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Vulnerability and resilience: Coalescing or paralleling approaches for sustainability science?

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ABSTRACT

Vulnerability and resilience constitute different but overlapping research themes embraced by sustainability science. As practiced within this science, the two research themes appear to coalesce around one of the foundational pivots of sustainability, the coupled human–environment system. They differ in regard to their attention to two other pivots, environmental services and the tradeoffs of these services with human outcomes. In this essay I briefly review the emergence of sustainability science and the three foundational pivots relevant to vulnerability and resilience. I outline the distinctions and similarities between the two research themes foremost as practiced within sustainability science and especially in regard to the attention given to the three pivots. I conclude with the observation that improvement in the capacity of vulnerability and resilience research to inform sustainability science may hinge on their linkages in addressing tradeoffs.

1. Introduction

Sustainability science has emerged as the intellectual umbrella for addressing human–environment problems and practice arising from those research communities closely aligned with global climate and environment change. These communities, and thus sustainability science, maintain substantial interests in questions of vulnerability and resilience, registered by Working Group II of the Intergovernmental Panel on Climate Change (IPCC) which includes vulnerability (Parry et al., 2007) and the newly minted International Council of Science's Programme on Ecosystem Change and Society (PECS, www.icsu.org/1_icsuinscience/ENVI_-PECS_1.html) which builds on the Millennium Ecosystem Assessment through the resilience lens (Carpenter et al., 2009). Vulnerability and resilience constitute different but overlapping research themes, the shared understanding of which holds the potential to inform sustainability science inasmuch as either is consistent with the thematic foundations of this science. This possibility is explored here in three parts: (i) a brief review the origins of sustainability science and the identification of three foundational pivots—coupled human–environment systems, environmental services, and tradeoffs; (ii) discussion of the distinctions and complementarities between vulnerability and resilience research, especially those parts consistent with normal science, and the linkages each has with the three pivots; and (iii) comments on future integration between vulnerability and resilience research, concluding that attention to tradeoffs may hold the key improved intellectual integration of the two.

2. Sustainability science and three pivots

The emergence of the interdisciplinary science of sustainability was anticipated in the late 1980s with the release of *Sustainable Development of the Biosphere* (Clark and Munn, 1986) by the International Institute of Applied Systems Analysis, and *Our Common Future* (WCED, 1987), the well-known Brundtland Report. Its formal development followed several collaborative pathways over the past quarter-century, each associated with the expansion of research on global climate change to global environmental change (the Earth system) and, ultimately, its human dimensions. These pathways were galvanized by the International Council of Science (ICSU, 2002) subsequent to the "World Congress on Challenges of a Changing Earth 2001" in Amsterdam, sponsored by various global change science programs associated with the Council. The base themes and agendas of sustainability science emerged from various national and related committees, interdisciplinary workshops (e.g., Schellnhuber

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et al., 2004), reports (e.g., Kasemir et al., 2003), and commentaries in major outlets (e.g., Lubchenco, 1998; Raven, 2002) responding to the Council and human impacts on the Earth system. The 1999 release of *Our Common Journey* by the National Academy of Sciences (U.S.; NRC, 1999) and follow-up publications in *Science* (Kates et al., 2001) and the *Proceedings of the National Academy of Sciences* (*PNAS*; Clark and Dickson, 2003) staked out the integrative character of the subfield. By the middle of this past decade, the research on sustainability science was sufficiently robust that the *PNAS* created a new section for it (Clark, 2007), while internationally such journals as *Sustainability Science*, *Sustainability Science and Engineering*, *Journal of Sustainability Science and Management*, *Sustainability: Science, Practice, and Policy*, and *Current Opinion in Environmental Sustainability* emerged to handle the large growth in the array of this research. International programs, such as the Earth System Science Partnership (ESSP, www.essp.org), attempt to keep various formal research initiatives on track toward the types in integration needed to address the questions of sustainability science.

Sustainability science addresses the provisioning of humankind relative to functioning of the Earth system, assessed at different levels down to ecosystems. This focus crosscuts all definitions of sustainability science no matter the other attributes that are variously appended to it, such as the co-production of research problems between science and society or the usefulness of research products for decision-making (e.g., Clark, 2007; Kates et al., 2001; Lubchenco, 1998; Raven, 2002). In principle, co-production and usefulness are applied to a full range of stakeholders (e.g., Reynolds et al., 2007), although it is recognized that the move from theory to practice engages different constituencies that are differentially empowered in the decision-making process.[1] However derived, a sustainable human–environment system is envisioned as provisioning humankind (in amount and distribution; Dasgupta, 2001; Kates and Dasgupta, 2007) without threatening nature's support system (Kates et al., 2001). Viewed thusly, the human and environmental subsystems are intimately linked, and the environment constitutes the subsystem providing services required for the maintenance of humankind, regardless of our awareness of, or the lack economic value placed on, them. These subsystem linkages and environmental services constitute two of the foundational pivots of the science in question.

The coupled human–environment systems or CHES (Turner et al., 2003a,b; also coupled human and natural systems or CHANS [Liu et al., 2007a,b] and social-ecological systems or SES [Berkes et al., 2003]) recognizes the synergy or interdependency of the human and environmental subsystems in determining the condition, function, and response (e.g., to a disturbance, perturbation, or hazard) of either subsystem or that of the system as whole. In vulnerability parlance, for example, the sensitivity of CHES to a disturbance is predicated on that synergy (Turner et al., 2003a,b). Contrary to the implications of some critiques (e.g., Banerjee, 2003; Head, 2007), sustainability science is fully cognizant that treating two interacting subsystems constitutes a social construct. It treats human–environment dynamics this way for the analytical convenience of capturing the different kinds of the processes at work in each subsystem, and out of concern that emphasis on one "interacting" system fosters the danger of reducing the understanding of social dynamics to environmental ones, or vice versa.

[1] The various concepts, approaches, programs, and related politics that ultimately begot sustainability science as well as the formal research programs feeding into it have been critiqued throughout its development, perhaps with more attention to its climate change dimensions (e.g., Bäckstrand, 2003; Banerjee, 2003; Cohen et al., 1998; Demeritt, 2001; Demeritt, 2006; Lélé, 1991; Meppem and Bourke, 1999; Ravetz, 2006) and with surprisingly little response from those being critiqued (but see Schneider, 2001).

Environmental or ecosystem services (also natural capital) are the direct benefits (e.g., resources) and life supporting processes emanating from the environment (Daily, 1997; Daily et al., 2000; Jansson et al., 1994). At the global scale, these services are the product of the Earth system, and at local to regional scales, ecosystems. The Millennium Ecosystem Assessment (MEA, 2005) identifies four categories of services: provisioning (e.g., food, water), regulating (e.g., climate and flood regulation), cultural (e.g., recreation, spiritual places), and supporting (e.g., nutrient cycling, soil formation). What to value is not the question; in principle, all services are in play, and as noted above, the range of views about them should be inclusive. Discussion is on-going among research communities, however, concerning the logic of including the supporting category as a service. Beyond this typological issue lies a more fundamental problem. Some regulating and most supporting services (or the environmental function implied in the last term) have long been taken for granted and are not explicitly valued in most economic and socio-political systems (Daily et al., 2000). How to place economic value on the full array of environmental services (e.g., Ando et al., 1998; Carbone and Smith, 2010) and the discount rate for their loss constitute a major, even divisive, analytical issue. Exemplary are attempts to place value on the Earth system (e.g., Constanza et al., 1997) and the loss of its services with climate change (Stern, 2007) versus the various criticisms of them by resource and environmental economists (e.g., Bockstael et al., 2000; Dasgupta, 2007; Nordhaus, 2007). Perhaps the telling point for this discussion is that the need to place value on these services is linked to assessments of human outcomes, economic or otherwise.

Sustainability science examines the relationships between environmental services and human outcomes, in part to uncover those qualities that make CHES less vulnerable or more resilient to the multitude of forces (i.e., disturbances, stressors, perturbations) acting upon them. The overwhelming majority of contemporary CHES involve societal efforts to expand the limits and reduce the vagaries of nature in attempts to improve provisioning and regulating services and thus the material well-being of people: for example, irrigating crops and applying synthetic fertilizer for increasing food production, burning savanna grasses for new livestock fodder, or impounding water to provision cities, power electricity, provide recreation facilities, and control flooding. Such efforts invariably focus on a few environmental services and human outcomes (e.g., water control-flood protection or food production-security), although the consequences of the activities involved play out through the entire system (e.g., food production-security on albedo and evapotranspiration and climate on water and energy needs). Attempts to improve some services invariably reduce others, while increased material well-being is historically associated with environmental drawdown and the costs of maintaining or substituting for losses in services (MEA, 2005). This realization leads to a third foundational pivot, tradeoffs.

Owing to human activity, CHES axiomatically involve tradeoffs – improvements, maintenance, and loses – among environmental services and between those services and human outcomes. Tradeoffs may be addressed in two ways: by their economic value (Bockstael et al., 2000; Smith, 1996) or by comparison of their physical measure (e.g., amount or change in amount of stratospheric ozone, soil moisture, pollinators, amount of crops produced, number of air conditioned houses, number of households below the poverty line). Economic tradeoff constitutes the more elegant assessment consistent with the use of economic concepts and theory. This approach fails to treat all environmental services, however, especially supporting ones (above), because these services currently have no market value and thus no shadow prices. Comparison of physical measures is less elegant, in principle can treat all environmental services, but has yet to be employed sufficiently to demonstrate its usefulness (but see Bennett et al., 2009; Raudsepp-Hearne et al.,