochastic vulnerability models for specific exposure units;
- Reanalyzing relevant parts of the large inventory of previous case studies on ecological and social vulnerability in order to feed and test novel multi-factor approaches like the degradation syndromes concept;
- Conducting and critically evaluating "flagship experiments" in state-of-the-art vulnerability assessment, building upon ongoing assessment processes[xxii] and evaluating "success cases" that may point to improved ways of enhancing capacities and improved mitigation to reduce current and future vulnerabilities to risks and increased stress;
- Launching a capacity-building effort by which vulnerability scholars, assessors, and participants, such as local decision-makers, stakeholders and lay citizens, are networked and placed in continuing dialogue, with special attention to engaging developing countries that often are those most vulnerable.

Full realization of such a strategy could require a decade or more of sustained effort, supported with a level of attention and funding similar to that which was committed to understanding the causes and nature of global environmental change beginning in the mid-1980s. This is an ambitious objective, but one that could hardly be more needed or timely as we contemplate the evolution of global change research and assessment programs into the 21st century.

***Footnote, page 1**

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Endnotes

[i] Social Learning Group. *Learning to Manage Global Environmental Risks:* (MIT Press, Cambridge, 2001). Charles Herrick and Daniel Sarewitz. 2000. *Science, Technology, & Human Values* **25**(3):309 (2000).

[ii]The IPCC employs vulnerability as a central organizing concept for the Working Group II contribution to the IPCC's third assessment report, *Climate Change: Impacts, Adaptation and Vulnerability* < http://www.usgcrp.gov/ipcc/>; World Economic Forum, *Pilot Environmental Sustainability Index* < http://www.ciesin.org/indicators/ESI/ESI.pdf>; World Food Programme, *WFP Vulnerability Analysis and Mapping* < http://www.wfp.it/vam/vamhome.htm>

[iii] The assessment process for climate change has evolved over time to include consideration of vulnerability. The initial mandate of the Intergovernmental Panel on Climate Change (IPCC) in 1988 was to assess the state of knowledge of natural and anthropogenically induced climate change, its impacts on natural and social systems and the potential of options for mitigation that would diminish adverse impacts. Based upon its assessment of impacts, the IPCC identified from climate change acting in combination with other stresses, though vulnerability was human settlements, populations, regions, and sectors thought to be most vulnerable to harm not a focus of the assessment. See IPCC, *Policymaker's Summary of Working Group II, Impacts Assessment of Climate Change* (Australian Government Publishing Service, 1990). The second IPCC assessment (R. Watson et al., *Climate Change 1995: Impacts, Adaptations and Mitigation of Climate Change*, Cambridge University Press, 1996) was expanded to include adaptation to climate change. For this second assessment, Working Group II of the IPCC focused on the sensitivity, adaptability, and vulnerability of systems to a range of climate changes as an approach to provide useful information to decision makers given the uncertainties regarding regional scale climate change (Watson, et al., *Preface to Climate Change 1995: Impacts, Adaptations and Mitigation of Climate Change*, Cambridge University Press, 1996). However, the published literature on climate change adaptation and vulnerability was insufficient then to allow a satisfactory development of this component of the assessment (see R. Kates, *Environment* **39(9)**, 29, 1997). In the IPCC's special report, *The Regional Impacts of Climate Change: An Assessment of Vulnerability* (Watson et al., Cambridge University Press, 1998), vulnerability of natural and social systems was again a key focus, though the literature on vulnerability remained thin relative to that on impacts of climate change. Building on the growing emphasis on vulnerability, the mandate of the third IPCC assessment (2001) calls for assessment of vulnerability to climate change in the larger context of other global change stresses. Similarly, the recent U.S. National Assessment of the Potential Consequences of Climate Variability and Change seeks to "understand the vulnerabilities and opportunities resulting from climate change and variability for the United States, its people, its environment and economy..." (http://www.nacc.usgcrp.gov/). But while the most recent IPCC and U.S. National assessments were intended to assess vulnerability, our own experience (one of us co-chairs IPCC WG2, another played a central role in the US National Assessment) reflects the general consensus of participants that it proved extremely difficult for them to implement a vulnerability framework in a comprehensive way.

[iv] J. Ribot, *GeoJournal* **35(2)**:119; C. Vogel, *LUCC Newsletter* **3**, 15 (1999) http://www.uni-bonn.de/ ihdp/lucc/publications/ luccnews/news3/coleen.html; S. Cutter, *Prog. Human Geography* **20(4)**, 529 (1996); T. Downing et al., *Climate Change Vulnerability: Toward a Framework for Understanding Adaptability to Climate Change* (Environmental Change Unit, University of Oxford, Oxford, 2000).

[v] For example, the Famine Early Warning System and the World Food Programme.

[vi] The authors participated in the workshop on "Vulnerability to global environmental change: Challenges for research, assessment and decision making," held at Airlie House in Warrenton, Virginia from May 22-25, 2000. Participants were drawn from the natural science, social science, assessments, and decision making communities. In particular, the workshop brought together individuals involved in the Intergovernmental Panel on Climate Change's Working Group on Impacts, Adaptation and Vulnerability, the US National Assessment on the Potential Consequences of Climate Variability and Change, the International Human Dimensions of Global Environmental Change's Task Force on Vulnerability, and the Global Environmental Assessment Project.

[vii] The methodology of impact assessment as applied to climate change is described in T. Carter et al., *IPCC Technical Guidelines for Assessing Climate Change Impacts and Adaptations* (University College, London and Centre for Global Environmental Research, Japan, 1994) and in J. Feenstra et al., *Handbook on Methods for Climate Change Impact Assessment and Adaptation Strategies* (United Nations Environment Programme, Kenya and Institute for Environmental Studies, The Netherlands, 1998).

[viii] For example, these may simultaneously include such factors as changes in land use condition, demography, economic conditions. See National Research Council, *Our Common Journey: A Transition Toward Sustainability* (National Academy Press, Washington, 1999); WBGU (German Advisory Council on Global Change), *World in transition: The research challenge*. Annual Report 1996. (Springer-Verlag, Berlin, 1997; http://www.awi-bremerhaven.de/WBGU). The IPCC special report *The Regional Impacts of Climate Change* (R. Watson et al., 1998) found that, while vulnerability of global food supply to climate change is low, some regions, particularly in the tropics and subtropics, are vulnerable to increased risk of hunger as a consequence of climate change. The report also found considerable variation in vulnerability across regions at sub-continental scales.

[ix] See, for example, L. Comfort et al., *Environmental Hazards* **1**: 39 (1999).

[x] See, for example, Ribot (note 4 above) and G.E. Clark et al., *Mitigation and adaptation Strategies for Global Change* **3**:59 (1998).

[xi] For an overview of the implications of scale in the assessment and management of global environmental change see D.W. Cash and S.C. Moser, *Global Environmental Change* **10**(2): in press (2000).

[xii] R. Kasperson et al., Eds. *Regions at Risk: Comparisons of Threatened Environments.* (United Nations University, Tokyo, 1995); H-J. Schellnhuber et al., *GAIA* **6(2)**, 19 (1997); M. Ludeke et al. in *Indicators of Sustainable Development* B. Moldan et al., Eds. (Wiley and Sons, London, 1997), pp. 96-98.

[xiii] See Chapter 6 in NRC (Note 8, above); Carnegie Commission on Science, Technology and Government, *International Environmental Research and Assessment: Proposals for Better Organization and Decision Making* (Carnegie Commission, New York, 1992); D. Bell et al., in *Agriculture, environment and health: Sustainable development in the 21st Century*, V, Ruttan, Ed..(University of Minnesota Press, Minneapolis, 1994), pp. 358-379; Cash D.W. "Distributed assessment systems: an emerging paradigm of research, assessment and decision-making for environmental change". *Global Environmental Change* (forthcoming). H.J. Schellnhuber et al., *GAIA* **6** (2): 19 (1997); G. Petschel-Held et al., *Environmental Modeling and Assessment* **4**(4): 295 (1999).

[xiv] See Chapter 3 in NRC (Note 8 above).

[xv] Within the context of climate change, an inverse vulnerability concept is adopted, for example, by the "tolerable windows approach". See for instance, T. Bruckner et al., *Environmental Modeling and Assessment* **4**(4): 217 (1999).

[xvi] It is increasingly recognized that analysis of impacts of environmental change, as well as vulnerability to environmental change, requires development of scenarios of the future that include consideration of not just the environmental stress that may be the primary subject of the investigation, but also encompass other factors that will influence impacts and vulnerability. For example, T. Carter et al., *Preliminary Guidance Material on the Use of Scenario Data for Climate Impact and Adaptation Assessment* (IPCC Task Group on Scenarios for Climate Impact Assessment, 1998), describes methods for the development of scenarios of future social, economic and environmental conditions that can be expected to add to or ameliorate stresses that may interact with climate change, or that would influence adaptive capacity.

[xvii] J. Ribot, *GeoJournal*, **35**(2): 119 (1995); Downing, T., *Assessing socioeconomic vulnerability to famine: Frameworks, concepts and applications* (Final Report to the US Agency for International Development, Famine Early Warning System Project, January, 1991); S. Davies, *Adaptable Livelihoods: Strategic Adaptation to Food Insecurity in the Malian Sahel* (Basingstoke, UK, Macmillan, 1996).

[xviii] Future scenario-generating exercises will be constructing subregional narratives, but downscaling will continue to be a significant technical challenge; it is expected that expert judgment will be needed to complement scenario exercises with impacts models; this will have to be a continuous process building towards a shared sense of ownership in how vulnerability is defined and assessed. See, for example, D.S. Rothman and J. Robinson, *Environmental Monitoring and Assessment* **4**: 23 (1997). Such "scenario workshops" have been used successfully by some European parliamentary technology assessment offices on issues such as sustainability. For overviews, see Simon Joss in

Norman J. Vig and Herbert Paschen, eds., *Parliaments and Technology: The Development of Technology Assessment in Europe* (Albany: SUNY Press, 2000), pp. 325-62; and Richard E. Sclove. 1999. "The democratic politics of technology: the missing half." The Loka Institute. <http://www.loka.org/idt/intro.htm>.

[xix] There are several approaches available (impacts/adaptation models, scenario games, customized models for scenario games, responses to 'what if' narratives, large periodic assessments); whichever ones are used, there will need to be an institutional structure that would support the assessment tools or provide a forum for these exercises; sustaining the engagement process will require a critical mass of people beyond ad-hoc volunteers. See S.J. Cohen, *Environmental Modeling and Assessment* **2**:281 (1997); S.J. Cohen et al. *Water International* **25**(2): in press (2000).

[xx] Both the US National Research Council and the International Human Dimensions of Global Environmental Change Programme are considering such ventures.

[xxi] The authors benefited from an early discussion draft addressing some of these issues prepared for UNEP by the Environmental Change Unit at the University of Oxford.

[xxii] Candidates include the planned Millennium Ecosystem Assessment, the 4th IPCC assessment, the Arctic Climate Impact Assessment and the hoped-for next round of the US National Assessment of Global Change.