Battelle
The Business of Innovation

PNWD-4087

Vulnerability and Resilience in the Face of Climate Change: Current Research and Needs for Population Information

EL Malone

Battelle
Pacific Northwest Division
Richland, Washington 99352

Prepared for
Population Action International
1300 19th Street, Suite 200
Washington, DC 20036 USA
under Contract No. 55849

August 2009

LEGAL NOTICE

This report was prepared by Battelle Memorial Institute (Battelle) as an account of sponsored research activities. Neither Client nor Battelle nor any person acting on behalf of either:

MAKES ANY WARRANTY OR REPRESENTATION, EXPRESS OR IMPLIED, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, process, or composition disclosed in this report may not infringe privately owned rights; or

Assumes any liabilities with respect to the use of, or for damages resulting from the use of, any information, apparatus, process, or composition disclosed in this report.

Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by Battelle. The views and opinions of authors expressed herein do not necessarily state or reflect those of Battelle.


This document was printed on recycled paper.

(9/2003)

Battelle
The Business of Innovation

PNWD-4087

Vulnerability and Resilience in the Face of Climate Change: Current Research and Needs for Population Information

EL Malone

Battelle
Pacific Northwest Division
Richland, Washington 99352

Prepared for
Population Action International
1300 19th Street, Suite 200
Washington, DC 20036
under Contract No. 55849

August 2009

Summary

Studies of vulnerability and resilience have multiplied with the growing realization that societal response, particularly societal capacity to adapt to climate change impacts, determines both the severity of impacts and the costs of adaptation. The definition and focus of such studies come from other research communities, including research in impacts of climate change (emphasizing physical impacts), natural hazards and disasters (the hazards themselves plus societal preparation and response/recovery), and sustainability (societal conditions and decisions about using natural resources). Although research in vulnerability and resilience began by emphasizing vulnerability, the focus has shifted at least in part to resilience as a positive concept that can be more integrated with general development goals.

Methods and approaches encompass using sets of indicators (sometimes using mapping techniques), performing case studies, analyzing systemic processes, and developing scenarios of the future. A host of factors has been employed in vulnerability and resilience studies, ranging from agricultural productivity and water availability to governance and public perception.

Factors that characterize resilience include a potentially endless set, encompassing climate and other environmental conditions, human management of natural systems, and demographic and societal characteristics that can promote or inhibit resilience. Even if an agreed-on set could be established, the challenges of accounting for interactions among factors and the dynamism of future change would remain. Three approaches can provide bases for analyses:

1. Establishing standards for a resilient society, i.e., integrated factors that would characterize resilience.

2. Detailed analysis of five general dimensions: socio-demographic conditions, economics, natural resource use/dependence, governance and policy, and culture.

3. Societal and cultural ties, i.e., the ways people interact and collectively approach change and problem-solving.

One common lack across vulnerability and resilience studies is an examination of studied populations, beyond aggregate numbers and poverty status (measured, typically, in GDP per capita). With the exception of the livelihoods approach, there is limited research that integrates household configurations and patterns of resource use, sources of vulnerability, and the role of public health (including reproductive health) can play in resilience to climate change.

Keywords: Climate change, vulnerability, resilience, adaptive capacity, population

Contents

Figures

Tables

1.0 Introduction

Tension exists between the need to conduct global analyses of climate change and the likely highly differentiated small-scale impacts of climate change. Because of the global nature of the issue—neither greenhouse gas concentrations nor global climate are regional or local phenomena—studies of greenhouse gas emissions and their impacts on the climate are essential to scope the issue, especially to address issues of potential mitigation. However, since climatic impacts on natural and socio-economic systems are likely to be felt and responded to at regional/local levels, the heterogeneous conditions of individual societies necessitate more localized studies. Furthermore, the impacts of climate change will be different *within* any particular society, since rights and resources are unevenly distributed.

At more local levels, analyzing the relationships between exposure and sensitivity to climate change and climate variability, as well as the potential of adaptive capacity building and coping, is a crucial aspect in decision making processes regarding where to invest, who should make the investment (government, firms, nonprofits, private citizens, etc.), and when.

Thus, the study of climate change and its impacts on natural systems is inadequate in the face of questions about societal capabilities to cope with or adapt to these impacts—their vulnerability, resilience, and adaptive capacity. Recognizing this, the Intergovernmental Panel on Climate Change's Third Assessment Report (Working Group 2) has as its subtitle, "Impacts, Adaptation and Vulnerability" (IPCC WG 2 2001). (Previous Working Group 2 reports were subtitled, "Impacts, Adaptation and Mitigation" and "The IPCC Impacts Assessment.") In the Third Assessment Report, chapters and sections were allocated, but literature relating to climate change vulnerability was sparse and the assessment correspondingly inadequate in giving satisfactory information. In the Fourth Assessment Report (IPCC WG 2 2007) coverage of a wider set of studies was expanded, but the research assessed remains heterogeneous and unsystematic.

Increased visibility of research focused on vulnerability and its associated terms – resilience, adaptation, and adaptive capacity – has spawned more research; scientists from adjacent fields such as climate impacts, natural hazards, and sustainability have turned their attention to vulnerability and resilience. But the terms remain contested, studies are fragmented or too aggregated to be useful to decision-makers, and policy relevance continues in short supply.

Research on vulnerability and resilience is rooted in the common-sense observation that similar climate events can produce very different levels of socioeconomic impact, depending not only on the location and timing of occurrence, but also the resources and agility of the societies who experience climate change impacts. The degree of impact depends on the ways in which the natural triggering event interacts with particular ecosystems and with the specific characteristics of the society affected, including its level of economic development; the types of livelihoods of its members; education levels; and other factors that generally determine both how resilient the affected population is as well as what resources are available for adaptation.

Vulnerability, resilience, and adaptive capacity are the central concepts for this type of analysis because together they provide a framework that links biophysical climate sensitivity to social/economic factors that mitigate or amplify the consequences of environmental changes. The framework specifically

includes economic and social, political, and cultural resources available to different groups for adaptation and also provides a capability for assessing synergies and tradeoffs with other environmental conditions and trends (e.g., land use, soil/water quality) that will condition climate-related impacts. Thus the concept and approach stand in stark contrast to so-called "static impact assessments" that assess impacts by projecting potential future climates onto current social and economic conditions. Understanding the causes of vulnerability will support analysis of policy options to address its underlying causes rather than just its symptoms. Understanding resilience and adaptive capacity will provide guidance on where to direct resources to build on existing strengths or open new areas of support.

This paper addresses four related topics: (1) varying definitions of vulnerability and resilience (and, to a lesser extent, adaptive capacity) and the implications of those differences for societal analysis, (2) candidate approaches to characterizing societal resilience to climate change, (3) methods for assessing resilience, and (4) the potential contribution of a richer understanding of affected populations to the study of resilience.

2.0 Definitions

The terms "vulnerability," "resilience," and "adaptive capacity" have different meanings for different researchers. Although people know intuitively that vulnerability means a potential for harm and resilience has to do with resisting or coming back from harm, all three terms are fairly abstract. Different definitions lead to different emphases and different research approaches, so it is worthwhile to review some of these differences and to establish a set of differences and associated research approaches.

Vulnerability assessment and resilience analysis have roots in at least three disparate research communities: climate change impacts, hazards/disasters, and sustainability. As an extension of research on *impacts* of climate change, vulnerability assessment continued the linear and quantitative approaches of that community's studies, identifying, for example, land and people "at risk" from sea level rise. Interest in the extreme weather consequences of climate change attracted researchers who have long been studying the interaction of natural-world *hazards* (including storms, droughts, and floods—but also earthquakes, tsunamis, and severe pollution events like extensive oil spills) and societal preparation and response. As the clear connections between societal actions re climate change and general societal status and development came into view, *sustainability* researchers focused on climate change as one more element affecting the ability of human societies to continue to flourish.

These three scientific analytic roots are not distinguished by all researchers. Robinson and Herbert (2000:144) distinguish only climate change impacts and sustainability research roots, focus on vulnerability, and ignore resilience as a concept. They comment that

> In general, the climate change literature is science-driven, based on a problem definition, and approach to analysis, which emerged out of the natural sciences. It is academically rigorous, but difficult to connect directly to policy. The sustainable development literature, on the other hand, is problem-driven, emerging directly out of a concern for particular policy and social issues, such as poverty or environmental degradation. Reflecting this range of concerns, it is much more diverse and

less intellectually rigorous and coherent. On the other hand, it is usually connected closely to policy issues.

Hallie Eakin (2008), on the other hand, refers only to "hazards research in human geography and political-economic perspectives on development and poverty." She discusses the hazards paradigm as focusing on the outcomes of extreme events, with vulnerability as a function of exposure. Adger (2006) analyzes only two, but not the same two: rather, a hazards approach and an entitlements approach to the concept of vulnerability. (The entitlements approach, based on the work of Amartya Sen [1981], focuses on the resources that humans can command in a society, using all the rights and opportunities they have.) In Eakin's and Adger's analyses, climate impacts are treated as hazards (see the discussion of climate as hazard in Meyer et al. 1998); this conflation holds in theory, but in practice hazards are usually short-term events, whereas climate change includes many long-term, gradual changes.

Each of these research communities defines vulnerability and resilience in characteristic ways. Although the two terms plus adaptive capacity are generally treated as complementary, or at least related, the definitions reflect the different concerns of each community.

2.1 Definitions by Impacts-Oriented Researchers

Impacts research has a physical science orientation that stems from its evolution as an outgrowth of the science of the global climate, which has identified and quantified the major processes involved in interactive temperature, precipitation, and windiness. Over time, the various chemical and physical processes of the atmosphere, and the influences of the ocean, land, ice, albedo, etc. have been incorporated or represented in greater and greater detail. Impacts researchers similarly developed quantitative analyses of important elements of climate change impacts on the physical world and its systems: oceans, fresh water, plants (including crops), ecosystems, etc.

The latest definitions of vulnerability and resilience from the Intergovernmental Panel on Climate Change (IPCC) are as follows:

- Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity (IPCC WG2 2007:883).
- Resilience: The ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress and change (IPCC WG2 2007: 880).

The IPCC definition of adaptive capacity, in line with the two definitions above, is: "the ability of a system to adjust to *climate change* (including *climate variability* and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences" (IPCC WG2 2007:869). Both this definition and the definition of vulnerability are intended to apply to physical and social systems.

These definitions of vulnerability and adaptive capacity focus on the damage done by the physical system, which can (at least in principle) be quantified: lives lost, land inundated, crops destroyed or reduced, species lost, etc. Adaptive capacity is treated as a functional term, its function being to reduce the impact of climate change. Thus, vulnerability is in effect a residual term—what is left when exposure-plus-sensitivity is reduced by adaptive capacity.

Another, although unstated, definition of vulnerability used in the IPCC reports conceptualizes the terms as one side of a cost-benefit analysis. That is, the costs of preventing climate change are weighed against the damage it could do (i.e., vulnerability); if the costs of mitigation—or even adaptation—are greater than the damages, society (at local, national, or international levels) can choose to, in Ian Burton et al.'s (1993) phrase "bear the loss."[1] Differential impacts and equity are secondary considerations, principally because they cannot be weighed in the cost-and-benefit scale.

2.2 Definitions by Hazards/Disasters Researchers

Research with roots in the scientific study of natural hazards and responses integrates information about climate extremes such as severe storms and droughts with social information about vulnerabilities and resilience. Extreme events are the easiest impacts of climate change to visualize, so this line of research has appropriately become a rich area of inquiry.

Definitions of vulnerability in the hazards research literature tend to focus on characteristics that will help people plan for, cope with, resist and recover from the damages of natural hazards. In this regard, such dimensions as physical, social, cultural and psychological vulnerability are included; these dimensions may be examined under conditions of gender, time, space and scale.

Cutter (1996) identifies three distinct foci of definitions for vulnerability: (1) as risk of exposure to hazards (e.g., settlements in flood plains), (2) as a capability for social response (e.g., exit road systems and insurance), and (3) as an attribute of places (e.g., vulnerability of coastlines to sea level rise). The hazards orientation is clear. There are climate hazards (plural), but the crossover concept is the consideration of climate (singular) as a hazard under climate change. That is, even those features of climate that may be slow (like sea level rise) instead of sudden and severe or that may be benign in today's world (like early springs) may become hazardous in a new, different climate regime.

2.3 Definitions by Sustainable Development Researchers

Impacts research emphasizes the physical characteristics of vulnerability; hazards research accounts for human responses; sustainable development research focuses on the societal characteristics that make people vulnerable—elements of governance and institutions. Researchers of sustainable development examine general development issues such as poverty and capacity-building. In this perspective, vulnerability is thought of as a characteristic of a society, a lack of capabilities or "capitals"[2] (Sen 2000) such that they cannot cope with or adapt to climate change manifestations.

[1] Other options are "share the loss" and "avoid the loss."
[2] Natural, economic, human, social, even network capital can be included.

Two definitions of vulnerability are representative of the literature oriented toward sustainable development:

- For poor people, vulnerability is both a condition and a determinant of poverty, and refers to the (in)ability of people to avoid, cope with or recover from the harmful impacts of factors that disrupt their lives and that are beyond their immediate control. This includes the impacts of shocks (sudden changes such as natural hazards, war or collapsing market prices) and trends (for example, gradual environmental degradation, oppressive political systems or deteriorating terms of trade). In relation to climate change, vulnerability relates to direct effects such as more storms, lower rainfall or sea level rises that lead to displacement, and to indirect effects such as lower productivity from changing ecosystems or disruption to economic systems (International Institute for Sustainable Development 2003).
- Vulnerability is the inequitable harm to developing countries caused by the pollution-producing activities of industrialized countries (e.g., McMichael 1993).

The emphasis on society and societal characteristics is clear and clearly different from the climate change impacts-oriented research. In the latter, vulnerability inheres mostly or completely in the characteristics of climate change impacts; in sustainability analyses, vulnerability inheres mostly or completely in societal characteristics.

One branch of research that is contributing to both the literatures on sustainable development and climate change has been developed out of Holling's theories of ecosystem resilience (Holling 1975). The Stockholm Environmental Institute and the Stockholm Resilience Centre have grown out of and fostered this research. The latter's definitions of resilience and vulnerability are as follows:

- Resilience refers to the capacity of a social-ecological system both to withstand perturbations from, for instance, climate or economic shocks and to rebuild and renew itself afterwards (Stockholm Resilience Centre 2007b)
- Vulnerability refers to the propensity of social and ecological system to suffer harm from exposure to external stresses and shocks. Research on vulnerability can, for example, assess how large the risk is that people and ecosystems will be affected by climate changes and how sensitive they will be to such changes. Vulnerability is often denoted the antonym of resilience (Stockholm Resilience Centre 2007a).

Here the term "social-ecological system" is meant to convey the integration of the physical and social aspects of vulnerability. Moreover, this systems approach is a strength of the resilience-oriented research community; the systems approach to resilience emphasizes the dynamism of systems that need to respond to changes, in contrast to approaches discussed earlier. Another strength of this research community is that it accounts for multiple time and spatial scales, at least conceptually. However, most of the research done within the resilience community emphasizes ecological aspects and is highly theoretical, in contrast to the hazards research community which emphasizes case studies.

2.4 Definitions Used in this Paper

The focus of this paper is resilience to climate change. When impacts research began to expand beyond estimates of damages to agriculture, coastal areas, and the like, the initial focus was on vulnerability. However, both analytically and pragmatically, resilience is a more useful focus.

Vulnerability is a deficit concept; researchers and analysts are examining what is wrong, with at least an implicit conclusion that vulnerability-contributing factors need correction. Such an approach poses problems for those who might use the research. Because high values of many attributes are good (high income, test scores) but high vulnerability is bad, instead of trying to raise low values, the recommendations have the counter-intuitive effect of suggesting that decision-makers work on lowering high values.

Due to these difficulties with vulnerability, we focus instead on the concept of resilience. In contrast to vulnerability, resilience is a positive concept; high "scores" are good and factors like air pollution and lack of education are negatives. This association makes intuitive sense as the results of a quantitative assessment are discussed. The concept of resilience has a robust history in ecology, beginning with Holling (1973). In addition, Folke (2006) describes the evolution of the term's meaning in ecology and in social-ecological systems analysis. Originally, resilience most often meant a return to a previous state. A perturbation hit a system and (quickly or gradually) went back to its original condition. Subsequent work, both on ecosystems and societies, has identified the potential for multiple equilibria and the possibility of successfully adapting to changed circumstances by developing a new state. This is important for developing countries, in which the original state may not be the desired state to which to return. Thus, resilience includes both an element of recovery and an element of change.

When the term resilience is used with an emphasis on society while also integrating environmental characteristics, it can be equated with adaptive capacity. Brooks and Adger (2005:168) provide an elaborated definition of adaptive capacity, which resonates with our definition of resilience:

> In practical terms, adaptive capacity is the ability to design and implement effective adaptation strategies, or to react to evolving hazards and stresses so as to reduce the likelihood of the occurrence and/or the magnitude of harmful outcomes resulting from climate-related hazards. The adaptation process requires the capacity to learn from previous experiences to cope with current climate, and to apply these lessons to cope with future climate, including surprises.

3.0 Research Methods: Measuring Vulnerability and Resilience

The resilience or adaptive capacity of a society, no matter how it is defined or described, is not easy to measure. Early literature on the subject frequently assumed that wealthy, industrialized countries would be able to adapt while poor, less industrialized countries would not (e.g., Magalhães 1996)—i.e., the measure of wealth is sufficient to predict adaptive capacity. The IPCC Third Assessment Report identified five features "that seem to determine their adaptive capacity: economic wealth, technology, information and skills, infrastructure, institutions, and equity" (Smit et al. 2001:895), but then went on to

point out that all features are highly contingent on varying social conditions and, moreover, adaptive capacity is also linked to overall development and sustainability. However, recent research questions even this assumption. For instance, measures of overall development may be focused on economic growth to the exclusion of environmental or worker protection.

Another important methodological issue is the level at which research is conducted. Researchers, faced with the question of the appropriate research level—global, regional/country or local—have generally used one of two prevailing approaches. The first of these approaches is to conduct highly aggregated quantitative studies of emissions and concentration levels. The second approach is to conduct disaggregated, often purely qualitative, case studies of single countries or localities. Further, a third approach, theoretical systems analysis, is emerging but not yet a mainstream methodology. These different approaches have opened two gaps: an inability to compare countries and regions with regard to their resilience to climate change impacts, and a lack of studies that account for societal inequalities that will themselves be affected unequally by climate change. These gaps prevent decision-makers from carefully weighing options that have short- and long-term implications.

This analysis has already touched on two major and one non-mainstream scientific methods used in research about vulnerability, resilience, and adaptive capacity: indicators-based research, case studies, and systems analysis. A fourth approach may be characterized as a scenarios approach.

3.1 Indicators-Based Research

The discussion in the next section lists several sets of indicators that have been used in research studies, and these are representative of the climate change literature. This section describes some of a much broader literature on social indicators, a literature that includes more detail on social conditions, environmental factors, or both.

Cutter et al. (2003) developed a county-level Social Vulnerability Index (SoVI) for the United States. To construct the index, they reduced 42 demographic and social variables (none relating to hazards, although vulnerability to hazards was the focus of the study) to 11 independent factors accounting for 76% of the variance among counties (in deaths from weather-related hazards). Seven of the factors were (in order, 1-5 and 10-11) personal wealth, age, density of the built environment, single-sector economic dependence, housing stock and tenancy, occupation, and infrastructure dependence. Factors 6-9 related to race and ethnicity—African American, Hispanic, Native American, and Asian. This index provides a good picture of the population in the United States that is vulnerable to hazards—that is, for whom hazards become disasters. Anyone familiar with this analysis, for instance, was not surprised to learn that the poor, the aged, the hospitalized, the poorly housed, and people of color were hardest hit by the impacts of Hurricane Katrina.

At the other end of the spectrum, the Environmental Performance Index developed by Yale and Columbia Universities (CIESIN and YCELP 2008) focuses on the environment as used or misused by humans. Environmental health and ecosystem vitality are gauged using 25 indicators tracked in six policy categories: environmental health, air pollution (and its effects on ecosystems), water (and its effects on ecosystems), productive natural resources, biodiversity and habitat, and climate change. None of the indicators addressed population, or demographic factors, despite the aim of being policy relevant. The

2008 index centers on (1) reducing environmental stresses on human health, and (2) promoting ecosystem vitality and sound natural resource management.

Prescott-Allen (2001) provides a host of indicators at the country level, integrating them in his presentation of "eggs," in which the yolk represents the human condition, surrounded by the white, which represents the ecosystem condition. The eggs for a region can then be placed on a square which is color coded to represent five states: good, fair, medium, poor, and bad. Below is an example for Northern Africa, with a cluster of countries ranking medium-to-fair on ecosystem wellbeing but poor on human wellbeing. For example, Ethiopia ranks in the lowest quintile in terms of human wellbeing and at the bottom of the fair quintile in ecosystem wellbeing).

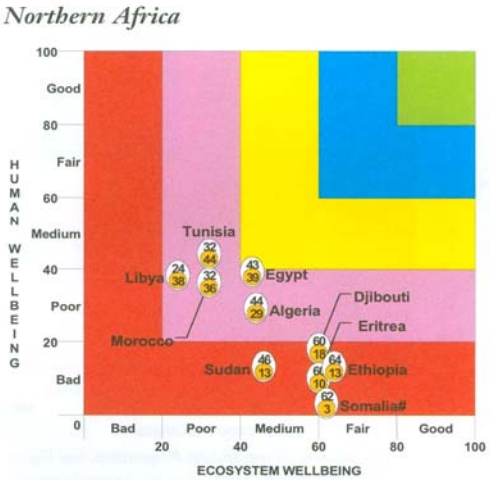

Figure 1. The "eggs" in this figure score the human condition (the yolk) within the ecosystem condition (the white). The eggs are set in a background that maps both conditions, showing comparisons among (in this case) North African countries. Source: Prescott-Allen 2001.

Studies of vulnerability and resilience have used mapping techniques to integrate information about various aspects of vulnerability. For instance, combining exposure and/or sensitivity variables and adaptive capacity variables can locate vulnerable areas. This technique can locate "hot spots" of vulnerability or point out the difficulties and uncertainties in identifying areas as vulnerable (Patt et al. 2005, Preston et al. 2007). Two examples illustrate this methodology.

O'Brien et al. (2004) mapped, separately and together, adaptive capacity, the climate sensitivity index, vulnerability, and exposure to globalization in India at the district level. The researchers examine areas in India that are "double exposed" to climate change and to globalization.

Yohe et al. (2006a, b) co-mapped the two IPCC-defined components of vulnerability: exposure (measured as temperature increase at two sensitivity levels: 1.5°C and 4.5°C) and adaptive capacity (measured as the geometric mean of seven proxy variables, including economic, human, and environmental resources). They produced a series of global maps to explore the potential for various countries' adaptive capacity to deal with climate change in the future.

Indicators research has both strengths and weaknesses. The use of representative indicators in a mathematical framework was an advance on the early laundry lists of factors that could be said to be relevant to a region's or country's vulnerability (later, adaptive capacity or resilience). Moreover, their use has allowed valuable comparative analysis to take place and provided insight into the many ways a country, state, or region could be vulnerable. But they have weaknesses, too: indicators may not truly represent the qualities that researchers want to measure, variables may be overlapping, gaps may arise from lack of data, and indicator sets typically do not provide interactions and feedbacks characteristic of real systems in the real world. Moreover, they may focus policy attention on fixing the indicator rather than the conditions represented by the indicator.

Moreover, most indicators studies lack the "view from below," i.e., the perspective of individuals, households, and local societies who will experience the impacts of climate change. Indicators of adaptive capacity, almost without exception, reflect an external perspective—of the country, of the economy, of technology, and so on. They describe populations in very aggregated terms, typically as total numbers of people and GDP per capita. They fail to account for how everyday life is lived and how well households are actually doing on the ground, rather than on average.

3.2 Case Studies

To meet the need for detailed knowledge, researchers use case studies. Many such studies exist; they have been assessed in the last two IPCC reports (see IPCC 2007, 2001) and appear in journals such as *Global Environmental Change* (e.g., the 2006 special issue on resilience, vulnerability, and adaptation edited by Colleen Vogel, Volume 16). Examples of case studies in the literature range from an analysis of the Bangladesh National Water Management Plan (Agrawala et al. 2003) to drought in Mexico (Luers et al. 2003) to changes in the insurance sector. Adger et al. (2007) cites many others, and Franklin and Downing (no date) single out studies on migratory insectivorous birds (Canada), cash crops versus subsistence crops and storage (Samoa), fish stock collapses (Baltic Sea), and lagoon ecosystem renewal (Brazil) as strong examples of resilience. From these studies, Franklin and Downing (ND) derive key factors in strengthening resilience: strong institutions, cross-scale communication, political space for experimentation, social justice, and use of ecological knowledge.

Case studies provide fine-grained analyses but little comparability, except where research has been undertaken with a common framework (e.g., Abler et al. 2003). The findings of each case study have to be evaluated anew in subsequent studies of other places if any general insights are desired. So, much-desired transfer or replicability potential may be lost in the need to conduct a sizeable number of similar studies. Thus, case studies often lose the big picture view and fail to connect what is happening in one place with what is happening in another.

3.3 Systems Approach

The third approach taken to measuring resilience involves the systems approach advocated by Holling-influenced researchers and taken up by an interdisciplinary group of scientists. One potentially productive fruit of the theoretical research is an analysis of global syndromes of change (Schellnhuber et al. 2002). In this approach, researchers have attempted to incorporate systems complexity, including

incomplete, vague, or qualitative knowledge into a formal framework. They have suggested 16 syndromes:

Utilization Syndromes:

- *Sahel Syndrome:* Overcultivation of marginal land
- *Overexploitation Syndrome:* Overexploitation of natural ecosystems
- *Rural Exodus Syndrome:* Environmental degradation through abandonment of traditional agricultural practices
- *Dust Bowl Syndrome:* Non-sustainable agro-industrial use of soils and bodies of water
- *Katanga Syndrome:* Environmental degradation through depletion of non-renewable resources
- *Mass Tourism Syndrome:* Development and destruction of nature for recreational ends
- *Scorched Earth Syndrome:* Environmental destruction through war and military action

Development Syndromes:

- *Aral Sea Syndrome:* Environmental damage of natural landscapes as a result of large-scale projects
- *Green Revolution Syndrome:* Environmental degradation through the introduction of inappropriate farming methods
- *Asian Tigers Syndrome:* Disregard for environmental standards in the course of rapid economic growth
- *Favela Syndrome:* Environmental degradation through uncontrolled urban growth
- *Urban Sprawl Syndrome:* Destruction of landscapes through planned expansion of urban infrastructures
- *Disaster Syndrome:* Singular anthropogenic environmental disasters with long- term impacts

Sink Syndromes:

- *Smokestack Syndrome:* Environmental degradation through large-scale diffusion of persistent substances
- *Waste Dumping Syndrome:* Environmental degradation through controlled and uncontrolled disposal of waste
- *Contaminated Land Syndrome:* Local contamination of environmental assets at industrial locations.

The German Advisory Council on Global Change (1996:116-117) elaborates on the Sahel Syndrome by listing its typical manifestations as soil degradation, the spread of desert-like conditions, the depletion of fossil aquifers, the conversion of semi-natural ecosystems (deforestation, for example), the loss of biodiversity and changes in regional climate. The problems people face arising from the Sahel Syndrome include mounting poverty, rural exodus, greater vulnerability to food crises as well as rising frequency of political and social conflicts over scarce resources. Eventually, affected groups have less and less scope for action (with resulting severe famine in extreme cases).

The work on syndromes shows several promising characteristics. First, although every place is unique and its set of vulnerable or resilient characteristics is likewise unique, it may be possible to define a relatively small set of interactions types that describe linked social-environmental change. Second, this approach meets the inescapable need to integrate quantitative and qualitative knowledge in order to identify the pattern(s) of change in particular places. Third, the system approach accounts for interactions among variables. Fourth, each syndrome can be mapped to at least three possible outcomes: population decline and collapse from overuse of the environment, steady-state population and resource use, and increasing population with increasing use of available resources.

A potential problem in the syndromes approach is the large number of variables—80—and the resulting problems in data availability and quality, as well as issues of overlap. Moreover, once the conceptual framework is established, modeling (especially with the overhead of massive data gathering) may not yield any more insight than a thoughtful qualitative analysis bolstered by data as available.

But perhaps the most important problem in this approach is the failure to account for anything other than resource use in population health or decline. For instance, fertility declines could change the outcome of any syndrome.

The value of the conceptual work may be captured in resilience analysis by trying to identify different functional processes that contribute to syndromes, or patterns, of resilience. The usual approach is to identify the important elements in a resilient society, as previously discussed. A syndromes-like approach would recognize that these elements connect and influence each other in different ways in different societies and connect to and influence their environments in different ways.

3.4 Scenarios Approach

Scenarios are plausible pictures of the future – not predictions, but a description of possible conditions. Often two or more scenarios are developed, frequently with a group of experts or stakeholders, in order to examine either the consequences of certain alternative decisions to be made in the near future or to test (at least in conversation) what the important kinds of developments or conditions might be as they play out in the future.

A scenarios approach can take the form of forecasting/projecting or "backcasting." In forecasting, or projecting, researchers specify a number of variables and explore what different rates of change or various constraints mean for future values of those variables. Backcasting involves specifying, with a group of stakeholders, a desirable future and then exploring the conditions and actions (i.e., an unlimited set of variables that emerge from dialogue) that can lead to that future (Robinson 1988, 1990). Once a future condition is agreed upon, participants can determine either next steps ("What can we do today?") or a series of actions/activities that will bring about that condition. This methodology, which relies heavily on stakeholder involvement, analyzes future options in light of how desirable futures could be attained, rather than the more usual exploration of futures that are likely given a set of starting assumptions.

4.0 Factors that Characterize Resilience

We know that uncertainty in projections of global change grows as spatial scale decreases; for instance, scientific findings about projected global warming are fairly certain, but changes in the climate of the Mid-Atlantic coast of the United States or the steppes of Central Asia or the tropics are generally much more uncertain. As we look into the future, we find our crystal balls somewhat cloudy at the global scale but very dim indeed at the local or even regional scale. Similarly, although projections of increasing prosperity at the global scale are based on hundreds of years of data, projections of such conditions as regional conflicts, market booms and busts, and commodity production are more matters for educated guesses than predictions. Finally, trying to account for a changing climate and changing societies as an integrated system with nonlinear properties is daunting.

Nevertheless, this is the challenge we set ourselves in identifying the factors that characterize resilience.

Resilience of societies and activities is an excellent umbrella concept for those factors that mediate between geophysical conditions and events, on the one hand, and human abilities to cope with, take advantage of, or adapt to those conditions and events, on the other hand (Rayner and Malone, 2000a:216-217). As explored throughout this paper, resilience is a composite concept, incorporating environmental, social, economic, political, demographic, cultural, gender and psychological factors, in describing the capacity to recover and survive, to change and grow. This conceptualization draws attention to the amplifiers or attenuators of the impacts of climate change and points toward characteristics of certain groups, certain institutions, and certain places. It also emphasizes the degree to which the risks of climate catastrophe can be cushioned or ameliorated by adaptive actions that are or can be brought within the reach of populations at risk.

For instance, Yohe and Tol (2002:26) identified eight generalized "determinants of adaptive capacity," many of which are societal in character, although the authors draw on an economic vocabulary and framing:

1. The range of available technological options for adaptation
2. The availability of resources and their distribution across the population
3. The structure of critical institutions, the derivative allocation of decision-making authority, and the decision criteria that would be employed
4. The stock of human capital, including education and personal security
5. The stock of social capital, including the definition of property rights
6. The system's access to risk-spreading processes
7. The ability of decision-makers to manage information, the processes by which these decision-makers determine which information is credible, and the credibility of the decision-makers themselves
8. The public's perceived attribution of the source of stress and the significance of exposure to its local manifestations.

Each of these factors could be assigned a subjective value from 0 to 5 to construct an index of capacity. Yohe and Tol apply such an index to a hypothetical example of evaluating water management options in Egypt by their likely outcomes as measured by the index.

The Vulnerability-Resilience Indicators Model (VRIM) (Moss et al. 2001, Brenkert and Malone 2005, Malone and Brenkert 2008) identifies 17 factors (listed in Table 1) that together assess the resilience of a society. Managed and unmanaged land, economic activities that are natural resource-intensive, and socioeconomic characteristics are represented. The VRIM has been used to compare 160 countries (Moss et al. 2001, Malone and Brenkert in press a), evaluate adaptive capacity at temperature increases of 1.5°C and 4.5°C (Yohe et al. 2006a,b), analyze India and Indian states under current conditions (Brenkert and Malone 2005) and future scenarios (Malone and Brenkert 2008), and examine resilience in Mexico and Mexican states (Ibarrarán et al. in press).

Azar et al. (1996) propose indicators to assess sustainability, although no example uses are given in the article. They derive four principles of sustainability and develop indicators under each (see Table 2). Under Principle 4, equality in both current and future generations is implied but without specifying, e.g., class, race, or gender.

Table 1. The sectors and variables used in the Vulnerability-Resilience Indicators Model (VRIM). Source: Brenkert and Malone 2005.

Sectoral Indicators	Proxy Variables	Proxy For
Food security	Cereals production/ crop land area	Degree of modernization in the agriculture sector; access of farmers to inputs to buffer against climate variability and change
	Protein consumption/ capita	Access of a population to agricultural markets and other mechanisms (e.g., consumption shift) for compensating for shortfalls in production
Water resource sensitivity	Renewable supply and inflow of water	Supply of water from internal renewable resources and inflow from rivers divided by withdrawals to meet current or projected needs
Settlement/ infrastructure sensitivity	Population at flood risk from sea level rise	Potential extent of disruptions from sea level rise
	Population without access to clean water	Access of population to basic services to buffer against climate variability and change
	Population without access to sanitation	
Human health sensitivity	Completed fertility	Composite of conditions that affect human health including nutrition, exposure to disease risks, and access to health services
	Life expectancy	
Ecosystem sensitivity	% Land managed	Degree of human intrusion into the natural landscape and land fragmentation
	Fertilizer use/ cropland area	Nitrogen/phosphorus loading of ecosystems and stresses from pollution
Human and civic resources	Dependency ratio	Social and economic resources available for adaptation after meeting other present needs
	Literacy	Human capital and adaptability of labor force
Economic capacity	GDP(market)/ capita	Distribution of access to markets, technology, and other resources useful for adaptation
	An income equity measure	Realization of the potential contribution of all people

Environmental capacity	% Land unmanaged	Landscape fragmentation and ease of ecosystem migration
	SO_2/area	Air quality and other stresses on ecosystems
	Population density	Population pressure and stresses on ecosystems

Table 2. Proposed principles to be used in assessing sustainability. Source: Azar et al. 1996.

Principle 1: Substances extracted from the lithosphere must not systematically accumulate in the ecosphere.	Principle 2: Society-produced substances must not systematically accumulate in the ecosphere.	Principle 3: The physical conditions for production and diversity within the ecosphere must not systematically be deteriorated.	Principle 4: The use of resources must be efficient and just with respect to meeting human needs.
1.1 Lithospheric extraction compared to natural flows	2.1 Anthropogenic flows compared to natural flows	3.1 Transformation of lands	4.1 Overall efficiency
1.2 Accumulated lithospheric extraction	2.2 Long-term implication of emissions of naturally existing substances	3.2 Soil cover	4.2 Intragenerational justice
1.3 Non-renewable energy supply	2.3 Production volumes of persistent chemicals	3.3 Nutrient balance in soils	4.3 Intergenerational justice
	2.4 Long-term implication of emissions of substances that are foreign to nature	3.4 Harvesting of funds	4.4 Basic human needs

Brooks et al. (2005) list 46 proxy variables; the researchers specifically include governance, geography and demography, and technology (not explicitly included in the VRIM). They looked for correlations among these vulnerability proxies and historical decadal mortality and derived from these results 11 key indicators of vulnerability: population with access to sanitation, literacy rate (15-24-year-olds), maternal mortality, literacy rate (over 15 years), calorie intake, voice and accountability, civil liberties, political rights, government effectiveness, literacy ratio (female to male), and life expectancy at birth. (The emphases on health, education, and freedom of action and speech are notable.) These key indicators were then discussed in focus groups to validate them. Finally, Brooks et al. ranked countries in Sub-Saharan Africa on the basis of these key proxy variables. In contrast to Azar et al., this set of indicators explicitly considers some aspects of reproductive health and gender equity.

However, these efforts at compiling indicators do not specify in their lists or models the interactions and feedbacks among the drivers/factors in resilience. Other, more general indicator sets (e.g., Prescott-Allen's *Wellbeing of Nations* or the *Calvert-Henderson Quality of Life Indicators*) (Prescott-Allen 2001, Henderson et al. 2000) have this same limitation. However, the variables and any indicator and indexes derived from them remain transparent to a user or reader.

Brooks and Adger (2005) point out that the concept of adaptive capacity only makes sense in the context of what resources and systems would be affected by climate change. Some aspects of adaptive capacity can be generally useful, such as the flexibility that high levels of education brings. Other aspects are very specific, such as the ability to build coastal protection infrastructure or to plant drought-resistant crops. The U.S. Agency for International Development's project Famine Early Warning System (FEWS 1999), for instance, focused its vulnerability assessment guidance on food security.

Drawing on the hazards literature for an assessment of social vulnerability to climate change in Africa, Vincent (2004) selects variables that define coping ranges for various elements: economic well-

being and stability, demographic structure, institutional stability and strength of public infrastructure, global interconnectivity, and natural resource dependence. Coping ranges define the extent of short-term variation that a society has demonstrated it can deal with—e.g., occasional droughts. Each of these determinant areas has 1-3 component indicators associated with it; for instance, demographic structure includes dependent population and proportion of the working population with HIV/AIDS.

Downing (2005), at the other end of the aggregation-disaggregation spectrum, advocates a grassroots process in which community stakeholders determine *what* they are vulnerable to (droughts, storms, etc.), *who* is vulnerable, *how* future vulnerability is shaped, and at *what scales*. Thus, a good vulnerability assessment will be unique to the community where it is developed; plans for mitigation and adaptation will be specific to that place and society. Brooks and Adger (2005) discuss a similar bottom-up, place-and-community specific approach to assessing and building adaptive capacity, and Smit and Wandel (2006:288) join the chorus by describing "participatory vulnerability assessments [that] allow for the recognition of multiple stimuli beyond those related to climate, to include political, cultural, economic, institutional and technological forces. Furthermore, the methodologies recognize the interaction of various exposures, sensitivities and adaptive capacities over time."[3]

Trying to distill the insights from these and many other studies—much less to choose an authoritative set of factors—is a potentially endless task. There is some convergence, to be sure, but many areas in which there is sharp disagreement or dissatisfaction with the level of detail or representativeness. This paper takes a different tack in developing and specifying the characteristics that would contribute to societal resilience. That is, the analysis addresses the questions, "What would a society that is resilient to climate change look like? What characteristics would it have?" Following are three alternative ways to describe such a society. ("Society" may mean all the people in a country; in a smaller geographic unit, e.g., a state or community; or a group that coheres around an identity, such as ethnicity. The term includes both government and citizens.)

4.1 Approach 1: Establishing Standards

In the first approach, standards are set for a resilient society. This is in contrast to most studies, which only represent conditions as they are (for exceptions, see Jones et al. 2005 and Luers et al. 2003). Following is one such set of standards:

A locale well prepared to adapt to climate change would have a healthy environment to start with and resources with which to manage change. There would be clean air and plenty of clean water. Urban areas would be designed to deliver needed services and, while affording people adequate living space, would not increase vulnerability by, e.g., expansion into below-sea-level land or agriculturally productive areas. A healthy percentage of land would be protected for environmental purposes. This describes a region that is not very sensitive to climate change—some of these attributes have to do with natural endowments, but all are affected by human use.

[3] This is also the approach of the United Kingdom's Climate Impacts Programme, although that program's focus is on impacts rather than on vulnerability or resilience.

On the social side, a prosperous economy would indicate that the region is resilient, since it has at least financial and institutional resources to cope with or adapt to changes in climate. Income would be high and distributed relatively evenly, leading to low poverty rates. Crime would be low, and education levels would be high. Gender equity would be the norm in law and in practice. The region would have low energy usage (for example, high public transportation usage), and health care would be very accessible. In Amartya Sen's (2000) terms, people would have the ability to choose how to live their lives, and their life chances would have a favorable outlook. Importantly, the levels of "healthy," "adequate," "high," and "low" would be defined by the society.

4.2 Approach 2: Detailed Analysis

To perform a more detailed analysis of current socioeconomic conditions in interaction with environmental conditions, more structure than is given in the first approach may be desirable. Malone and LaRovere (2005) suggest a structure for characterizing socioeconomic conditions, including socio-demography, economics, natural resource use, governance and policy, and culture.

Socio-demographic analysis: A resilient society would have a population which is not overcrowded and in which people are distributed in areas in which they can earn a living. A resilient society would have people who are healthy and do not die prematurely. Women and couples would have the number of children they want and can care for.

The number of people in the society (population size) is a typical starting place in socio-demographic analysis, but societal well-being depends on how these people are distributed in the area (density, urbanization, land per household, etc.), the land tenure regime, the rate of population growth (including in- and out-migration), age distribution and family size, health, and education. A comparison with a larger societal group (e.g., if the primary analysis is at the subnational level, then the comparison would be with national-level demographic characteristics) will yield insights about resilience at both scales.

Economic analysis: A resilient society offers at least moderate diversity in economic activity, so that switches from one livelihood (e.g., farming) to another (e.g., shop-keeping) are possible. Males and females would be at least moderately educated (i.e., have enough "human capital" to enable choices with regard to livelihoods), have opportunities for alternative employments, and are as well off as neighboring societies or the larger society of which they are a part. The society – here individuals working through governmental structures – would have the ability to determine its participation in markets. Households should have some savings and access to credit and welfare programs to tide them over in lean times. Finally, incomes and/or other returns to economic activity should be sufficient to support dependents.

People's principal ways of making a living and the important livelihoods in the area/society are crucial types of information in analyzing resilience. Trends are important, also; for example, in an agricultural society, changes in the types of crops grown, off-farm employment rates, or general productivity can indicate whether resilience is increasing or decreasing. Other relevant knowledge might include the rate of participation in formal and informal markets, favorable and fair land tenure systems, the extent of credit for small businesses (such as farms), income, and savings.

Natural Resource Use/Dependence: A resilient society will meet the definition of sustainability in resource use. That is, the society's members should only use enough to meet their needs without compromising future use; the ability of the environment to regenerate should be equal to or more than people's withdrawals from it (for food, drinking, sanitation, shelter, and other needs).

The knowledge of how and how much people use their resources (land, water, forests, minerals, etc.) allows an assessment of whether or not climate change would cause material changes in the economy and way-of-life of a society. If so, the full accounting of resources and other factors such as service sector activities will indicate whether the society can redirect livelihoods to alternative activities and sources of income.

Analysis of Governance and Policy: In a resilient society, governance (including all levels of government and organizational influence) supports productive lives, regulates markets for the good of producers and consumers, provides safety nets when people cannot help themselves, and keeps people generally safe from crime and violence. All citizens, including minorities and females, have equal rights and the means to assert them.

Support of the government through changing times can mark the difference between an easy transition and a difficult one. Relief programs (including unemployment income), job training, insurance, crop supports, import duties, and development policies—and the demonstrated ability of the government to implement such programs—provide a context in which people expect that they will get support through hard times or not.

Cultural Analysis: A resilient society reflects the social and cultural values that contribute towards social, human, and natural capital. The society respects the range of cultures within the society that promote social, human and natural capital.

The way families are defined and supported within society by governments and local communities and members' duties to one another, their relationship with nature, and the tendency to accept (or reject) outside help or technology are integral parts of the society's ability to change along with the climate.

4.3 Approach 3: Social and Cultural Ties

A resilient society, in this approach, would be a society characterized by multiple, complex, diverse network ties among its people (social capital) and a societal disposition to provide its members with actionable choices about how to live their lives (i.e., not just the "right" to do something, but the means as well). Different cultural perspectives would be valued for their potential to offer alternative meanings and courses of action.

The resilience of a society is at its heart inherent in the qualities of its people, individually and collectively. Indicators research (and, to an extent, case study research) measures these qualities by what are thought to be the outward manifestations of this resilience. A perhaps more direct method draws on the research of Cultural Theory (Douglas 1978, Rayner and Malone 2000b; Sen 1979, 2000; Putnam 1992) to think about the sources of resilience that reside in the people themselves.

Cultural Theory analyzes four different perspectives on social life, and by accounting for both the pull of individualism and the pull of the societal group, is one solution to the social science problem of whether social structures totally constrain individuals (social determinism) or individuals are totally free agents (free will). Cultural Theory resolves the tension between these two poles in at least four different "ideal type" ways, leading to predominant ways of thinking in a society. Thus, some societies are markedly individualistic (such as the United States), some are hierarchical (such as Japan), some egalitarian (such as Norway), and some fatalistic (usually smaller societies where the individual as seen as powerless against the powers of the universe). Douglas' original diagram of Cultural Theory looks like this (where "grid" means the control of the individual by societal rules and "group" means the importance of the group to individuals):

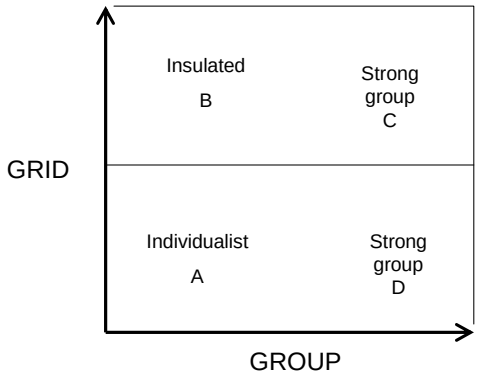

Figure 2. Cultural Theory classifies groups according to their orientation to the group (strong or weak) and the extent to which the group is highly controlled by rules (high or low grid). Source: Douglas 1978.

Cultural Theory helps explain differences in social structures, views of nature, and the way people diagnose problems and propose solutions to them (Thompson and Rayner 1998). The theory also describes the strengths and weaknesses of types of groups or societies and the ways in which the types provide sources for alternative strategies as societies develop and are confronted with novel problems.

Each society has elements of all four perspectives, with one or two predominating. Any perspective that is very strongly adopted by a society has real dangers that could be corrected by features of the other perspectives. So a resilient society is one that values all of its perspectives and is able to switch strategies when one strategy fails.

How does a society accomplish preserving its perspective options? Here Robert Putnam and Amartya Sen suggest appropriate safeguards.

Putnam's landmark research on Italian states (1992) demonstrated that people's multiple, overlapping, disparate ties are a good predictor of prosperity and high satisfaction with life. Knowing each other in various ways (e.g., a sports club and a workers' union) and having associations through others as well (e.g., a cousin on the school board knows the board president), people are motivated to work out problems instead of retreating into oppositional camps, and they can derive satisfaction in their lives from multiple sources.

From Sen (2000) comes the insight that lack of goods or services is not the essence of poverty. Instead, poverty means lack of choices during the life course. Recognizing that individuals have different capabilities and needs, Sen advocates a development goal of all people having the positive means to live the lives they want to live. This is especially relevant to women in many societies; in high-poverty areas, they tend to have the fewest choices, yet are responsible for children and activities that relate to adaptation. For instance, some people may be happy with a minimal education, while others want Ph.D.s. One handicapped person may want transportation to compensate for her deficits, while another may not. Government, organizations, and associations can provide resources to foster different capabilities.

5.0 Potential Contributions of Demography to Resilience Research

The weaknesses of most indicators research, highly aggregated case studies, and research focused on environmental factors can be at least partially offset by using or enriching the demographic analysis that helps describe more characteristics of the people who are vulnerable, who will be affected by climate change, and who will undertake any mitigation or adaptation activity. In other words, *all* research approaches to resilience will benefit from more demographic knowledge, including the fertility and mortality patterns of societies. Knowing how many children people have and why they have that number could help understand patterns of resilience and adaptation. Analyzing when infants, children and adults die and different mortality patterns for males and females can also contribute to understanding resilience. Understanding age structure, household size, population distribution in urban and rural areas, and migration patterns can provide a social context that allows analysts to see how households are constituted, the elements that affect their functioning, and what disrupts them (e.g., resulting in migration). These same demographic elements help case studies to account for the larger context in which communities are set and to investigate both sending and receiving areas when people migrate. Analyzing population growth rates can help explain the ability of societies to provide growing populations with provision of education, health and other services.

The importance of population-related data for resilience may also be seen in the area of livelihood resilience. In many cases, poor people make ends meet in a number of ways, mixing, perhaps, hunting, herding, fishing, selling labor, craft production, etc. When any one combination of these becomes hard to sustain, extra effort is channeled into other activities, permitting individuals and families to survive difficult changes in the subsistence environment.

Thus, an essential factor in understanding the resilience of individuals, households, and societies is fertility and health data. First, even the broad-brush analysis of socioeconomic characteristics of Cutter et al. (2003) may be of value in pinpointing and including all vulnerable groups in a society. But more important, the details of needs (met or unmet) for family planning and reproductive health services, immunization, clean water, adequate food—at the individual and household level—shows *what* is needed to build resilience and *where* the information, services, etc. are needed.

An important dimension of assessing resilience is identifying the risks people face, especially those they self-report, and their strategies and desired strategies to build resilience. Imposed, this-is-good-for-you programs have a small chance of succeeding next to programs that fulfill felt needs.

6.0 Conclusion

Climate change research is increasingly focused on the capacity of human societies to respond to climate impacts. For this line of inquiry, vulnerability, resilience, and adaptive capacity provide conceptual frameworks for examining the social-environmental systems that exist and will need to change in reducing greenhouse gas emissions and especially in adaptive to an altered climate.

The concepts of resilience and adaptive capacity encompass a suite of characteristics that enable societies to change. Measuring resilience or adaptive capacity is not easy; it is complicated by different data types (physical and social data), timescales, boundaries (e.g., political or geographical), and views on what are important variables. Given these difficulties, measurement and evaluation are even further challenged by the need to define interactions among various social characteristics and among social and physical system relationships. To date, diverse sets of indicators, case studies, systems analysis and scenario exercises have been used in both quantitative and qualitative approaches. One chronic lack in the studies to date has been meaningful information about population, despite the acknowledgement that population and social variables, in concert with environmental conditions, can provide important insights. The ways in which households are structured, their health status (including reproductive health), and the opportunities they have to live the lives they want to live (the choices they have) are crucially important to their ability to maintain or building resilience to climate change.

7.0 References

Abler, R. 2003 (ed). Global Change in Local Places: Estimating, Understanding, and Reducing Greenhouse Gases. Cambridge: Cambridge University Press.

Adger, W. Neil. 2006. Vulnerability. Global Environmental Change 16, 268-281.

Agrawala, Shardul, Tomoko Ota, Ahasan Uddin Ahmed, Joel Smith and Maarten van Aalst. 2003. Development and Climate Change in Bangladesh: Focus on Coastal Flooding and the Sundarbans. Organization for Economic Cooperation and Development, Paris, France.

Blaikie, P., T. Cannon, I. David and B. Wisner. 1994. At Risk: Natural Hazards, People's Vulnerability, and Disasters. Routlege, London.

Brenkert, Antoinette L., and Elizabeth L. Malone 2005. "Modeling Vulnerability and Resilience to Climate Change: A Case Study of India and Indian States." Climatic Change 72, 57-102.

Brenkert, Antoinette L., Maria Ibarrarán, Elizabeth L. Malone, and L. Herrara. 2006. Vulnerabilidad y resilencia ante el cambio climático: un análisis exploratorio para México. Presented to Políticas Publicas para Crecimiento y Desarrollo, IBERGOP, 28 de agosto de 2006.

Brooks, Nick and W. Neil Adger 2005. Assessing and enhancing adaptive capacity. In Adaptation Policy Framework for Climate Change: Developing Strategies, Policies and Measures, Ian Burton, Elizabeth L. Malone and Saleemul Huq (lead authors). Cambridge University Press, Cambridge.

Brooks, Nick, W. Neil Adger and P. Mick Kelly. 2005. The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. Global Environmental Change 15, 151-163.

Burton, I., R.W. Kates and G.F. White 1993. The Environment as Hazard. 2nd edition. Guilford Press, New York.

CIESIN and YCELP [Center for International Earth Science Information Network and Yale Center for Environmental Law and Policy] 2008. 2008 Environmental Performance Index http://sedac.ciesin.columbia.edu/es/epi/.

Cutter, Susan L. 1996. Vulnerability to environmental hazards, Progress in Human Geography 20, 529-539.

Cutter, Susan L., Bryan J. Boruff and W. Lynn Shirley. 2003. Social vulnerability to environmental hazards. Social Science Quarterly 84:2, 242-261.

Douglas, Mary. 1978. Cultural bias. Occasional Paper 35, Royal Anthropological Institute, London. Reprinted in In the Active Voice, 1982, Mary Douglas. Routledge, London.

Downing, Thomas E. and Anand Patwardhan. 2005. Assessing vulnerability for climate adaptation. In Adaptation Policy Framework for Climate Change: Developing Strategies, Policies and Measures, Ian Burton, Elizabeth L. Malone and Saleemul Huq (lead authors). Cambridge University Press, Cambridge.

Eakin, Hallie. 2008. Human vulnerability to global environmental change. In Encyclopedia of Earth. www.eoearth.org/article/Human_vulnerability_to_global_environmental_change

FEWS [Famine Early Warning System] 1999. FEWS Current Vulnerability Assessment Guidance Manual. U.S. Agency for International Development, Washington, DC. http://www.reliefweb.int/rw/lib.nsf/db900SID/LGEL-5RMFNN/$FILE/fews-vulnerable-aug99.pdf?OpenElement

Folke, C. 2006. Resilience: the emergence of a perspective for social-ecological analyses. Global Environmental Change 16, 253-267.

Franklin, Stuart and Thomas Downing. No date. Resilience and vulnerability. Poverty and Vulnerability Programme, Stockholm Environment Institute http://www.Gecafs.org

German Advisory Council on Global Change. 1997. World in Transition: the Research Challenge. Annual Report 1996. Springer-Verlag, Berlin http://www.wbgu.de/wbgu_jg1996_engl.html.

Henderson, Hazel, Jon Lickerman and Patrice Flynn, eds. 2000. Calvert-Henderson Quality of Life Indicators: A New Tool for Assessing National Trends. Calvert Group Ltd., Bethesda, MD.

Herbert, D. and J. Robinson. 2000. Integrating climate change and sustainable development. In Climate Change and Its Linkages with Development, Equity, and Sustainability, M. Munasinghe and R. Swart (eds), pp. 215-242. IPCC and WMO, Geneva.

Holling, C.S. 1973. Resilience and stability of ecological systems. Annual Review of Entomology 6, 163-182.

Ibarrarán, Maria E., Elizabeth L. Malone, and Antoinette L. Brenkert. In press. Climate change vulnerability and resilience: current status and trends for Mexico. Environment, Development and Sustainability.

International Institute for Sustainable Development. 2003. Livelihoods and Climate Change: Combining disaster risk reduction, natural resource management and climate change adaptation in a new approach to the reduction of vulnerability and poverty. International Institute for Sustainable Development, Winnipeg, Canada. http://www.iisd.org/pdf/2003/natres_livelihoods_cc.pdf

IPCC WG2. 2001. Climate Change 2001: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change, J.J. McCathy, O.F. Canziani, N.A. Leary, D.J. Dokken and K.S. White, eds., Cambridge University Press, Cambridge, UK,

IPCC WG2. 2007. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, eds., Cambridge University Press, Cambridge, UK.

Jones, Roger and Rizaldi Boer. 2005. Assessing current climate risks. In Adaptation Policy Framework for Climate Change: Developing Strategies, Policies and Measures, Ian Burton, Elizabeth L. Malone and Saleemul Huq (lead authors). Cambridge University Press, Cambridge.

Luers, A.L., D.B. Lobell, L.S. Sklar, C.L. Addams and P.A. Matson. 2003. A method for quantifying vulnerability, applied to the agricultural system of the Yaqui Valley, Mexico. Global Environmental Change 13, 255-267.

Magalhães, A.R. 1996. Adapting to climate variations in developing regions: a planning framework. In Adapting to Climate Change: An International Perspective, J. Smith, N. Bhatti, G. Menzhulin, R. Benioff, M.I. Budyko, M. Campos, B. Jallow and F Rijsberman, eds. Springer-Verlag, New York.

Malone, Elizabeth L. and Antoinette Brenkert. In press. Vulnerability, sensitivity, and coping/adaptive capacity worldwide. In The Distributional Effects of Climate Change: Social and Economic Implications, M. Ruth and M. Ibarraran, eds. Elsevier Science, Dordrecht.

Malone, Elizabeth L. and Antoinette L. Brenkert. 2008. Uncertainty in resilience to climate change in India and Indian states. Climatic Change.

Malone, Elizabeth L. and Emilio L. LaRovere. 2005. Assessing current an changing socio-economic conditions. In Adaptation Policy Framework for Climate Change: Developing Strategies, Policies and Measures, Ian Burton, Elizabeth L. Malone and Saleemul Huq (lead authors). Cambridge University Press, Cambridge.

McMichael, Anthony J. 1993. Planetary Overload: Global Environmental Change and the Health of Human Species. Cambridge University Press, Cambridge.

Meyer, William B., Karl W. Butzer, Thomas E. Downing, B.L. Turner II, George W. Wenzel and James L. Wescoat. 1998. Reasoning by analogy. In Human Choice and Climate Change, Volume 3: Tools for Policy Analysis, Battelle Press, Columbus, OH.

Moss, Richard H., Antoinette L. Brenkert and Elizabeth L. Malone 2001. Vulnerability to Climate Change: A Quantitative Approach. 2001. With Richard Moss and Antoinette Brenkert. PNNL-SA-33642, Pacific Northwest National Laboratory, Washington, DC.

Nakicenovic, N. and R. Swart. 2000. Special Report on Emissions Scenarios. Cambridge University Press, Cambridge.

O'Brien K,, R. Leichenko, U. Kelkar, H. Venema, G. Aandahl, H. Tompkins, A. Javed, S. Bhadwal, S. Barg, L. Nygaard L and J. West. 2004. Mapping vulnerability to multiple stressors: climate change and globalization in India. Global Environmental Change 14:303-313.

Patt A., R.J.T. Klein and A. de la Vega-Leinert. 2005. Taking the uncertainty in climate-change vulnerability assessment seriously. C.R. Geoscience 337:411-424.

Prescott-Allen, Robert. 2001. The Wellbeing of Nations: A Country-by-Country Index of Quality of Life and the Environment. Island Press, Washington, DC.

Preston B.L., D. Abbs, B. Beveridge, C. Brooke, R. Gorddard, G. Hunt, M. Justus, P. Kinrade, I. Macadam, T.G. Measham, K. McInnes, C. Morrison, J. O'Grady, T.F. Smith and G. Withycombe. 2007. Spatial approaches for assessing vulnerability and consequences in climate change assessments. www.mssanz.org.au/modsim07/papers/4_s30/SpatialApproaches_s30_Preston_.pdf

Rayner, Steve, and Elizabeth L. Malone 1998. Human Choice and Climate Change (4 vols). 1998. Co-editor with S. Rayner, Vols. 1-3; coauthor with S. Rayner, Vol. 4. Battelle Press, Columbus, OH.

Rayner, Steve and Elizabeth L. Malone 2000a. Climate change, poverty, and intergenerational equity: the national level. In Climate Change and Its Linkages with Development, Equity, and Sustainability, M. Munasinghe and R. Swart (eds), pp. 215-242. IPCC and WMO, Geneva.

Rayner, Steve and Elizabeth L. Malone 2000b. “Security, governance, and the environment.” In Environment and Security: Discourses and Practices, M. Lowi and B. Shaw (eds). MacMillan, Basingstoke, UK.

Robinson, John B. 1988. Unlearning and backcasting: rethinking some of the questions we ask about the future. Technological Forecasting and Social Change 33:4, 325-338.

Robinson, John B. 1990. Futures under glass: a recipe for people who hate to predict. Futures 22:8, 820-842.

Schellnhuber, H.-J. M.K.B. Lüdeke and G. Petschel-Held. 2002. The syndromes approach to Scaling: describing global change on an intermediate functional scale. Integrated Assessment 3(2-3), 201-219.

Sen, Amartya. 1981. Poverty and Famines: An Essay on Entitlement and Deprivation. Oxford University Press, Oxford.

Sen, Amartya. 2000. Development as Freedom. Anchor Books, New York.

Smit, Barry and Johanna Wandel. 2006. Adaptation, adaptive capacity and vulnerability. Global Environmental Change 16, 282-292.

Stockholm Resilience Centre. 2007a. “Resilience dictionary.” http://www.stockholmresilience.org/research/whatisresilience/resiliencedictionary.4.aeea46911a3127427980004355.html

Stockholm Resilience Centre. 2007b. “What is resilience?” http://www.stockholmresilience.org/research/whatisresilience.4.aeea46911a3127427980004249.html

Vincent, Katherine 2004. Creating an Index of Social Vulnerability to Climate Change for Africa. Working Paper 56, Tyndall Centre for Climate Change Research, East Anglia, Norwich, UK.

Vogel, Colleen. Vulnerability and global environmental change, LUCC Newsletter 3, http://www.lucc.vogel.vuln.review.article.html.

Yohe, G., Malone, E., Brenkert, A., Schlesinger, M, Meij, H., Xing, X. and Lee, D., 2006a. “A Synthetic Assessment of the Global Distribution of Vulnerability to Climate Change from the IPCC Perspective that Reflects Exposure and Adaptive Capacity.” Palisades, NY (Center for International Earth Science Information Network, Columbia University, http://ciesin.columbia.edu/data/climate/).

Yohe, G., E.L. Malone, A.L. Brenkert, M. Schlesigner, H. Meij, and D. Lee. 2006b. Geographic Distributions of Vulnerability to Climate Change. Integrated Assessment Journal 6:3.

Yohe, Gary and Richard S.J. Tol 2002. Indicators for social and economic coping capacity—moving toward a working definition of adaptive capacity. Global Environmental Change 12, 25-40.