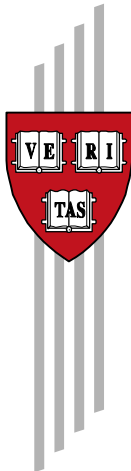


**The Ruffolo Curriculum on  
Sustainability Science  
2008 Edition**

Krister Andersson, Michael Burns, Marcel Bursztyn,  
Adam Douglas Henry, Ann Laudati, Kira Matus, and  
Elizabeth McNie

CID Graduate Student and Research Fellow Working  
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Bursztyn, Adam Douglas Henry, Ann Laudati, Kira Matus,  
Elizabeth McNie, and the President and Fellows of Harvard  
College



# Working Papers

Center for International Development  
at Harvard University

# **The Ruffolo Curriculum on Sustainability Science**

**2008 Edition**

Krister Andersson, Michael Burns, Marcel Bursztyn, Adam Douglas Henry, Ann Laudati, Kira Matus, Elizabeth McNie

## **Abstract**

The growing attention to sustainability science in recent years underscores the need for more clarification on several key questions that inhibit development within the field. Central among these questions are: What is sustainability science, and how is it distinct from sustainable development or other established disciplines that contribute to sustainability science? What are the key research questions, and how does one engage in sustainability science? How do we teach sustainability science? This working paper, presented as a graduate-level curriculum in sustainability science, represents our attempt to answer these questions. We expect this curriculum to grow and evolve as it is applied in different institutional settings, and we invite users to participate in future revisions or use this curriculum as a template for their own needs. The general format of the curriculum includes a theoretical core of sustainability science, defined collectively by narratives and key readings within 11 individual modules. Modules also emphasize applications of the theoretical concepts to practical problems of sustainability; we suggest various applications that may be substituted with preferred applications as needed.

**Keywords:** sustainability science, environment, development, curriculum, social-ecological systems, coupled human-natural systems

**JEL subject codes:** A23, Q01, O13, Q56, Q58

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It is available at <http://www.cid.harvard.edu/cidwp/grad/032.html>. Professor William Clark has approved this paper for inclusion in the working paper series. We welcome users to adapt this curriculum in any way that suits their needs, although when using or referencing the Ruffolo Curriculum we would appreciate the use of the citation. We welcome feedback and contributions to this curriculum. Comments may be directed to the managing editor at [ruffolo\\_curriculum@hks.harvard.edu](mailto:ruffolo_curriculum@hks.harvard.edu). If you would like to receive periodic updates on the Ruffolo Curriculum, please send an email to [majordomo@lists.hmhc.harvard.edu](mailto:majordomo@lists.hmhc.harvard.edu) with the message, "subscribe ruffolo\_curriculum." This is a self-subscribing list; do not include quotes in the body of your message and leave the subject line blank.

The Ruffolo Curriculum is a collaborative effort amongst authors, who are credited on individual modules, and an editorial board that is directly responsible for the overall content and organization of the curriculum. The directors of the Sustainability Science Program act as "publishers," and thus make final decisions on content.

The Sustainability Science Program at Harvard's Center for International Development seeks to advance basic understanding of the dynamics of human-environment systems; to facilitate the design, implementation, and evaluation of practical interventions that promote sustainability in particular places and contexts; and to improve linkages between relevant research and innovation communities on the one hand, and relevant policy and management communities on the other. See <http://www.cid.harvard.edu/sustsci>.

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## **Preface to the Ruffolo Curriculum**

The Ruffolo Curriculum is the product of a seminar organized by research fellows and faculty within the Sustainability Science Program at Harvard University's Center for International Development. This seminar was meant to be a forum for fellows to discuss key research questions within sustainability science and to collectively work to advance the practice of sustainable development—that is, to ensure the long-term well-being of humans without jeopardizing the integrity of ecological systems. Of course, dealing with problems of sustainability requires the synthesis of ideas and methodologies from a wide range of disciplines. We quickly realized that successfully working together depends, first and foremost, on our ability to speak a common language in which to discuss issues of sustainability. This curriculum represents our shared efforts to develop such a language.

We had three main goals in preparing this curriculum. First, this curriculum attempts to define the field of sustainability science by collecting multiple research traditions into a central theoretical core. Our interpretation of this “central core” is reflected in the narratives that appear in each of the eleven modules that comprise the Ruffolo Curriculum. Second, this curriculum demonstrates how one engages in sustainability science by providing applications of the core ideas to practical problems of sustainable development. Although these applications are less well-developed, each module contains at least a few readings that illustrate how the theoretical ideas presented in each module have been applied to real-world problems. Our third goal is to emphasize that sustainability science requires a conception of “knowledge” and “science” that transcends classical boundaries. We argue that sustainability science requires soliciting diverse experiences and world views—thus we encourage teaching sustainability science in a way that reflects this knowledge integration characteristic by encouraging active dialogue and learning.

This curriculum is not meant to be the final word on sustainability science, but is rather a starting point. We therefore expect the Ruffolo Curriculum to grow and evolve as is it applied in different institutional settings, and as we benefit from the input of new talent and fresh ideas. To accomplish this, we plan to reproduce this curriculum on a yearly basis, and to maintain an online library of additional media that may be used as supplemental teaching materials.

The Ruffolo Curriculum is named in honor of Giorgio Ruffolo, Italy's first minister of the environment. In 2007, the Italian Ministry for the Environment, Land, and Sea made a generous gift to the Center for International Development to support the Giorgio Ruffolo Fellowships in Sustainability Science. This fellowship program provides a forum for scholars and practitioners from around the world to advance the field of sustainability science, one result of which was our seminar series and this curriculum project.

# Module 1

## Introduction to Sustainability Science

Adam Douglas Henry

Sustainability science is an emerging field of research that seeks to promote sustainable futures by developing a better understanding of the complex interactions between human and natural systems. The need for a *science* of sustainability is demonstrated by long-standing difficulties in promoting sustainable development—broadly defined as the practice of enhancing human well-being whilst preserving fragile ecological systems. The concept of “sustainability” as a policy goal has influenced the official policy agendas of governance institutions at multiple scales, and yet there is no broad consensus on the best way to meet this challenge. A strategy to achieve the seemingly conflicting goals of sustainability and development must be grounded in a better understanding of the relationships between coupled social and ecological systems. The central purpose of sustainability science is to use rigorous scientific methods to better understand these relationships, but with the underlying normative purpose of promoting a sustainable future.

To accomplish this goal, sustainability science must borrow theoretical concepts and methodologies from a wide range of established fields. Despite this, sustainability science is more than the sum of its disciplinary parts. But if sustainability science is *not* merely a collection of established research programs related to human-environment interactions, then what is it? How does one actually engage in sustainability science? Perhaps the best place to begin is with the core research questions—a scientific field, after all, is defined largely by the puzzles it seeks to explain. One representative instantiation of these core questions is reported in Kates *et al.* (2001), and includes seven broad queries and scientific challenges ranging from the identification of tipping points at which ecological systems face a significantly increased risk of degradation (Kates *et al.*, core question #4) to the delineation of incentive structures that can promote more sustainable human-environment interactions (Kates *et al.*, core question #5).

Further scholarship has refined and complemented these questions, and we move closer to a comprehensive list of puzzles to address in sustainability science. Core research questions such as those proposed by Clark, Crutzen, and Schellnhuber (2004) lend more clarity to the structure of a future research program by focusing on four basic types of queries: analytical, operational, normative, and strategic. Although these questions are generally more specific than those of Kates *et al.* (2001), they still present daunting methodological challenges (e.g., “How are abrupt and extreme events processed through nature-society interactions?”—an analytical question) and questions whose answer is highly dependent on location and context (e.g., “What is the structure of an effective and efficient system of global environment and development institutions?”—a strategic question).

All of the core questions that have been proposed in sustainability science belie a rich and complex landscape of inquiry within individual fields. Tackling any of these

puzzles will require a great deal of prior “micro-questioning,” and will likely involve research efforts that transcend multiple disciplines and employ multiple methodologies. The overarching purpose of this curriculum is to provide guidance on how one can make a practical start in sustainability science by outlining a set of knowledge with which all sustainability scientists should be familiar.

We introduce sustainability science by focusing first on characteristics that we believe collectively define the field. These characteristics are interwoven throughout the individual modules, and each carry implications for the way in which various disciplinary perspectives are employed within sustainability science.

### ***Sustainability science is problem-driven***

Sustainability science emerged from the recognition that we face severe problems of ecological degradation and human poverty, and that these problems are inextricably related. This implies that normative goals and questions play a prominent role in sustainability science, since at some point we are required to make judgments regarding the problems to be solved and the tradeoffs that we are willing to make in solving these problems.

But while the issue of *which problems we are going to study* is a normative question, *how we study them* is a positive question. Because of the critical importance of these normative concerns in sustainability science, the best strategy is to explicitly address the normative component of our research questions rather than assume them away or work to build an artificial separation between the positive and normative aspect of scientific research. We do this by immersing sustainability science in a pool of competing values, rather than avoiding values.

### ***Sustainability science focuses on the interactions between human and natural systems***

Although sustainability science draws upon many different research traditions, we focus in particular on how those research traditions help to understand the complex *intersections* between social and ecological systems. Focused study of individual systems (e.g., social or ecological) is certainly important, but that is left to other fields of inquiry.

This means that sustainability science faces the particularly difficult problem of creating a common language between scholars who have traditionally studied social systems and scholars who have traditionally studied ecological systems.

### ***Building a science of sustainability requires integrating multiple forms of knowledge***

In addition to building a common language between scholars of natural and social systems, a major goal of sustainability science is to build dialogue and collaboration across different sectors of the knowledge enterprise, such as academics, practitioners in the field, and local stakeholder groups. Sustainability science must also accommodate multiple knowledge systems, from local traditional knowledge to standard reductionist “scientific” knowledge, even though these systems are traditionally at odds with each other.

### Study Questions

- 1) What distinguishes sustainability science from sustainable development? What defines the *science* portion of sustainability science?
- 2) Why are cross-scale perspectives important to sustainability science?
- 3) How do we engage in sustainability science? How do we work at the boundary between practice and theory?

### Key Readings

Liu, J., T. Dietz, S. R. Carpenter, M. Alberti, C. Folke, E. Moran, A. N. Pell, P. Deadman, T. Kratz, J. Lubchenco, E. Ostrom, Z. Ouyang, W. Provencher, C. L. Redman, S. H. Schneider, and W. W. Taylor (2007). "Complexity of Coupled Human and Natural Systems." *Science* 317(5844): 1513–1516.

Kates, R. W., W. C. Clark, R. Corell, J. M. Hall, C. C. Jaeger, I. Lowe, J. J. McCarthy, H. J. Schellnhuber, B. Bolin, N. M. Dickson, S. Faucheux, G. C. Gallopin, A. Grüber, B. Huntley, J. Jäger, N. S. Jodha, R. E. Kasperson, A. Mabogunje, P. Matson, H. Mooney, B. Moore III, T. O’Riordan, and U. Svedlin (2001). "Sustainability Science." *Science* 292: 641–642.

### Application Readings: Giant Panda Conservation

Liu, J., M. Linderman, Z. Ouyang, L. An, J. Yang, and H. Zhang (2001). "Ecological Degradation in Protected Areas: The Case of Wolong Nature Reserve for Giant Pandas." *Science* 292: 98–101.

Liu J., Z. Ouyang, W. W. Taylor, R. Groop, Y. Tan, and H. Zhang. "A Framework for Evaluating the Effects of Human Factors on Wildlife Habitat: the Case of Giant Pandas." *Conservation Biology* 13(6): 1360–1370.

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Clark, W. C. (2007) “Sustainability Science: A Room of Its Own.” *Proceedings of the National Academy of Sciences* 104(6): 1737–1738.

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## **Module 2**

### **Values and Principles in Sustainability Science**

**Marcel Bursztyn  
Krister Andersson  
Adam Douglas Henry**

Since the 1972 Stockholm UN Conference on Human Environment many events occurred and blueprints have been produced stating values and principles understood to be basic to sustainability. In the 1970s environmental values were influenced by the search for better life quality in developed countries. The situation now is very different, however—the whole world must be involved. But in a diverse and unequal world, where a wide range of lifestyles and cultural standards co-exist, the perceptions and willingness to change vary greatly from one society to the next. In spite of a general concern over negative global environmental change, there are widely different views over the correct set of priorities and distribution of responsibilities. Values and beliefs guide these positions.

#### **Values and sustainability**

One of humanity's great contemporary challenges is to agree on a set of foundational values that are congruent with a desired direction of societal change. This does not mean that these foundational values need to be identical—these values are going to look very different in varied cultural and historical contexts—but it does mean that these foundational values must be compatible with each other and compatible with the goal of supporting a sustainability transition.

The discourses of national leaders often seem congruent with a unified and harmonized strategy for a transition toward sustainability. This is evidenced by global environmental treaties, speeches in global forums, and the UN Charter on Human Rights. Despite this, however, actual flows of resources and actions on the ground bear witness to discrepancies between those values that are openly declared and the values that actually determine actions

The study of values, despite its apparent intangibility, has practical implications for short-term policy decisions. Most tools for decision making (such as benefit-cost analysis) require many value-based judgments, such as the definition of how future benefits will be valued. In the area of climate change policy, for example, the so-called “Stern Report” stirred up controversy when it applied an unconventionally low discount rate of 0.1 percent, implying that future generations' well-being is just as important as our own today. Other economists, such as William Nordhaus and Partha Dasgupta, have argued that a higher discount rate would be more defensible when analyzing today's policy options. So, who is right? The choice of an appropriate social time discount rate has long been debated. Some scholars argue that giving future generations less weight than the current generation is ethically indefensible. There is no definitive answer to this question because it requires a moral judgment comparing the well-being of those alive

today and those who will be alive in 50 or 100 years. The right answer depends ultimately on the values of the person who ventures an answer.

Philosophically, the notion of value is different from the narrow economic view. While the latter is related to the utility and desirability of a certain object, the former concerns the broader ethical fundamentals that guide behavior. Values and principles are the results of historical processes. For instance, since the 18th century “all men are created equal” became a value spread worldwide (although its effective adoption has taken more than a century). Here it is worth noting that there is a difference between values as the valuation of something (e.g., of future generation’s utility) versus an object that is “valued” as being intrinsically good in of itself (e.g., peace or environmental well-being or sustainable development).

The 20th century was marked by a constant introduction of new values, which correspond to specific principles. Here, we define principles as a set of applied guidelines to achieve a desired goal, such as a democracy. The goal is underpinned by a set of recognizable values. In the case of democracy, one underlying value is that all individuals are equal. For example, social protection and welfare became a mainstream issue to public policies since the early 1900s. The end of the Second World War in 1945 brought “peace” to the agenda as a key value. During the 1950s, the value of freedom served as a driving force for international relations (supporting the independence of the last colonies), and for social change (supporting the rise of social movements, such as the fight for civil rights). Development became an important value during the 1950s. Since the 1970s, environmental protection gained importance as a value present in public policies and international relations, but origins go back as far as the late 19th century. Its evolution led to a new concept that became an important value in the late 1980s: sustainable development. As it became clear that it is not possible to reach sustainability under very polarized social conditions, poverty reduction emerged as a key value to support a transition to sustainability.

### **The ethical foundations of sustainable development**

Within the field of sustainability science, it is important to consider the relationship between the need for sustainable development and the ethical foundations that support this need. The aim of ethics is the regulation of the power of acting, and it faces the threats posed by harmful technological interventions that grow in an “ethic vacuum.” Recognizing this, Jonas (1984) proposed the adoption of a new principle of responsibility where the highest rule is “let mankind exist!”

The traditional concept of a social contract as an ethical fundament fails when we must today assure quality of life for future generations is, however, formal and its ethical and moral dimension only emerge with the existence of a feeling for doing goodness by its own inherent objective, as it shames on the selfishness of power (Jonas 1984).

Jonas proposes to build an “ethical modernity” that limits the capacity of humans to be a destructive agent on the sustainability of life. From that perspective, we can conceive sustainable development as a horizon within the framework of an ethical modernity, and not only of a technical modernity. Therefore, the promotion of sustainable development requires not only wisdom and knowledge but also the ability to provide technically viable and ethically desirable solutions.

Such know-how can also be defined as the knowledge and the skills that help to promote the continuation of life. It should be expressed in terms of the different organized ways through which societies act or interact (e.g., through production processes, trade, disease prevention, water supply management, *et cetera*). As pointed out by Morin (1990) and Wilson (1996), the approach to deal with complex and interacting systems, like life, society, the environment, economics and the world, must be transdisciplinary, so that the unity of knowledge is not lost. It must also not separate the observer from the observed or the object from the subject as they are intimately interconnected or one may belong or be part of the other. A given technology is sustainable and belong to an ethical modernity not because it resulted from the freedom of choice of economic alternatives but because abides by the sustainability principle.

### **Value conflict and learning**

Values can vary greatly across cultures. Within the academic world, values are often different among disciplines (e.g., between economists and ecologists). The great diversity in values within and across societies has major implications for sustainability. One reason is that value conflicts are important sources of political conflict in issues surrounding environment and development (Sabatier and Jenkins-Smith 1999; Lackey 2006; Dietz, Stern and Rycroft 1989; Dietz 2001). One challenge for sustainability science is therefore to better understand how individuals with vastly different value systems are able to agree on mutually agreeable strategies to address problems of sustainable development. Another challenge stems from the realization that values are important determinants of environmental behavior (Stern et al. 1999), much of which is “altruistic” in the sense that it defies common notions of rationality. This implies a need to better understand the precise role of values in supporting behaviors necessary for a sustainability transition.

These roles also imply an even more important challenge for sustainability science: to better understand how values for sustainability are learned. Despite a general realization that strategies to achieve a sustainability transition must work in spite of diverse values systems, there is also no doubt that sustainability will also require the emergence of new and changing values. Unfortunately, we lack clear theoretical perspectives on how values for sustainability are learned.

Sustainability science is a rich field due to its broad view of life support systems, but for the same reason it is also complex and perhaps even polemical. The rise of this field is itself a consequence of a crisis in the way sciences and their values have evolved: fragmented in disciplines that are based upon principles and values that sometimes show contradictions among themselves.

A list of principles and values relevant to sustainability science varies across authors. Nonetheless, three common themes emerge. These include: 1) The shift from a predominantly anthropocentric to a more “eco-centric” view (Curry 2006), 2) the adoption of “prevention,” “precaution,” and “polluter-pays” as guiding principles for environmental regulations, and 3) the acceptance of international principles, such as common but differentiated responsibilities.

### Study Questions

- 1) For what purpose do we conserve nature?
- 2) Is there a need to universalize values in a diverse world, and how might this be done?
- 3) Which are more important: common values or social contracts aimed at sustainable development?
- 4) Which principles and values are indispensable, and which are just desirable?
- 5) Can we expect to tackle environmental challenges without previously (or simultaneously) facing social challenges (such as hunger, poverty, health and education)?

### Key Readings

Dietz, T., A. Fitzgerald, and R. Shwom (2005). "Environmental Values." *Annual Review of Environment and Resources* 30: 335–372.

Leiserowitz, A. A., R. W. Kates, and T.M. Parris (2006). "Sustainability Values, Attitudes, and Behaviors: A Review of Multinational and Global Trends." *Annual Review of Environment and Resources* 31: 413–444.

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Matus, K., T. Yang, S. Paltsev, J. Reilly, and K-M Nam (2008). "Toward Integrated Assessment of Environmental Change: Air Pollution Health Effects in the USA." *Climatic Change* 88: 59–92.

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Stern, P. C., T. Dietz, T. Abel, G. A. Guagnano and L. Kalof (1999). "A Value-Belief-Norm Theory of Support for Social Movements: The Case of Environmentalism." *Human Ecology Review* 6: 81–97.

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#### Online Materials

[http://sustsci.harvard.edu/ists/docs/whatisSD\\_env\\_kates\\_0504.pdf](http://sustsci.harvard.edu/ists/docs/whatisSD_env_kates_0504.pdf)

<http://www.encyclopedia.com/doc/1G1-131366153.html>

## Module 3

# Trends and Transitions

Ann Laudati

Human impacts on the natural environment have accelerated over the past hundred years as populations have expanded, technologies developed, and societies changed (DeFries *et al.* 2006). The greatest challenge of our generation is to envision and achieve a world that captures the “three pillars of human well-being.” These are environmental and ecological health, economic robustness and freedom from poverty, and social justice (see Holdren 2008). Sustainability science advances such a path by focusing on the interactions between environmental and human systems at multiple scales, the complex mechanisms that lead to degradation of these systems, and the concomitant risks to human well-being and security (Clark 2007). Underlying such investigations is the recognition that meeting such a challenge will require an accelerated transition toward sustainability (Kates *et al.* 2001). This requires asking where we are headed, where we want to go, and how we can get there. In addition, however, we must first address two key questions: Where are we, and how did we get here? (see Raskin *et al.* 2002).

A core question of sustainability science asks, “How are long-term trends in environment and development reshaping nature–society interactions in ways relevant to sustainability?” (Kates and Parris 2003). This module presents an up-to-date understanding of how human actions are transforming the Anthropocene by exploring the long-term trends and transitions of social and environmental changes that significantly affect the prospects for sustainability over the next half century. A description of 10 major classes and 26 long-term global and regional trends that either favor or impede progress towards a sustainability transition provide an initial checklist of the major forces affecting sustainability. These currents can be used to navigate towards a sustainability transition in the 21<sup>st</sup> century. We do this by considering 1) the human potential to slow or accelerate each trend, and 2) the extent to which local populations can contribute to altering the trends affecting them. Finally, it is important to identify the principal driving forces and processes underlying these trends and determine how these relate to alternative sustainability scenarios.

### Key Readings

DeFries, R., G. P. Asner, and J. Foley (2006). “A Glimpse Out the Window: Landscapes, Livelihoods, and the Environment.” *Environment* 48(8): 22–36.

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### Study Questions

#### *Questions related to trends:*

- 1) The reading on long term trends identifies 10 classes and 26 global and regional trends important for a sustainability transition. What's missing? Of the trends listed, are there any that should be discarded or altered?
- 2) Does the sum of these trends demonstrate that we have indeed transitioned into a new era of sustainability? What factors should we consider and to what degree should we weigh them when evaluating this question?

#### *Questions related to transitions:*

- 3) How can you tell when a societal and/or environmental transition is occurring or has occurred? Give a recent or current example.
- 4) Can we make similar projections (to inform policy decisions) based on a model of land-use transitions?

#### *Questions related to driving forces:*

- 5) What important drivers are omitted or are not subsumed under IPAT or its derivatives? Are there alternative models we can learn from and/or how would you reform the IPAT equation?
- 6) Why have IPAT and its derivatives survived so well despite extensive critiques?

#### *General questions:*

- 7) Are trends and transitions even a useful tool to think about future sustainability and base policy decisions on?
- 8) Do the current policy directions toward green technologies and other efforts towards sustainability represent long term currents or are they merely short term tides that will eventually lose their defining features?

### Supplemental Readings

Adams, W.M. (2001). "Environment, Degradation, & Sustainability." Pp. 175–214 In W.M. Adams. Green Development: Environment & Sustainability in the Third World. London: Routledge.

**Synopsis:** Through extensive practical case studies drawn from Africa, Latin America, and Asia Adams engages with the view that a scientific understanding of the environment must be considered within the socio-economic realities it is situated. In particular, he challenges mainstream and ‘western’ thinking on issues such as population, consumption, and degradation illustrating the inherently complex and increasingly political nature of human-environment interactions.

Raskin, P., T. Banuri, G. Gallopín, P. Gutman, A. Hammond, R. Kates, and R. Swart (2002). Great Transition: The Promise and Lure of the Times Ahead. A report of the Global Scenario Group. SEI PoleStar Series Report no. 10. Boston: Stockholm Environment Institute.

**Synopsis:** Produced through The Global Scenario Group founded by the Tellus Institute and Stockholm Environment Institute in 1995, this widely accessible book engages in a process of scenario development. It first examines the prospects for world development in the twenty-first century by defining transitions within a historical perspective while subsequently advancing an alternative path towards sustainability, the *Great Transition*, centered on the quality of life, human solidarity, environmental resilience, and an informed and engaged citizenry. The book concludes by identifying strategies of change including human actions and values required for a transition to a more sustainable and just future.

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Clark, W.C. (2007). “Sustainability Science: A Room of Its Own.” *Proceedings of the National Academies of Science* 104: 1737–1738.

Holdren, J.P. (2008). “Presidential Address: Science and Technology for Sustainable Well-being.” *Science* 319(5862): 424 - 434

Kates, R.W., W. C. Clark, R. Corell, J. M. Hall, C. C. Jaeger, I. Lowe, J. J. McCarthy, H. J. Schellnhuber, B. Bolin, N. M. Dickson, S. Faucheux, G. C. Gallopin, A. Grübler, B. Huntley, J. Jäger, N. S. Jodha, R. E. Kasperson, A. Mabogunje, P. Matson, H. Mooney, B. Moore III, T. O’Riordan, and U. Svedin. (2001). “Policy Forum: Environment and Development: Sustainability Science.” *Science* 292(5517): 641–642.

## Module 4

### Resilience Theory

Michael Burns  
Jan Sendzimir

Resilience theory has co-evolved with the development of the theory of complex adaptive systems, encompassing as it does a diversity of ideas about what factors influence non-linear dynamics within systems of the type defined, for example, by human-environment relationships.

A variety of definitions for resilience has emerged, with the following being widely used: "... the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks" (Walker *et al.* 2004: 2). As described by Sendzimir (2006), this definition refers to the factors that combine to build and sustain a system's identity: its structure (the web of interactions that link the system's key actors or processes), function (the services or activities that characterize the system), and feedbacks (the processes that cyclically reinforce or dampen activities in the system).

The resilience concept attempts to capture the tension between stasis and dynamism, building and destruction, single acts or actors and collective response within systems in which humans and the environment interact. Resilience theory is applied effectively if this tension between opposites is reflected in the hypotheses and models that guide the study of sustainable human-environment relationships. Resilience theory addresses a broad scope of issues because it integrates both stasis and dynamism. This is both valuable and useful, and the tension should not be lost because of pressure to simplify hypotheses. Of particular interest is the understanding of causal influences/disturbances and trajectories through which irreversible or difficult-to-reverse system change might occur—for example, changes attributable to unsustainable development. It is accepted, however, that change resulting from "disturbance" can be appreciated as an enabling phenomenon that presents opportunities for system adaptation and sustainability through recombination of evolved structures, renewal of the system, and emergence of new trajectories.

This understanding reflects the revolt that resilience theory has led against conventional paradigms that suggest 'system health' is evident in monotonic and smooth trajectories within a single, static equilibrium. It is also an understanding accommodated within sustainability science—that human-environment relationships can be adaptively managed, within the latitude of social and environmental capacity, to persist whilst reflecting difference and change, for example, in response to environmental change, alternative worldviews and values, *et cetera*.

Resilience theory has a history of bridging theoretical and policy debates. It began as a radical challenge to equilibrium-based paradigms, especially those that supported centralized top-down management and control of natural resource systems. Its development pointed toward the inevitability of surprise in complex adaptive systems

(especially those defined by human-environment relationships) and a mandate to shift from control to managing the capacity of systems to cope with, adapt to and shape change. From a normative perspective, sustainability science acknowledges that resilience in and of itself is neither good nor bad. Resilience simply reflects the potential of a system to persist in a particular identity in the face of stress and/or disturbance.

### Key Readings

Gunderson, L. H., C. S. Holling, I. Pritchard, and G. D. Peterson. (2002). Resilience of Large Scale Resource Systems. In L. H. Gunderson and L. Pritchard (Eds). Resilience and the Behavior of Large-scale Systems. SCOPE Series. Washington, D.C.: Island Press.

Walker, B., C. S. Holling, S.R. Carpenter, and A. Kinzig. (2004). Resilience, Adaptability and Transformability in Social-ecological Systems. *Ecology and Society* 9(2): 5. [online] URL: <http://www.ecologyandsociety.org/vol9/iss2/art5>.

### Study Questions

- 1) Does resilience theory provide use-inspired possibilities for understanding dynamic human-environment system relationships and for managing these relationships (whilst they inevitably change) for sustainable ends that are valued by society?
- 2) Does resilience theory reveal places of leverage within complex adaptive systems where structural, functional and feedback system attributes can be adaptively managed to promote sustainable development?
- 3) Does resilience theory suggest that it is practically possible to gauge system resilience and proximity to thresholds of irreversible system change?
- 4) Does resilience theory perhaps over-promise the understanding it provides of emergent properties of complex adaptive systems?

### Application Readings:

#### How to do Resilience Analysis

Walker, B., S. Carpenter, J. Anderies, N. Abel, G. Cumming, L. Lebel, G. Peterson, and R. Pritchard. (2002). Resilience Management in Social-ecological Systems: A Working Hypothesis for a Participatory Approach. *Conservation Ecology* 6(1): 14. [online] URL: <http://www.consecol.org/vol6/iss1/art14>.

**Synopsis:** The article covers key aspects of resilience theory and proposes a practical approach to resilience analysis - i.e. a 'how to do' the analysis. The authors explain a

pragmatic 4-step process or framework for analyzing resilience in social-ecological systems as a basis for managing system resilience. The first step involves the participatory construction of a conceptual model of the system, incorporating insights that explain how the system got to be what it is. Step 2 involves a scenario-type process of envisioning some plausible system futures, contrasting some extreme examples. Step 3 comprises a resilience analysis based on simple models of the system's dynamics, which can be used to explore attributes that affect resilience (latitude, resistance, precariousness, etc.). Step 4 involves stakeholder evaluation of the process and outcomes in terms of policy and management implications.

O'Farrell, P., D. Le Maitre, C. Gelderblom, D. Bonora, T. Hoffman, and B. Reyers. (2008). Applying a Resilience Framework in the Pursuit of Sustainable Land-use in the Little Karoo, South Africa. In M. Burns and A. Weaver (Eds). *Exploring sustainability science: A southern African perspective*. Stellenbosch, South Africa, AFRICAN SUN MeDIA.

**Synopsis:** The authors describe the rangeland management policies in South Africa's semi arid Little Karoo—policies that have singularly focused on the short term achievement of maximum yields from ecosystems. Locked into this production paradigm, social-ecological system resilience is shown to have been progressively compromised by a series of external shocks—droughts, floods, constraints in supply of financial capital, *et cetera*. Analysis of the system response to these shocks using a resilience framework, which incorporates scientific as well as local community knowledge, clearly reveals a trend towards system decay. Scenarios are used to inform adaptive management options, and one of these describes a situation in which a broad economic base is established in the region - an alternative to the prevailing narrow agricultural option. This is shown to offers possibilities for the social-ecological system to more easily absorb and respond to environmental and economic shocks of the type that have historically compromised its resilience.

Walker, B., and D. Salt. (2006). Resilience Thinking: Sustaining Ecosystems and People in a Changing World. Washington, D.C.: Island Press.

**Synopsis:** This is an accessible entrée into complex ecological and social interactions, from an ecologist's perspective. It presents 5 case studies.

### Supplemental Readings

Holling, C. S. (1973). Resilience and Stability of Ecological Systems. *Annual Review of Ecological Systems* 4:1–23.

**Synopsis:** A seminal foundational publication on resilience theory (focused on ecosystems).

Sendzimir, J. (2006). Critical Examination of Resilience Theories and Measures. Report to CAVES Project (Complexity: Agents, Volatility, Evidence and Scale) Deliverable 6. EU 6th Framework. URL: [http://cfpm.org/caves/wiki/uploads/CAVESWiki.Publications/CAVES\\_deliverable6.pdf](http://cfpm.org/caves/wiki/uploads/CAVESWiki.Publications/CAVES_deliverable6.pdf).

**Synopsis:** An introduction to resilience theory for social scientists.

Holling, C. S., and L. H. Gunderson. (2002). Resilience and Adaptive Cycles. Pp. 25–62. In L. H. Gunderson and C. S. Holling (Eds). Panarchy: Understanding Transformations in Human and Natural Systems. Washington D.C.: Island Press.

**Synopsis:** Some of the chapters included in Gunderson and Holling's (2002) compendium of multi-perspective writings on resilience theory make good reading in the sense that they move beyond explaining resilience theory in terms of its narrow application to ecosystems towards experimenting with its application to social and social-ecological systems. In this regard, the chapter by Holling and Gunderson is useful since it both covers the essentials of resilience theory and refers to some examples of its application to system vulnerability assessment (examples of ecosystems and social systems that vary in terms of vulnerability to environmental change/external variability).

Bennett, E. M., G. S. Cumming, and G. D. Peterson. (2005). A Systems Model Approach to Determining Resilience Surrogates for Case Studies. *Ecosystems* 8: 945–957.

**Synopsis:** Amongst the many challenges to 'doing' resilience analysis, for example using the framework proposed by Walker *et al.* (2002), is the identification of resilience surrogates that permit empirical measurement of resilience. Although limited to ecosystem resilience analysis, the article provides some guidance as to how these surrogates can be derived.

Walker, B. H., L. H. Gunderson, A. P. Kinzig, C. Folke, S. R. Carpenter, and L. Schultz (2006). A Handful of Heuristics and Some Propositions for Understanding Resilience in Social-ecological Systems. *Ecology and Society* 11(1): 13. [online] URL:<http://www.ecologyandsociety.org/vol11/iss1/art13/>.

**Synopsis:** In this article, the authors present a list of heuristics and propositions for the basic understanding of the concept of resilience within the framework of social-ecological systems. It concludes with a series of questions, for example: (i) Can we identify a set of well described examples that can be used to establish a typology of different types of phase transitions? (ii) Can such a typology be used to provide clues as to how and when these different types of transitions occur, and give insights for appropriate interventions? (iii) Are different sets of forward-looking tools (e.g., scenario development, markets) capable of mitigating or avoiding losses of capital during phases of release and reorganization?

Abel, N., D. H. M. Cummings, and J. M. Anderies. (2006). Collapse and Reorganization in Social-ecological Systems: Questions, Some Ideas and Policy Implications. *Ecology*

*and Society* 11(1): 17. [online] URL:  
<http://www.ecologyandsociety.org/vol11/iss1/art17/>.

**Synopsis:** This article tests the explanatory usefulness and policy relevance of the adaptive cycle theory in exploring the processes of system collapse and recovery. The authors refer to regional social-ecological systems, including Zimbabwe and Australia, as case studies. The article addresses the need for empirical analysis relating to resilience theory.

## Module 5

### Tools for Complex Systems Analysis

Kira Matus  
Adam Douglas Henry

Sustainability science focuses on the intersection of human and environment systems. Taken individually, most of these underlying systems—both ecological and social—are difficult to conceptualize and study with traditional linear methods. Models are confounded by unexpected phenomena such as emergent properties, threshold behaviors, and the amplification impacts of feedback mechanisms. In sum, the most pressing and fascinating problems in sustainability science require grappling with complexity.

The study of complex systems emerged in mathematics and the physical sciences and has moved into the natural and social sciences (Lansing 2003). Liu *et al.* (2007) describe six well-worked case studies of the human-environment systems central to sustainability science. This meta-analysis identifies six key properties of what are generally termed “complex adaptive systems” (CAS). These properties are:

- reciprocal effects and feedback loops,
- non-linearity and thresholds,
- surprises (emergent properties),
- legacy effects and time lags,
- resilience, and
- heterogeneity.

In order to engage in research on complex adaptive systems, it has become necessary to develop new tools and methods that deal with these properties. Although it seems that complex adaptive systems defy complete understanding, creative and optimistic scholars continue to work to find ways to deal with seemingly intractable problems.

Sustainability science cannot ignore complexity. Successfully dealing with complexity requires the use of multiple approaches to modeling, however, and an exhaustive review of these methods is beyond the scope of a single module. This module therefore focuses on network analysis as one promising emergent method to understand complex dynamics.

#### Key Readings

Lansing, J. S. (2003). “Complex Adaptive Systems.” *Annual Review of Anthropology* 32: 183–204.

Janssen, M. A., Ö. Bodin, J. M. Anderies, T. Elmqvist, H. Ernstson, R. R. J. McAllister, P. Olsson, and P. Ryan (2006). "A Network Perspective on the Resilience of Social-Ecological Systems." *Ecology and Society* 11(1): 15. [online] URL: <http://www.ecologyandsociety.org/vol11/iss1/art15/>.

### Application Readings: Social Networks and Structural Holes

One of the most prominent foci of network analysis is understanding information flows between linked agents—in particular, the networks literature is often preoccupied with understanding how patterns of interactions affect the problem-solving capability of individuals or groups of individuals.

One influential idea that has emerged from this literature is the concept of "structural holes," or how fragmentations within a network tend to impede the flow of information or fresh ideas. The argument is that agents who close structural holes (e.g., boundary-spanning agents) have a greater potential to innovate because of the diversity of their surrounding network. They are therefore privy to a richer set of information and worldviews than other agents. Embedded in this argument is the assumption that densely-connected networks tend towards homogeneity because agents have many opportunities for mutual learning and information exchange. Thus, if you are only connected within your particular "fragment" of the network, then you are not likely to learn anything new from your surrounding social environment.

The collaborative policy literature has picked up on these ideas, and proposes that one of the major sources of dysfunction within policy processes are four types of structural holes that are often seen within policy networks. These structural holes create a rift between vertical levels of government, horizontal jurisdictions, fields of expertise, and ideological orientations. One of the goals of collaborative institutions is to create networks that bridge these structural holes; these networks are hypothesized to improve policy outcomes because they promote common ways of viewing problems and encourage norms of reciprocity and cooperation.

When we shift to a view of agents interacting over time, however, we begin to see a problem with the strategy of closing structural holes as a way to improve outcomes. Although innovation and "good ideas" may come from connecting diverse parts of a network, bridging structural holes also has the long-term effect of homogenizing the once-disconnected sets of agents. This reduces diversity, and hence undermines the value of the boundary-spanning links. In this sense, networks can potentially become "rigid" and, once again, inhibit learning and innovation for sustainability.

Burt, R. S. (2004). "Structural Holes and Good Ideas." *American Journal of Sociology* 110(2): 349–399.

Schneider, M., J. Scholz, M. Lubell, D. Mindruta, and M. Edwardsen (2003). "Building Consensual Institutions: Networks and the National Estuary Program." *American Journal of Political Science* 47(1): 143–158.

## Module 6

### Introduction to Governance for Sustainability

Krister Andersson

The purpose of this module is to gain a better understanding of the role of governance in efforts to make human-environment interactions more sustainable. The concept of governance is central to the study of coupled human and natural systems, because governance is one of the main instruments available to influence human behavior on a large scale. As such, a transition toward sustainability implies a transformation of the way humans interact with the environment. The extent to which such a transformation of human behavior actually occurs is likely to depend on the effectiveness of our current efforts to govern human-environmental interactions.

Governance is the traditions and institutional arrangements by which authority is exercised within a polity.<sup>1</sup> In other words, governance is the process by which authority is conferred on rulers, by which they make the rules, and by which those rules are enforced and modified over time. This means that to study governance one needs to be able to identify both the rulers and the rules, as well as the various processes by which they are selected, defined, and linked together and with society more broadly (Kaufman *et al.* 2003).

There are four main reasons governance is important for addressing unsustainable human-environment interactions. First, the absence of governance arrangements means that natural resource users are only constrained by the limited physical and technological capacities when making user decisions. Under such conditions, overuse may occur, possibly leading to a “tragedy of the commons” (Hardin 1968; Ostrom 1990; Dietz *et al.* 2003; Berkes *et al.* 2006). Second, inappropriate governance arrangements may produce incentives that are incompatible with sustainable resource use. For example, excessive centralized control over resources and decision-making may produce disincentives for local resources users to invest in resource improvement and management strategies (Wunsch and Oluwu 1992; Hooghe and Marks 2003). Third, low capacity to implement governance arrangements may prevent such arrangements from affecting human decision making. For example, many less developed countries have highly sophisticated laws and regulations but often lack the human, financial and infrastructure capital to implement the rules on the books (Ascher 1999; Agrawal and Gibson 1999; Chayes and Chayes 1993). Finally, effective governance systems are necessary in order to reach decisions regarding human-environment interactions that societies will perceive as legitimate, just and equitable; indeed, procedural justice is often the yardstick by which the legitimacy and fairness of policies is measured.

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<sup>1</sup> This definition is adapted from Kauffman *et al.* (2003). Other definitions include “The way power is exercised through a country’s economic, political, and social institutions” (World Bank 1997). “The exercise of economic, political, and administrative authority to manage a country’s affairs at all levels. It comprises mechanisms, processes, and institutions, through which citizens and groups articulate their interests, exercise their legal rights, meet their obligations, and mediate their differences” (UNDP 1999).

### Key Readings

Dietz, T., E. Ostrom, and P. Stern. (2003). The Challenge to Govern the Commons. *Science* 302 (5652): 1907–1912.

Folke, C., T. Hahn, P. Olsson, and J. Norberg. (2005). Adaptive Governance of Social Ecological Systems. *Annual Review of Environment and Resources* 30: 441–473.

### Study Questions

- 1) According to some authors, essentially all environmental problems are due to institutional failure. Do you agree?
- 2) Dietz et al (2003) state that “Now, every local place is strongly influenced by global dynamics”. What are the implications of this statement for the governance of human-environmental interactions?
- 3) What is the difference between government capacity and governance capacity? And between adaptive government and adaptive governance?

### Application Readings: Fisheries

Berkes, F. *et al.* (2006). “Globalization, Roving Bandits, and Marine Resources.” *Science* 17(311): 1557–1558.

### Application Study Questions

- 1) Berkes et al (2006) paint a gloomy picture for much of the world’s fisheries. What options exist for governance?
- 2) Outline some of the pros and cons of state institutions in managing water and fish resources respectively?

### Supplemental Readings

Agrawal, A., and C. C. Gibson (1999). “Enchantment and Disenchantment: The Role of Community in Natural Resource Conservation.” *World Development* 27(4): 629–649.

Asher, W. (1999). Why Governments Waste Natural Resources: Policy Failures in Developing Countries. Baltimore, MD: The Johns Hopkins University Press.

Chayes, A., and A. H. Chayes (1993). “On Compliance.” *International Organization*

47(2): 175–205.

Hardin, G. (1968). The Tragedy of the Commons. *Science* 162(3859): 1243 –1248.

Hooghe, L., and G. Marks (2003). “Unraveling the Central State, But How? Types of Multilevel Governance.” *American Political Science Review* 97(2): 233–243.

Kaufmann, D., A. Kraay, and M. Mastruzzi (2003). “Governance Matters III: Governance Indicators for 1996–2002.” Working Paper, Washington DC: The World Bank. Accessible online at: [www.worldbank.org/wbi/governance/govdata2002/](http://www.worldbank.org/wbi/governance/govdata2002/).

Meinzen-Dick, R. (2007). “Beyond Panaceas in Water Institutions.” *Proceedings of the National Academy of Sciences* 104(39): 15200–15205.

Ostrom, E. (1990). Governing the Commons. Cambridge, MA: Cambridge University Press.

Olowu, D., and J. S. Wunsch (1990). The Failure of the Centralized State: Institutions and Self-Governance in Africa. Boulder, CO: Westview Press.

## Module 7

### Introduction to the Analysis of Governance

Adam Douglas Henry

Governance arrangements have the potential to both promote and hinder sustainable outcomes—thus it is crucial to better understand the complex relationships between governance, human behavior, and sustainability. This requires theoretical tools to systematically analyze governance systems. Such tools allow us to better understand the circumstances under which governance may act as a hinge to promote sustainable outcomes.

This module emphasizes two key messages. First, governance systems are extremely complex and cannot be understood without the aid of a simplifying framework. Second, it is usually beneficial to apply multiple theoretical frameworks to understand these systems. Different frameworks are often useful for explaining different phenomena, and the application of multiple theoretical perspectives to understand a single problem often yields more than the sum of the parts.

Simplification is crucial because governance systems typically involve many hundreds of actors, operating in multiple capacities at different scales of government, all marshalling a variety of resources to achieve their goals. Given some phenomenon to be explained—such as why policy responses to global environmental problems often lag behind the state of the science—the typical number of variables to be considered is staggering. It is therefore necessary to simplify analysis. This is done by applying one or more theoretical frameworks that help to guide inquiry; these frameworks specify the actors to be included in an analysis, their roles and motivations, and allow us to predict the eventual relationships between governance arrangements and sustainability.

As an application of the analysis of governance, this module presents two promising candidate frameworks that may be used to analyze complex governance systems and their impact on sustainability. These include the Advocacy Coalition Framework (ACF) and a recent variant of the Institutional Analysis and Development (IAD) framework, both of which have been extensively applied to understanding issues of environmental policy and natural resources management. Applying these two frameworks to analyze a single system can illuminate unique but important aspects of governance for sustainability.

#### Key Readings

Sabatier, P. (1999). “The Need for Better Theories.” Pp. 3–17. In P. Sabatier (Ed.). Theories of the Policy Process. Westview Press.

Ostrom, E. (2007). “A Diagnostic Approach for Going Beyond Panaceas.” *Proceedings of the National Academy of Sciences* 104(39): 15181–15187.

### Application Readings: The Advocacy Coalition Framework

Schlager, E. (1995). "Policy Making and Collective Action: Defining Coalitions within the Advocacy Coalition Framework." *Policy Sciences* 28: 243–270.

Sabatier, P. A., W. D. Leach, M. Lubell, and N. Pelkey (2005). "Theoretical Frameworks Explaining Partnership Success." Pp. 173–199. In P. A. Sabatier, W. Focht, M. Lubell, Z. Trachtenberg, A. Vedlitz, and M. Matlock (Eds.). Swimming Upstream: Collaborative Approaches to Watershed Management. Cambridge, MA: The MIT Press.

### Supplemental Readings

Agrawal, A. (2001). "Common Property Institutions and Sustainable Governance of Resources." *World Development* 29(10): 1649–1672.

## Module 8

### Governance of Cross-scale Human-Environment Interactions

Ann Laudati

In both the natural and social sciences, processes that occur at one scale may lack congruence at other scales<sup>2</sup>. Appropriate models for governance must therefore reflect the dynamic, complex, unpredictable, non-linear, cyclical, episodic, patchy, redundant, and heterogeneous nature of ecological systems and human systems (Holling *et al.* 1998; Poiani *et al.* 2000; Berkes 2002). In both the natural and social sciences processes that occur at one scale may lack congruence at other scales. The division of a dynamic system therefore into a centralized ('scaling up') or a decentralized ('scaling down') management systems is highly problematic (Pritchard and Sanderson 2002). As Berkes *et al.* (2002) argue, the persistence of environmental degradation may be related in part to the lack of attention to cross-scale linkages while uniform large-scale systems have largely failed in ecological niches of high risk (Ostrom 1995). Neither large-scale nor small-scale systems are a solution by themselves, but together they can make up part of an effective governance mix (Ostrom 1995).

Site-specific studies, for example, show that various institutional structures are necessary for common-pool forestry due to cultural and ecological diversity. Multi-level governance can build capacity to change and manage for resilience (Holling and Sanderson 1996). This may be accomplished through at least four ways, such as:

- connecting community based management with regional/national government-level management,
- linking scientific management and traditional management systems,
- encouraging the sharing of knowledge and information, and
- promoting collaboration and dialogue around goals and outcomes (Sinha 2008).

Instead of looking for one "correct" governance scale, appropriate models for ecological and human systems require input from multiple scales and sectors involved in environmental management. This is especially true in light of the current conditions of globalization and the concurrent rise of institutions such as trade blocs and International Non-Governmental Organizations which straddle geographic scales.

One challenge of multi-level governance will be to maintain a balance between scales (McKean 1996) without defaulting to either extreme of the global-local nexus and thereby overlooking the intermediate scales (Zimmerer 2000). This requires attention to horizontal and vertical linkages (Berkes 2002; Young 2002). On a final cautionary note, scale appears to be socially and politically constructed in an on-going relational process involving a multiplicity of actors at different levels (Smith 1992, 1993; Delaney and Leitner 1997; Cox 1998). Thus, we must critically reflect on the adoption of adaptive, multi-level governance for ecosystem management. Forces of concern include the role of

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<sup>2</sup> I would like to thank Mary Brooks at the University of Texas, Department of Geography, whose unpublished paper on cross-scale governance provided inspiration for this narrative.

power, scale and levels of organization, knowledge valuation, the positioning of social actors and social constructions of nature (Armitage 2008; see also Towers 2000; Swyngedouw 1997; Williams 1999). In its ideal form, however, cross-scale governance can ultimately be used as a tool for political change leading to participation, empowerment, and social equity.

### Key Readings

Cash, D. W., W. Adger, F. Berkes, P. Garden, L. Lebel, P. Olsson, L. Pritchard, and O. Young. (2006). "Scale and Cross-scale Dynamics: Governance and Information in a Multilevel World." *Ecology and Society* 11(2): 8.

**Synopsis:** Provides a useful study of the major cases of "scale challenges" faced by the human-environmental systems and by their respective governance institutions.

Gibson, C., E. Ostrom, and T. K. Ahn (2000). "The Concept of Scale and the Human Dimensions of Global Change: A Survey." *Ecological Economics* 32: 217–239.

**Synopsis:** This paper reviews the fundamental aspects of scale particularly in regard to dimensions of environmental change.

Ostrom, E., C. Burger, C. Field, R. Norgaard, and D. Policansky (1999). "Revisiting the Commons: Local Lessons, Global Challenges." *Science* 284: 278–282.

**Synopsis:** This article discusses new insights about common property resource management including the challenges facing the management of large-scale resources that depend on international cooperation. The authors stress the importance of institutional diversity as well as biological diversity for our long-term survival.

Young, O. R. (2002). The Institutional Dimensions of Environmental Change: Fit, Interplay and Scale. Cambridge, MA: MIT Press.

**Synopsis:** In the section devoted to scale, Young argues that we cannot just simply "scale up" from what we know about local institutions to create ways to address global problems, rather we should find ways various institutions located along the local-global continuum can contribute to each other.

### Study Questions

- 1) Does multi-scalar governance substitute for the need to create a general theory of human-environment interactions so that we can determine how to create the 'right' institutions for a given environmental problem?

- 2) Authors mention the challenge of both mediating balance and equity within multi-scalar institutional governance, yet to what lengths do we try to maintain this balance without losing sight of the repercussions such actions might actually result in?
- 3) Given the various challenges of multi-scalar governance, particularly in terms of actual management, where should authors concentrate their efforts?

Application Readings:  
Incorporating Scale into Environmental Decision-Making

Bulkeley, H. (2005). "Reconfiguring Environmental Governance: Towards a Politics of Scales and Networks." *Political Geography* 24(8): 875–902.

**Synopsis:** This article engages with the current debates on the politics of scale and argues that environmental governance must be sensitive to both the politics of scale and the politics of networks. In making this argument, Bulkeley provides an overview of contemporary configurations of global environmental governance with reference to one transnational municipal network, the Cities for Climate Protection program. She concludes by arguing that in order to understand emerging hybrid forms of environmental governance and their political and ecological implications an alternative dialogue is necessary.

Keck, M., and K. Sikkink. (1999). "Transnational Advocacy Networks in International and Regional Politics." *International Social Science Journal* 51(159): 89–101.

**Synopsis:** Examines the role of transnational advocacy networks as a way to connect local actors as a new highly influential subject within international and interregional policy-making.

Other Works Cited

Armitage, D. (2008). "Governance and the Commons in a Multi-level World." *International Journal of the Commons* 2(1): 7–32.

Berkes, F. (2002). Cross-Scale Institutional Linkages: Perspectives from the Bottom Up. The Drama of the Commons. Natural Resource Council. Washington, D.C.: National Academy Press.

Cox, K. R. (1998). "Spaces of Dependence, Spaces of Engagement and the Politics of Scale, or: Looking for Local Politics." *Political Geography* 17(1): 1–23.

Delaney, D., and H. Leitner (1997). "The Political Construction of Scale." *Political Geography* 16(2): 93–97.

Herod, A., and M. W. Wright (2002). "Placing scale: An Introduction." Pp. 1–14. In A. Herod and M. W. Wright. Geographies of Power: Placing Scale. Oxford: Blackwell Publishers.

Sinha, H. 2008. "Integrating Multi Level Governance for Biodiversity Conservation: Biopsy of Indian Forest Management." Presented at "Governing Shared Resources: Connecting Local Experience to Global Challenges," 12th Biennial Conference of the International Association for the Study of Commons, Cheltenham, England, July 14–18, 2008.

Holling, C. S., and S. Sanderson (1996). "Dynamics of (Dis)harmony in Ecological and Social Systems." Pp. 57–85. In S. Hanna, C. Folke and K.-G. Mäler. Rights to Nature: Ecological, Economic, Cultural, and Political Principles of Institutions for the Environment. Washington, D.C.: Island Press.

Holling, C. S., F. Berkes, and C. Folke (1998). "Science, Sustainability and Resource Management." Pp. 342–362. In F. Berkes and C. Folke. Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience. Cambridge: Cambridge University Press.

McKean, M. A. (1996). "Common-property Regimes as a Solution to Problems of Scale and Linkage." Pp. 223–243. In S. Hanna, C. Folke, and K.-G. Mäler. Rights to Nature: Ecological, Economic, Cultural, and Political Principles of Institutions for the Environment. Washington, D.C.: Island Press.

Ostrom, E. (1995). "Designing Complexity to Govern Complexity." Pp. 33–45. In S. Hanna and M. Munasinghe. Property Rights and the Environment: Social and Ecological Issues. Washington, D.C.: The Beijer International Institute of Ecological Economics and The World Bank.

Poiani, K. A., B. D. Richter, M. G. Anderson, and H. E. Richter (2000). "Biodiversity Conservation at Multiple Scales: Functional Sites, Landscapes, and Networks." *BioScience* 50(2): 133–146.

Pritchard, L. and S. Sanderson (2002). "The Dynamics of Political Discourse in Seeking Sustainability." Pp. 147–169. In L.H. Gunderson and C.S. Holling. Panarchy: Understanding Transformations in Human and Natural Systems. Washington, D.C.: Island Press.

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## Module 9

### Transdisciplinarity

Michael Burns

“Fragmentation” is a metaphor to describe fractures in human-environment relationships, but also applies to the tendency within science to understand the world in its myriad separate parts. Nicolescu (2002: 34) describes this phenomenon of knowledge fragmentation as the “disciplinary big bang,” where new scientific disciplines and sub-disciplines are established at an exponential rate. This tendency arises from the principle that different cognitive challenges are addressed most efficiently through separate disciplines (Morin 2007). This is perhaps not unexpected given Foucault’s (1974) explanation of the extent to which codes of human culture on the one hand (such as those that determine values), and scientific theory and philosophical interpretation on the other, lead humans to order things in fragmented ways (Rapport 2000).

Although this tendency towards disjunction in knowledge production is no doubt productive, it provides an insufficient basis for understanding the complex systemic challenges of sustainable development. None of these challenges are contained within the boundaries of a single discipline (Daily and Ehrlich 1999; Lawrence and Depres 2004; Max-Neef 2005). The challenges of sustainable development can only be approached through the integration of knowledge between and beyond disciplines, and it is in response to this requirement that the concept of *transdisciplinarity* has emerged.

Describing transdisciplinarity, Max-Neef (2005) presents what he refers to as the “continuum of the discipline.” This continuum encompasses the isolated specialization of disciplinary research, the weak integration that occurs through multidisciplinary research and the high degree of cooperation and/or integration achieved through interdisciplinary research. Max-Neef (2005) describes cooperative interdisciplinary research as being determined by the coordination that is effected from a higher research level on research contributions generated at a lower level, thereby giving these latter contributions a defined purpose. Medicine, for example, becomes interdisciplinary as it draws from lower level disciplines of biology, chemistry, psychology, *et cetera*. However, cooperation achieved through interdisciplinary research provides no guarantee that the knowledge that is produced will respond to the needs of knowledge users (e.g. policy makers), will be interpreted correctly or will be put to practical effect in advancing sustainable development. It is in this context that the requirement for transdisciplinarity arises (Max-Neef 2005; Hadorn *et al.* 2006).

Lawrence and Depres (2004) describe transdisciplinarity as responding to four essential requirements:

- acknowledgement of the complexity of human-environment relationships, which defy understanding using traditional scientific approaches,
- a sensitivity to epistemologies that may differ from rational utilitarian valuation of human-environment relationships,
- avoiding fragmentation of knowledge and expertise, and

- the exchange of knowledge between researchers and society.

Thus, while multi- and interdisciplinary research remains within the scientific disciplines, transdisciplinary research entails dialogue and knowledge exchange *with society*. Drawing on Janstch's (1972) hierarchical ordering of knowledge, the totality of this exchange amongst and beyond disciplines is depicted by Max-Neef (2005: 7, 9) as a "pyramid of the transdiscipline." Transdisciplinarity emerges when there is dialogue, research coordination and knowledge exchange across and between four hierarchical levels: the purposive, normative, pragmatic and empirical levels (the respective domains, for example, of values, social systems design, physical technology and physics/biology/human psychology). It becomes effective only as the values and norms of science and society are made explicit, and meaning is attributed to scientific knowledge sought by society and delivered through research (Hadorn *et al.* 2006). According to Nicolescu (1996) "transdisciplinarity is at once between the disciplines, across the different disciplines and beyond all disciplines. Its goal is the understanding of the present world, of which one of the imperatives is the unity of knowledge."

### Key Readings

Max-Neef, M. A. (2005). "Foundations of Transdisciplinarity." *Ecological Economics* 53: 5–16.

### Study Questions

- 1) Are the complexities we encounter while responding to the challenges of sustainable development of such a nature that we need to go beyond disciplinary boundaries—i.e. do we need to generate *new integrated knowledge*, or can we make do with disciplinary knowledge?
- 2) Given the dominance of reductionism, mono-disciplinarity and hyper-specialization, is transdisciplinary dialogue really possible?
- 3) How do we deal with resistance to attempts to go beyond disciplinary boundaries in order to establish a 'meta-discipline' or 'meta-discourse' for crossing disciplinary boundaries?
- 4) How do we deal with power-knowledge relations in the establishment of new transdisciplinary knowledge across disciplinary boundaries?

### Application Readings: Breakthroughs Beyond Disciplinary Divides

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Science: A Southern African Perspective. Stellenbosch, South Africa: AFRICAN SUN MeDIA.

Bammer, G. (2005). Integration and Implementation Sciences: Building a New Specialization. *Ecology and Society* 10(2): 6. Accessible online at: <http://www.ecologyandsociety.org/vol10/iss2/art6/>.

### Supplemental Readings

van Breda, J. (2008). “Overcoming the Disciplinary Divide: Towards the Possibility of a Transdisciplinary Hermeneutics.” In M. Burns and A. Weaver (Eds.). Exploring Sustainability Science: A Southern African Perspective. Stellenbosch, South Africa: AFRICAN SUN MeDIA.

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Hadorn, G.H., D. Bradley, C. Pohl, S. Rist, and U. Wiesman (2006). “Implications of Transdisciplinarity for Sustainability Research.” *Ecological Economics* 60(1): 119–128.

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Nicolescu, B. (2002). La Transdisciplinarité, manifeste, Le Rocher, Monaco, coll. Transdisciplinarité, English translation: Manifesto of Transdisciplinarity. New York: State Univeristy of New York Press.

Rapport, D. (2000). “Transdisciplinarity: An Approach to Problem-solving in a Complex World.” Pp. 135–144. In M. Somerville and D. Rapport (Eds.). Transdisciplinarity: Recreating Integrated Knowledge. Oxford: EOLSS.

## Module 10

### Linking Knowledge with Action

Elizabeth McNie

Sustainable development is a knowledge-intensive activity, particularly because it involves problems related to coupled human-environmental systems. Scientific information can play an important role in such decisions in order to produce outcomes that meet the needs of humans without compromising the ability of natural systems to provide important services today and in the future. When western scientists unilaterally direct scientific information at a problem of sustainable development, however, it rarely achieves the desired outcomes. Failure of integrating and linking scientific knowledge with action can occur for a number of reasons, such as the following:

- The science is produced at a scale that is inappropriate for the problem.
- The science does not reflect or consider the complexity of the ecological systems at the problem site.
- The scientists fail to consider how to integrate the information with the social systems (for example, the scientific information does not consider the political and socio-economic constraints of the problem, nor does it consider the time-frame of the decision).
- The science fails to adequately consider other forms of knowledge. For example, western, local, and indigenous knowledge schemas all possess different notions about what constitutes expertise, truth, validity and value.
- Information-users put a high premium on trusting the sources of information and so western science (often produced anonymously and from afar from the perspective of users) reduces the likelihood that information will be used.
- Significant power, resource, and information asymmetries exist between western science and likely users of information in developing nations. These asymmetries create additional barriers to producing, integrating, and linking science with action.
- Scientists and decision makers cannot adequately communicate their ideas, knowledge, and concerns with the other due to differences in language, epistemologies and cultures.
- Barriers between science and society may be too robust, inhibiting efforts to adequately link science with other forms of knowledge and corresponding actions. Alternatively, the boundary between science and society may be weak or even non-existent, creating problems in which science becomes politicized, thus reducing its credibility and legitimacy.

This module examines the problem of integrating and linking multiple forms of knowledge (e.g., western science, local and indigenous knowledge, political knowledge, *et cetera*) with decisions and actions for sustainable development. We will explore

alternative approaches to integrating and linking multiple forms of knowledge with action, and provide examples from the field illustrating successful cases of how science can be brought to bear in solving problems of sustainable development.

### Key Readings

van Kerkhoff, L., and L. Lebel (2006). “Linking Knowledge with Action for Sustainable Development.” *Annual Review of Environmental Resources* 31: 445–477.

Lansing, S. (2007). Priests and Programmers: Technologies of Power in the Engineered Landscape of Bali. Princeton, New Jersey: Princeton University Press. Chapters 1, 2, 3 (pp. 50–59), 6, 7.

Mitchell, R. B., Clark, W. C., and Cash, D. W. (2006). “Information and Influence.” Pp. 307–338. In R. B. Mitchell, W. C. Clark, D. W. Cash, and N. M. Dickson (Eds.). Global Environmental Assessments: Information and Influence. Cambridge, Massachusetts: The MIT Press.

### Study Questions

- 1) What are the challenges (from ‘northern’ perspectives) in identifying and understanding the local or indigenous knowledge systems?
- 2) What approaches in linking knowledge with action can best address the problem of power, knowledge, and resource asymmetries?
- 3) Does linking knowledge with action, as explored in this lesson, differ from more ‘traditional’ modes of development work? Why or why not?

### Application Readings

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Forrester, J., and S. Cinderby (2005). “Geographic Information Systems for Participation.” Pp. 232–236. In M. Leach, I. Scoones, and B. Wynne (Eds.). Science and Citizens: Globalization & the Challenge of Engagement. London, New York: Zed Books.

Kristjanson, P., R. Reid, N. Dickson, W. Clark, P. Vishnubhotla, D. Romney, P. Bezkorowajnyj, M. Said, D. Kaelo, O. Makui, D. Nkedianye, J. Nyangaga, P. Okwi, R.

Puskur, S. Tarawali, S. MacMillan, D. Grace, T. Randolph, and H. Affognon (2007). “Linking International Agricultural Research Knowledge with Action for Sustainable Poverty Alleviation.” International Livestock Research Institute Innovation Works, Discussion Paper 01-07 (September 2007).

McNie, E., M. van Noordwijk, W. C. Clark, N. Dickson, N. Sakuntaladewi, Suyanto, L. Joshi, B. Leimona, and C. Kurniantan (2008). “Boundary Organizations, Objects, and Agents: Linking Knowledge with Action in Agroforestry Watersheds.” Workshop Report, Batu, Malang, East Java (26–29 July 2007).

### Supplemental Readings

Cash, D. W., W. Clark, F. Alcock, N. M. Dickson, N. Eckley, D. H. Guston, J. Jäger, and R. B. Mitchell (2003). “Knowledge Systems for Sustainable Development.” *Proceedings of the National Academy of Science* 100(14): 8086–8089.

Leach, M., I. Scoones, and B. Wynne (2005). “Introduction: Science, Citizenship and Globalization” and “Science and Citizenship in a Global Context” Pp. 3–38. In M. Leach, I. Scoones, and B. Wynne (Eds.). Science and Citizens: Globalization and the Challenge of Engagement. London, New York: Zed Books.

McNie, E. (2007). “Reconciling the Supply of Scientific Information with User Demands: An Analysis of the Problem and Review of the Literature.” *Environmental Science and Policy* 10: 17–38.

# Module 11

## Learning, Reflection and Evaluation

Fred Carden

A core theme of sustainability science is the importance of ongoing learning. This module introduces the importance of reflection and evaluation as part of learning about progress towards sustainability.

Evaluation is the systematic review of an activity or a set of activities to ascertain the contribution being made. Evaluation has two main purposes: accountability and learning. Both are essential for sustainability and sometimes both are addressed in the same study. Because our values affect what we perceive and accept as true, evaluators must understand the paradigm and frame of reference of the community within which they are working.

Accountability is the traditional role of evaluation in any system or organization. In this context, evaluation addresses the success and failure of programs by assessing effectiveness and efficiency. It allows us to determine *what* happened. Knowing what happened is helpful in two circumstances: 1) we must determine whether a completed activity was a success or failure, and 2) we must directly repeat or replicate what happened in another setting. A range of methods is used in accountability evaluation—experimental and quasi-experimental methods are important where the question is simple and sharply focused. A range of qualitative methods can be employed where more complicated questions and programs are under consideration. Given a particular question, it is critical to identify the most appropriate methodological approach.

In order to learn from past experience in complex adaptive systems, we also need to know *why, in what context, with what groups and in what ways*. This has led to a second thrust of evaluation, that of learning and reflection.

Learning has come to the fore in complex systems where it is recognized that constant changes require ongoing reflection, evaluation and adaptation. Evaluation for learning is concerned with “what works,” “in what context” and “for whom.” More importantly, it is concerned with what can be generalized to other projects, programs or systems. A range of methods is used, depending on the purpose of the evaluation and the level being considered (e.g., project, program, organization, system, or society). Theory-based evaluation approaches are central, including a range of methodologies such as Realist Evaluation, Outcome Mapping, Theory Based Evaluation, among others.

A core contribution of evaluation is measurement of progress: How do we know what we know? How does this help us to make decisions and choices about the future? Metrics are critical and can either help or distort our perception. Metrics must therefore be chosen carefully. Einstein’s comment that “what gets measured gets done” is both an urge to clarity but also a caution, since indicators frequently distort projects and programs. Measurement in experimental and quasi-experimental methods, as in other closed systems, is relatively straightforward and is aided by baselines and counterfactuals. Measurement in open systems is less straightforward when what *could*

have happened if you had *not* intervened is unknowable. In a theory-driven approach, comparison and adjudication replace counterfactuals.

### Key Readings

Rogers, P. (2008). "Using Programme Theory to Evaluate Complicated and Complex Aspects of Interventions." *Evaluation* 14(1): 29–48.

### Application Readings

Pawson, R. (2006). Evidence-based Policy: A Realist Perspective. London, Thousand Oaks, Delhi: Sage Publications.

**Synopsis:** Includes numerous examples of use of a theory-based approach to evaluation.

### Supplemental Readings

Cook, T. D. and D. T. Campbell (1979). Quasi-experimentation: Design and Analysis Issues for Field Settings. Boston: Houghton Mifflin.

Patton, M. Q. (2008). Utilization Focused Evaluation: The New Century Text, 4<sup>th</sup> edition. Thousand Oaks, CA, London, New Delhi.

Patton, M. Q. (2008). Qualitative Research and Evaluation Methods, 3<sup>rd</sup> edition. Thousand Oaks, CA, London, New Delhi.

Shadish, W. R., T. D. Cook and D. T. Campbell (2002). Experimental and Quasi-experimental Designs for Generalized Causal Inference. Boston: Houghton Mifflin Company.