Vulnerability to Climate Change
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Introduction

Regardless of academic discipline, whether human or political ecology, the social sciences, or emergent sustainability or global change sciences, vulnerability is a useful concept for discussing a relatively broad suite of environmental, socioeconomic, institutional, and political phenomena. Furthermore, regardless of the vulnerability analysis framework used, social, economic, institutional, and political structures modify social and environmental vulnerability. However, in the risk-hazards and geography literatures, vulnerability was initially assessed with a focus on environmentally driven outcomes. Traditionally, vulnerability research might employ the risk-hazards approach or a pressure-and-release model in studying sustainable livelihoods, vulnerability to climate change or to famines and food insecurity, human ecology, or the integrated vulnerability of socio-ecological systems. The literature corroborates, on the one hand, that institutions adapt to environmental risks and, on the other, that interdependence exists among environmental risk (either experienced or perceived), political economy of development, and systems’ resilience.

General Overviews

Leichenko and O’Brien 2002 and Reid and Vogel 2006 discuss vulnerability as a dynamic construct, simultaneously operational at different scales and resulting from multiple stressors. A simple definition encompassing both social and ecological aspects of vulnerability, such as external exposure, system sensitivity and resilience, and adaptive capacity, was proposed by Ziervogel, et al. 2006. These elements constitute the components of vulnerability according to conceptualizations across different theoretical approaches, and Adger 2006 provides a compendious review in this direction. A more concise definition of vulnerability that encapsulates these components within a working framework of analysis is offered by Turner, et al. 2003. Previous vulnerability literature tended to focus narrowly on perturbations and stressors leading to the formulation of Risk-Hazards and Pressure-and-Release Models, culminating in integrative vulnerability analyses frameworks (Turner, et al. 2003; Luers 2005, cited under Expanded Vulnerability Analysis). Finally, an important part of defining, conceptualizing, and analyzing vulnerability to climate change is a consideration of adaptation or adaptive capacity and, as Mosser 2010 and Wilbanks and Kates 2010 point out, increasing attention must be paid to incorporating adaptation in such analyses. Adaptive capacity denotes a system’s ability to modify its characteristics in response to various changes or cope with the consequences of shock or stress.


Adger shows that the key to understanding vulnerability lies in applying an integrative, coupled human–environment approach to the interactions between social dynamics within the socio-ecological system and to how these dynamics shape the resilience of different systems. Available online for purchase or by subscription.


This paper discusses the dynamics of agricultural vulnerability to global climate change through the lens of southern Africa. The authors point out how climate change and globalization act together to expose farmers to new and unexpected conditions and demonstrate that the interaction between the two is dramatically altering the ways in which farmers cope with climatic variability and change and exercise adaptation strategies. Available online for purchase or by subscription.


The paper covers a range of critical research needs in the area of vulnerability and adaptation and argues for capacity building and far-reaching changes in the incentive structure for various disciplines to engage in more practice- and policy-relevant research linking climate change, vulnerability, and adaptation strategies. Available online for purchase or by subscription.


A regional assessment study that uses the sustainable livelihoods framework (based on assessment of human, social, natural, physical, and financial capital as well as adaptive capacity) to account for the multiple stressors that increase vulnerability in resource-poor, rural communities in developing countries and to identify strategies used to secure livelihoods. Available online for purchase or by subscription.


Placing vulnerability analyses in the more general context of global environmental change and sustainability science, the authors raise a series of crucial questions pertaining to the kinds of people and locations that are vulnerable to multiple environmental changes and propose an expanded vulnerability analysis framework for the assessment of human–environment systems.


This article argues for a broadening in the adaptation to climate change effort. The authors suggest integrating the concept with broader frameworks of hazards research, sustainability science, and community and regional resilience. The authors use a variety of examples and case studies to illustrate the multiple threats and stresses that all communities and regions experience and offer ways that adaptation strategies can be made more efficient. Available online for purchase or by subscription.


This paper proposes a simple definition of vulnerability that assesses the degree to which people or the environment are susceptible to harm. This definition encompasses several components: external exposure to hazards or stressors, internal ability of ecosystems and human systems to cope with, recover from, or adapt to external stresses, which is directly linked to the system’s sensitivity, resilience, or adaptive capacity.
Reference Works

Vulnerability assessment tools in the context of climate change are relatively new and remain limited. However, information, methods, and tools used in other contexts and regions can be adapted to the needs of climate change impact studies. Basic knowledge about impacts, vulnerabilities, and adaptation to climate change can be found on the website of the Intergovernmental Panel on Climate Change, Working Group II (IPCC WGII). Association of American Geographers 2003 presents a good resource for understanding locality in global changes, particularly as they apply to climate change and variability. The other publications in this section are online resources that include climate data and social visualization tools that allow identification of hot spots vulnerable to climatic change. The Climate Data Guide: Climate Data Strengths, Limitations, and Applications provides a review of climate databases that would be helpful in identifying physical science changes in a region. For assessing and mapping vulnerabilities to climatic events, the following resources can be used: Climate Change Vulnerability Assessment and Adaptation Tools and Fairbank and Jakeways 2006. The Scenarios Network for Alaska and Arctic Planning resource can serve as a guideline for planning and decision making on topics of climatic change.

Mitigation is the central topic in this publication; however, the authors argue that information given on importance of place in the global change context remains critical in successful vulnerability assessments.

Climate Change Vulnerability Assessment and Adaptation Tools. Ecosystem-Based Management Tools Network.
This portal presents a set of tools that can help communities start planning for climate change in areas such as process, analysis, visualization, and socioeconomic and natural resources. Outside portals offer additional tools.

Community-generated expert guidance directed toward researchers and students for efficient use and identification of climate data sets. This website does not generate social data sets, but guidance about high-quality climate data is useful for identifying impacts of climate change at desired scales.

This is a training pack that will allow regional studies and mapping of climate change impacts in coastal areas. Resulting maps will identify hot spots of current and future vulnerabilities, thereby improving coastal management and reducing the impact and cost of climate change.

Intergovernmental Panel on Climate Change, Work Group II: Impacts, Adaptation, and Vulnerability.
The WGII of the IPCC provides varied resources, guidance, and citations on a broad range of issues related directly to vulnerability to climate change as well as associated impacts and adaptation strategies.
Types of Vulnerability

For ease of methodological presentation and conceptual navigation, this section divides the concept of vulnerability into two types: ecological/biophysical vulnerability and social vulnerability. We begin by reviewing definitions that span the purely ecological and the coupled social and ecological vulnerability fields and end with several definitions of vulnerability spanning the social sciences.

ECOLOGICAL/BIOPHYSICAL VULNERABILITY

The concept of ecological vulnerability, also referred to in the literature as biophysical or environmental vulnerability or the vulnerability of the built environment, is rooted in the natural risk-hazards, food security, and political ecology literatures and is nicely summarized by Belliveau, et al. 2006. Like much of the earlier literature, Burton, et al. 1993 defines ecological vulnerability in relation to the likelihood of impacts from a natural hazard on an ecosystem (or community) and is focused on the characteristics of the hazard, such as its areal extent, magnitude, and frequency. Specifically, Schröter, et al. 2005 presents ecological vulnerability as a function of three overlapping elements: the exposure, sensitivity, and adaptive capacity of an ecosystem to change—a definition also adopted by the Intergovernmental Panel on Climate Change (IPCC) in its fourth assessment report, Climate Change 2007 (Cambridge, UK, and New York: Cambridge University Press, 2007)—whereas Lavorel, et al. 2007 effectively uses these components to measure biophysical vulnerability to fire. O’Brien and Leichenko 2000 and Parry and Carter 1998 show that each “exposure unit” in a system has a unique degree of sensitivity or resilience to stressors that is ultimately also dependent on an entire array of factors. Liverman 2001 introduces another aspect of environmental vulnerability, perhaps less intuitive: the vulnerability of those living in the most precarious physical environments or in environments that will undergo the most dramatic physical changes.


This article provides a good illustration of the use of interdisciplinary knowledge bases, together with historical and prospective stakeholder information, to assess dynamic vulnerability—here, of grape farmers in Canada. This method is performed in two stages: first, determination of past and current risks and the adaptive strategies used to manage those, and second, projections of future vulnerability. Available online for purchase or by subscription.


Originally published in 1978 (New York: Oxford University Press). The authors assert that the global toll of natural disasters is bound to rise at least as fast if not faster than the increase of population and material wealth and that disasters may be less frequent but more catastrophic and more costly in lives in undeveloped and developing countries than in developed countries, where the inherent population vulnerabilities are smaller.

Lavorel, Sandra, Mike D. Flannigan, Eric F. Lambin, and Mary C. Scholes. “Vulnerability of Land Systems to Fire: Interactions

These authors propose an integrative approach to measuring environmental vulnerability to fire in the context of changing environmental parameters (increased fire incidence, human population and pressures, and so on), using the IPCC structure of vulnerability. In doing such assessments, multiple scales and factors need to be incorporated if the assessments are to serve as relevant and coordinative policymaking instruments. Available online for purchase or by subscription.


Liverman presents another perspective on environmental vulnerability by suggesting that vulnerability is disproportionately heightened for those living in the most precarious physical environments or in environments that are likely to undergo the most dramatic physical changes.


This article introduces the concept of the double exposure as a framework for examining the simultaneous impacts of climate change and globalization. *Double exposure* denotes that certain regions, sectors, ecosystems, and social groups will be confronted by both the impacts of climate change and the consequences of globalization. Available online for purchase or by subscription.


The authors discuss the vulnerability of a population in the context of climate change and health, defining vulnerability as a function of the extent to which health or the natural or social systems that affect health are sensitive to changes in climate, the capacity of the population to adapt to new climate conditions, and the degree of exposure to the climate-related hazard.


This paper provides a summary of the interrelated elements that form the basis of concept of global change vulnerability and defines vulnerability as “the likelihood that a specific coupled human–environment system will experience harm from exposure to stresses associated with alterations of societies and the environment, accounting for the process of adaptation” (p. 3). Available online for purchase or by subscription.

**SOCIAL VULNERABILITY**

Adger 1999 and Cutter, et al. 2003 define social vulnerability as the state of a human system of any scale that is shaped by biophysical, social, economic, and political processes that can expose people to risk and that can decrease their ability to avoid, withstand, or recover from external harm (see Belliveau, et al. 2006, cited under Ecological/Biophysical Vulnerability). Sen 1981 and Downing 1991 present specific examples of risk-inducing factors, including poverty, inequitable food entitlements, lack of legal and customary rights over access to water and other resources (see also Turner, et al. 2003, cited under General Overviews). In addition, social vulnerability is conceptualized using the IPCC vulnerability components: exposure and sensitivity as well as the capacity to adapt or recover, intimately linked to the system’s resilience in O’Brien, et al. 2004. Luers, et al. 2003
adds a fourth component to the three outlined by the IPCC, namely, the state of the system relative to a threshold of damage. Kelly and Adger 1999 shows that social vulnerability is determined by a large set of risk factors, apart from the ones related to biophysical events beyond a community’s or group’s control, such as those determined by climate change and its impacts. Furthermore, Blaikie and Brookfield 1987 and Brookfield 1999 explain that vulnerability is socially produced and that, at an underlying level, many vulnerability-inducing mechanisms and resulting hazards are attributable to human causes. More basically, some researchers discuss social vulnerability in terms of individual characteristics of people, in effect related to a group’s internal sensitivity, such as race and ethnicity, age, health state and access to medical services, income, type of dwelling unit, or type or loss of employment.


Presents an early attempt at creating a framework for analyzing social vulnerability in assessing the impacts of climate change and climate extremes, using the example of coastal Vietnam, where social vulnerability to such extremes is disproportionately enhanced by late-20th-century economic changes and transitions away from central planning. Available online for purchase or by subscription.


Blaikie and Brookfield develop a “chain of explanation” model to show that vulnerability is socially produced, that is, that most hazards are, at an underlying level, attributable to human causes (see also Brookfield 1999).


The author gives a thorough discussion of the relative importance of the role of socially produced versus geophysical underlying causes in explaining “natural” disasters. He examines three case studies to illustrate that ultimately, environmental disasters usually stem from a mixture of socially produced and geophysical causes and that these causes should be examined simultaneously. Available online for purchase or by subscription.


Cutter and colleagues demonstrate that social vulnerability is primarily a result of social inequalities (i.e., those social factors that determine or shape the susceptibility of various groups to risk and thus their ability to respond) as well as place inequalities, (i.e., the characteristics of communities and their built environment that in turn contribute to the social vulnerability of a specific locale). Available online for purchase or by subscription.


This paper offers an early synthesis of data on climate change and vulnerability on hunger on the continent of Africa. The paper provides a good review of limitations of assessments of climate change impacts on food supplies and a typology of vulnerability indexes and measures of vulnerability. Available online for purchase or by subscription.

Kelly and Adger develop an approach to measuring the vulnerability of various groups based on the social and economic well-being of society, proposing that vulnerability or security is determined by resource availability and the groups’ entitlement to make use of these resources, particularly in times of scarcity.


Luers and colleagues attempt to create measures of vulnerability applicable at any scale and for either a social or a physical parameter. Thus, these authors create generic metrics to assess the relationships between a wide range of stressors and their resulting variables of concern, using a general conceptual formula: vulnerability can be measured as a function of a system’s sensitivity to stress divided by the state relative to a threshold and multiplied by the probability of exposure to stress. The authors find that farmers, in the absence of adaptation strategies, are more vulnerable to market fluctuations than they would be to climatic changes. Available online for purchase or by subscription.


This paper uses Indian agriculture as an example for a methodology of investigation of the interactions between global stressors and regional vulnerabilities to climate change. Methods employed allow assessments within a nation or region, using both vulnerability and local-level case studies. Available online for purchase or by subscription.


Sen argues that famines result not from insufficient food stocks, but from the lack of coordination for food access, through legal and customary means, in periods of political or climatic stress and shows that entitlements are determined by what groups produce, prices they receive and relative costs of food, and their access to markets and additional resources.

**Measures of Vulnerability in Socio-ecological Systems**

This section discusses various means of measuring vulnerability as well as a chronological vulnerability model. We begin by presenting the risk-hazards and pressure-and-release models typical of the 1970s and 1980s and subsequently offer alternative models and metrics used to measure vulnerability to climate change. We end our discussion with an argument for an expanded vulnerability analysis framework that can be multidisciplinary in nature and that can facilitate the coalescence of models and metrics that span several fields of inquiry.

**RISK-HAZARDS AND PRESSURE-AND-RELEASE MODELS**

Prior to the overt consideration of the linked human–environment system in multidisciplinary fields of inquiry, two models emerged as paramount in analyzing socio-environmental vulnerability: the risk-hazards and pressure-and-release models. The model most often used was the risk-hazards model originally proposed by Burton, et al. 1993, which merely analyzed the impact of a hazard as a function of exposure to the hazard event and the sensitivity, dose–response, of the exposed entity, working from the hazard to the impacts. This model was subsequently criticized by disciplines such as human ecology for a
failure to treat possible internal routes of the system in case of amplification or attenuation of the impacts, make distinctions among subsystems and subcomponents that might be differentially exposed to the hazard, or consider the role played by social structures and institutions in shaping these differential exposures and responses (see Turner, et al. 2003, cited under General Overviews). As a result, the pressure-and-release model, into which some of the above critiques were incorporated in measuring vulnerability, started to be employed with Blaikie, et al. 1994, in which risk is defined explicitly as a function of the stressor, stress, or perturbation and the vulnerability of the exposed unit, and it is from the cumulative pressures of these two elements, hazards and vulnerability, that disasters result. Pelling 2003 uses this model specifically to discuss the factors that elevate vulnerability in urban settings. However, when assessing the greater potential for contribution to sustainability science of the pressure-and-release model, Turner, et al. 2003 notes that this model fails to address the coupled human–environment system or multiscalar causal sequences of hazards or to estimate feedback loops beyond the system of analysis. That is, it fails to address nested hierarchical responses (later crystallized in the theory of panarchy).

**Blaikie, Piers, Terry Cannon, Ian Davies, and Ben Wisner. At Risk: Natural Hazards, People’s Vulnerability, and Disasters. London and New York: Routledge, 1994.**

The authors propose that the vulnerability of the exposed unit is an additive function of root causes, local geography, and social differentiation and is therefore differentiated according to various exposure units, such as class, ethnicity, gender, and income, thus epitomizing the pressure-and-release model. This model synthesizes social and physical vulnerability but focuses primarily on social aspects, and it even prescribes principles and some specific actions for recovery and disaster mitigation.


The authors introduce the risk-hazards model in the vulnerability discourse as a framework for analyzing the impact of a hazard as a function of exposure to the hazard event and the sensitivity, or dose–response, of the exposed entity. This framework specifically starts with the hazard and then determines what the impacts of that particular event may be.

**Pelling, Mark. The Vulnerability of Cities: Natural Disasters and Social Resilience. Sterling, VA: Earthscan, 2003.**

Pelling shows that urban disasters tend to hit the poor, the marginalized, and the excluded with disproportionate force. He proposes that an effective approach to measuring the vulnerabilities of cities would be to integrate agency and structure in examining the production of vulnerability in specific locations, while acknowledging the relevance of physical and ecological systems in generating hazards that can trigger disaster for various communities.


These authors provide a compendious list of the elements that need to be included in vulnerability analyses (though failing to mention uncertainty). Elements critical for measuring vulnerability of coupled human–environmental systems include multiple interacting stressors and their sequencing, internal degree of exposure of a system, sensitivity, and the system’s resilience and the degree of restructuring after disturbance.

**ALTERNATIVE MODELS AND METRICS OF VULNERABILITY ASSESSMENTS**

Two overarching strands of research in the socio-environmental vulnerability arena have emerged: vulnerability to climate change and variability, epitomized in O’Brien, et al. 2004 (cited under Social Vulnerability), and vulnerability to poverty, largely discussed in Dercon 2005 and Silva 2007. The research on vulnerability to poverty explains why populations become and
remain poor, using analyses of economic factors and social relations. The research on vulnerability to climate change primarily analyzes existing physical, social, and ecological system vulnerability to predict region-specific trends in future climate change, using a wide range of methods. The main underlying assumption for the unequal vulnerability of groups and societies related to global change is that vulnerability becomes exacerbated by preexisting inequalities. A key to modeling potential responses in adaptation and vulnerability is to use spatially explicit models that account for multiple stressors in the analysis, as proposed by O'Brien and Leichenko 2000; Schröter, et al. 2005 (both cited under Ecological/Biophysical Vulnerability); and O'Brien, et al. 2004. For example, Smit and Wandel 2006 creates a series of vulnerability scores for communities, regions, or countries, using stakeholder-based participatory vulnerability assessments and impact assessments to formulate practical adaptation strategies at different scales. When measuring vulnerability, the focus is on not only the analysis of stressors and their corresponding impacts, as the risk-hazard models propose, but also the characteristics of the system under stress and its ability to respond. Thus, Luers, et al. 2003 (cited under Social Vulnerability) argues that it is increasingly important to identify which systems remain at certain kinds of risk and, at the same time, to understand why they are at risk. The number of case studies and regional studies on the assessment of socio-ecological vulnerability remains large, but the development of measures of vulnerability involves a complicated and complex methodological and practical issue, mainly as a result of the difficulty of accounting for uncertainty in socio-ecological systems. How vulnerability will be measured and at what scale are highly dependent on uncertainty. The more complex the system and the more cross-scale interactions there are, the more uncertain the analysis can become and the more important the approach to dealing with uncertainty becomes. To these general criteria, Schröter, et al. 2005 (cited under Expanded Vulnerability Analysis) adds that the knowledge base employed in analyses should be varied and flexible and should go beyond academic interdisciplinarity, also involving relevant stakeholders and indigenous and local knowledge; moreover, the information gathered should be both historical and prospective. A good illustration of some of these principles is in the method applied by Belliveau, et al. 2006 (cited under Ecological/Biophysical Vulnerability) to assessing dynamic vulnerability of grape farmers in Canada. Finally, other works, such as Liverman 1990; Jackson, et al. 2004; and Tran, et al. 2002, show that vulnerability assessments may usefully integrate diverse sectors in order to best capture the vulnerability of different population groups.


This book provides an excellent review of the sustainable livelihoods and vulnerability to poverty strand of research in the vulnerability arena, employing analyses of economic factors and social relations to explain why populations become and stay poor.


This article offers a comparative risk assessment based on spatial data overlays to assess species and habitat vulnerability to land-use change. Such approaches are relatively widely used in the literature as a result of this and work by Liverman. Available online for purchase or by subscription.


Liverman developed one of the first sets of robust methods to assess vulnerability, using comparative quantitative assessments of drivers of drought in rural Mexico. Her integrative assessment includes agriculture, technology, climate, and land tenure quantitative data to determine the locations, groups, and drivers of socio-ecological vulnerability. Available online for purchase or by subscription.

A final point related to the vulnerability to climate change line of discourse is the two meanings vulnerability has in this arena: as an end point, or the net impacts of climate change after accounting for adaptation, and as a starting point, in which vulnerability is generated by the multifold interaction between environmental and social processes and is exacerbated by climate change.


The author illustrates the relationship between international trade and income inequality to creating and maintaining uneven development patterns in less-developed countries. He demonstrates that regional trade and development policies would be more appropriate strategies for dampening social inequalities and vulnerabilities that are umbrella national policies. Available online for purchase or by subscription.


This article provides a great review of the concept of human adaptation to global changes in the context of vulnerability and adaptive capacity. The article presents a series of case studies of practical implementation of adaptation strategies at the community scale, showing that most adaptation schemes tend to focus on issues that are problematic already, whereas climate change–induced risk factors tend to be rolled together with other environmental and social stresses. Available online for purchase or by subscription.


Tran and colleagues use a combination of a fuzzy ranking method and analytic hierarchy process to rank ecosystems in terms of environmental conditions, using land cover, populations, roads, streams, air pollution, and topography data to create maps of cumulative impacts from risks across large regions. Available online for purchase or by subscription.

Expanded Vulnerability Analysis

Another way to measure the vulnerability of coupled human–ecological systems to climate change is through the “expanded vulnerability analysis” method outlined in Turner, et al. 2003 (cited under General Overviews) and Turner, et al. 2003 (cited under Risk-Hazards and Pressure-and-Relief Models) and expanded upon by Luers, et al. 2003 (cited under Social Vulnerability); Luers 2005; Eakin 2005; Schröter, et al. 2005; and Belliveau, et al. 2006 (the latter cited under Ecological/Biophysical Vulnerability). Furthermore, the expanded vulnerability analysis framework accounts for uncertainty in the context of double/multiple exposure multiscalar vulnerability analyses, building on work from Leichenko and O’Brien 2008. Especially for socio-ecological systems that are relatively dependent on a natural resource base, a combination of the six factors outlined in Turner, et al. 2003 and a measure of diversification of the income/livelihood/production base, plus an index of social migration and dependency on governmental remittances, appear to be the most efficient measure of vulnerability and...
This genre sprang from studies in Adger 2000 that clarified the link between the health of the resource base (as a measure of ecological resilience and livelihood diversification) and the socioeconomic well-being of resource-dependent communities. This train of thought was later developed by Adger, et al. 2002, which showed that the diversity and range of livelihood options and outcomes within a community increase the likelihood that the community will adapt and function in the face of adverse environmental changes. Similarly, Eakin 2003, and later Eakin 2005, demonstrate that vulnerability in this case is the result of multilevel interacting factors related to livelihoods, social structures, and agricultural policy, more broadly. Schröter, et al. 2005 presents an implementable eight-step approach to global change vulnerability assessments based on consideration of multiple interacting stresses, specificity of location, differential adaptive capacities, and prospective and historical perspectives. This approach is furthered by Polsky, et al. 2007 to create the vulnerability scoping diagram, a meta-analysis tool aimed at facilitating comparisons of vulnerability assessments that use dissimilar measures to assess differential vulnerabilities.


Adger argues that social resilience and, by extension, social vulnerability are intricately related to ecological or biophysical resilience, particularly for communities that are dependent on environmental resources for their livelihoods. Available online for purchase or by subscription.


Using longitudinal data on livelihood sources, the authors show that diversification of livelihood sources and higher income levels have a beneficial effect on socio-ecological resilience and indicate greater adaptability of coupled human–environment systems. That is, the more diverse the range of livelihood options and outcomes within a community, the more likely it is that the community will adapt and function in the face of adverse environmental changes. Available online by subscription.


Eakin 2003 demonstrates that for farmers in Mexico, diversification of production and institutional change are more important in restructuring farmers’ livelihoods than potential climatic risks; as a result, these farmers choose a high-yielding irrigated agriculture strategy as a replacement for maize, which is more sensitive to drought. Available online for purchase or by subscription.


This paper expands on Eakin 2003, bringing forth a multiscalar, multistressor assessment of rural vulnerability at the intersection of climatic risk, globalization, and market liberalization, using ethnographic data in support of the analyses. Available online for purchase or by subscription.


The authors point out the lack of clear connections, feedbacks, and linkages between climate change and globalization. The double exposure framework provides a generalized and widely applicable approach for the analysis of interactions between global environmental and economic changes, stressing in particular the ways that the two interacting processes spread risk.
and vulnerability over both space and time.


Luers acknowledges that the metrics previously proposed in Luers, et al. 2003 (cited under Social Vulnerability) are limited in applicability to systems for which critical social and ecological processes can be approximated mathematically. She proposes a three-dimensional surface of vulnerability tool that computes vulnerability as a function proportional to sensitivity and exposure and inversely proportional to the system state relative to a threshold of damage. Available online for purchase or by subscription.


The authors propose the vulnerability scoping diagram, a common and widely applicable assessment structure for organizing and comparing information about exposure, sensitivity, and adaptive capacity, despite underlying measurement differences among cases. Available online for purchase or by subscription.


This paper presents an implementable eight-step approach to global change vulnerability assessments and uses the examples of independent vulnerability assessments for the Great Plains region of the United States and for an agricultural region in Zimbabwe. Unfortunately, the authors do not offer a specific place-based study to illustrate the practical applicability of their approach. Available online for purchase or by subscription.

**Influential Factors**

This section discusses the factors that increase differential vulnerability of populations to climate change. A region’s vulnerability is affected by more than just local changes in precipitation, natural phenomena frequency or intensity, temperature, and sea level rise. Distal and proximal factors can stress resources in a given place. The composition of a population, its location, and where and why it migrates present unique characteristics in understanding its vulnerability. At the same time, types of policies, governments, and economy primary sectors will further affect resilience.

**DISTAL AND PROXIMAL FACTORS**

Ecosystems and societies are vulnerable to a host of proximal or distal as well as internal or external stressors and perturbations, such as extreme climatologic and hydrologic events (storms, floods, hurricanes, tropical storms, tornados, tsunamis, droughts, dust storms, avalanches) and other, similar climate change–induced impacts (sea level rise); chronic environmental degradation (soil erosion, desertification, soil salinization and salt water intrusion, loss of biodiversity and overexploitation of land and ocean resources, eutrophication of fresh water resources, decreases in overall water availability, decreasing water quality); shifts in global and local economic markets resulting from changing trade policies, macro- and microeconomic oscillations, and a host of perverse incentives; the impacts of globalization (global tourism and its effect on coastal regions and sensitive ecosystems); social changes, such as increased human mobility (responsible for increased spread of vector-borne and infectious diseases) and erosion of conventional social networks and capital; governance, institutional, and political changes (wars and instability); and emerging technological hazards, to mention but a few. In effect,
the social and ecological vulnerability to disasters or any other extreme or chronic event is directly influenced by the level of resilience in the system existing before and after the event has occurred (Adger et al. 2005). A large part of vulnerability, apart from natural disaster–induced vulnerability, comes from people's perceptions of insecurity regarding food supply and other types of economic well-being indicators and also from perceptions of security from fights and conflicts (Hewitt 1997). Another important set of drivers of social vulnerability is the socioeconomic structure and property relations in a community, analyzed under the general denomination of entitlements in Adger and Kelly 1999, and mentioned as one of the three major drivers of vulnerability in Turner et al. 2003 (cited under General Overviews), along with livelihood diversification and resilience. The idea of entitlements as a driver of social vulnerability is based on the assumption that a community's ability to cope with and adapt to stress is directly dependent on the extent to which individuals and groups are entitled to make use of certain resources, more specifically the framework of legal and customary rights to exercise command over food resources and other basic necessities. This research builds on the work of Sen 1981 (cited under Social Vulnerability), which argues that famines result not from insufficient food stocks, but from the lack of coordination for food access, through legal and customary means, in periods of political or climatic stress.


Using the example of Indonesia to support their argument, the authors make a very strong case that the outcomes of given extreme events and the ecological and social vulnerability to disasters are very strongly influenced by the degree of resilience present in a system before and immediately after the extreme event or disaster.


The idea of entitlements as a driver of social vulnerability is based on the assumption that a community's ability to cope with and adapt to stress is directly dependent on the extent to which individuals and groups are entitled to make use of certain resources, more specifically the framework of legal and customary rights to exercise command over food resources and other basic necessities. Available online for purchase or by subscription.


This book provides an excellent review of the various factors that make technological and natural hazards even more dangerous to humans, thus highlighting the idea that vulnerability-producing conditions and processes have social, economic, cultural, and political aspects that go beyond the normal environmental events that create disasters.

**HUMAN POPULATION DYNAMICS**

This section discusses the dynamics of human populations within different environments. Human population dynamics is divided into four distinctive groups pertinent to vulnerability assessments: urban environments, rural environments, small island states, and environmental migrations. Urban and rural environments are readily found in all countries and regions of study. Living in a rural environment makes populations more vulnerable, owing to the distances required to travel in order to acquire services and resources. However, urban environments also experience vulnerabilities, owing to high population density, which brings greater stress to infrastructures, resources, and services. In contrast, not every location would have the characteristics of small island states or experience environmentally induced migrations. Small island state vulnerabilities are formed by a combination of limited resources, land availability, location, and population density, among other factors. These three types of settlements have the possibility of experiencing environmentally induced migrations. These kinds of migrations
are potentially controversial because they could be seen as part of the problem and, at the same time, as part of the solution. Vulnerabilities could increase or decrease as a result of migration patterns and where and why they unfold.

Living in Urban Environments

In the early 21st century half the global population resides in urban environments. These environments are increasingly popular and convenient because of increased availability of services and resources within short distances. Despite the many benefits, living in cities creates a unique set of vulnerabilities to climate change. Cities sometimes struggle with sudden increases in residents, which stress demands for resources, infrastructure capacity, and professional services. As recently as the 1980s, “megacities” (cities with 10 million or more inhabitants) were formed by 2 percent of the world’s population; in the early 21st century that percentage has doubled. By 2015 each megacity could be inhabited by 400 million residents (de Sherbinin, et al. 2007). Because of transportation and economic benefits, many cities are located at low altitudes, which makes them more susceptible to sea level rise and the effects of increasing occurrence of extreme events, such as tropical cyclones.

Understanding existing patterns of urban vulnerabilities and how to act on this knowledge needs to be improved, and publications such as Bicknell, et al. 2009 address those concerns. Rosenzweig, et al. 2011 presents a combination of knowledge in the fields of urban impacts, vulnerabilities, and adaptation. Also, where and why vulnerabilities occur are considered in various studies, such as de Sherbinin, et al. 2007. In contrast, publications such as Organization for Economic Co-operation and Development 2010 focus on urban policies and approaches that could help reduce vulnerabilities and increase mitigation and adaptation efficiency. Romero Lankao and Qin 2011 offers limitations and conceptualizations of knowledge on urban vulnerabilities. It is understood that although often better equipped than rural areas, not all cities possess sufficient resources to cope with climate change.


Middle- and low-income cities are pressured to sustain infrastructure and service requirements adequately, in the face of an increasingly growing urban population. This book identifies risks and vulnerabilities of cities in Africa, Asia, and Latin America and suggests how they could adapt to those changes.


Each city possesses a distinctive combination of system characteristics that generate place-based vulnerabilities. This article analyzes these vulnerabilities in three global cities: Mumbai, India; Rio de Janeiro, Brazil; and, Shanghai, China. As stated by the authors, the article does not attempt to identify specific vulnerabilities in each city, but rather uses a hybrid model that incorporates scenario-based models (top-down approach) with vulnerabilities mapping (bottom-up approach).


This book is directed toward governments of cities and metropolitan regions in an effort to raise awareness and generate action toward impacts of climate changes. Climate change, urbanization, and economic growth are examined along with impacts of climate change specific to urban regions.

Romero Lankao, Patricia, and Hua Qin. “Conceptualizing Urban Vulnerability to Global Climate and Environmental Change.” Current Opinion in Environmental Sustainability 3.3 (2011): 142–149.
The authors present limitations that still challenge urban vulnerability research despite the growth in this area in the late 20th and early 21st centuries. This review proposes that interdisciplinary approaches in modern urban vulnerability research need to be synergized. Available online for purchase or by subscription.


The authors of this book are from a wide range of cities, in both developing and developed countries. The authors discuss risk frameworks, cross-cutting issues, and case studies in sectors such as health, water, transportation, energy, land use, and governance.

**Living in Rural Environments**

Rural environments are more vulnerable to climatic changes, particularly in developing countries, because their economies depend more directly on natural resources. Brondizio and Moran 2008 and Frank, et al. 2011 present how perception plays an important role in increasing or decreasing vulnerabilities among rural communities. In contrast, rural communities experience situations that are beyond perception only. These environments are stressed by outside forces, such as globalization, that, in combination with climatic changes, create unique vulnerabilities. Leichenko and O'Brien 2002 and Eakin 2005 show how the interaction of these two forces changes the vulnerabilities of a location. Nelson, et al. 2010 focuses on informing decision makers about the different dimensionalities of vulnerabilities and the composition of the population. Large farms can become more vulnerable to climatic changes, owing to the risks inherent in large-scale monocropping. Yet, these farms are more likely to have resources to cope with such changes. Conversely, small farmers face technological limitations, little access to extension services, and market disadvantage that will affect their coping capacity (Brondizio and Moran 2008). Rural communities suffer variable vulnerability; as explained by Tsosie 2007, indigenous communities often experience higher vulnerability than their rural, nonindigenous neighbors.


Climate change perception remains key in how small farmers react to climate change impacts. This study, conducted in the state of Pará in Brazil, analyzes how farmers failed to react to the worst El Niño drought event, in 1997–1998, because of lack of perceived danger. The article also notes that farmers prefer to live with risk than with uncertainty.


This article examines how farmers’ livelihood approaches are influenced by market liberalization, globalization, and climatic risk. This assessment uses case studies in the neighboring states of Puebla and Tlaxcala, both in Mexico. Available online for purchase or by subscription.


Perception is key to adequate management of climate change and can lead to vulnerabilities through different sociocognitive factors. This paper presents a conceptual model and empirical relations between social identity and adaptation, perception, and motivation, using, as an example, coffee organizations in Mexico. Available online for purchase or by subscription.

This paper examines how combined effects of globalization and climate changes are increasing farmers’ vulnerability, especially in developing countries. Some farmers would benefit from climate changes, whereas others would be negatively affected. The authors report these uneven results, using southern Africa as an example. Available online for purchase or by subscription.


Nelson and colleagues targeted this paper at audiences who give policy advice, with a focus on Australia’s rural communities. The authors offer a combination of holistic actions of adaptive capacity and hazard/impact modeling. This combination provides insights into numerous dimensions of vulnerability, including emergent ones. Available online for purchase or by subscription.


Climate change threatens traditional ways of living and jeopardizes the survival of indigenous communities. The author discusses the point of view of indigenous communities and their rights to environmental self-determination.

Small Island States

Small island states display diverse culture, history, politics, and populations. Yet, all of them are searching to achieve sustainability in the face of rising sea levels. Vulnerabilities to climate change for island populations are unique because of the existing constraints of limited land, which induce limited resources; vulnerability to global developments; small, highly dense populations; susceptibility to environmental hazards; and excessive dependence on international trade (Mercer, et al. 2007). Pelling and Uitto 2001 offers a combination of pressures at the global scale and local dynamics, which together create a set of unique vulnerabilities. A worst case scenario is a future in which small island states become uninhabited, as is analyzed in Barnett and Adger 2003. This type of future will present challenges for human security, sovereignty, and international norms of justice, creating other types of vulnerabilities for the surrounding neighborhoods. Mercer, et al. 2007 studies the value of indigenous knowledge as part of solution in coping to climatic events.


Atoll sovereign countries are on the United Nation’s list of least-developed countries (LDC). They confront common vulnerabilities to climate change. This article presents behaviorally and ecologically driven thresholds of change for these countries as well as policy implications and research challenges. Available online for purchase or by subscription.


Over centuries of adaptation to gradual changes, indigenous populations have needed to adjust their livelihood strategies. This
article offers a framework on how to incorporate indigenous knowledge of vulnerabilities with scientific knowledge. Available online for purchase or by subscription.


Interactions between local dynamics and global pressures have produced an increase in human vulnerabilities. This article provides a framework for assessing these types of interactions. Pelling and Uitto search to find causes of vulnerability and to learn how globalization would change the nature of those vulnerabilities. Available online for purchase or by subscription.

Environmental Migration

Overall, the literature agrees that environmentally-induced migrations will emerge in unprecedented scale and scope. Three distinguishable factors will increase the difficulty of future projections and complexity when examining environmental displacements: magnitude of changes at global scale is a new phenomenon, effects will not be localized or episodic, and humans are at the center of these changes and have potential to respond to them (Warner, et al. 2010). In the context of climate change, migration remains a controversial topic that may be both a driver of vulnerability and, as discussed in Bardsley and Hugo 2010, a solution for coping with environmental change. Despite the importance of migration, its interactions with climate change remain little understood. Among the more salient studies, Findley 1994 demonstrates that migration did not increase overall under a severe drought; however, analysis of age-sex composition of migrants showed an increase in the migration of women and children. Barbieri, et al. 2010 and Black, et al. 2011 discuss how because of its interaction with a combination of factors that induce migrations, climate change is not the sole cause of migration. At the same time, Warner, et al. 2010 recommends integrating existing non-environmentally induced migration studies with environmentally induced ones. Studying environmental migrations could be further enriched by transdisciplinary and integrated approaches from various disciplines.


This paper demonstrates the relationship between climate change, economic impacts, and migration. The paper contains state- and municipal-level migration scenarios driven by changes in performance of the primary economy sectors caused by a changing climate. The paper also discusses how to factor the increased vulnerability of migrant groups into Brazilian public policy and planning. Available online for purchase or by subscription.


This article uses two case studies, in Nepal and Thailand, to explain how climate change will influence migration and how to recognize thresholds of fundamental change to migration patterns. Migration is presented as part of the response to climate changes rather than as a failure to adapt. Available online for purchase or by subscription.


Black and colleagues offer a new conceptual framework for understanding how migration is affected by environmental changes. The authors provide five drivers that affect migration decision making: economic, political, social, demographic, and environmental. This framework could be used to assess policy options and develop plausible future migration scenarios.

A case study conducted in rural Mali shows that overall migration did not increase during the drought of 1983–1985. However, there was a vast increase in the migration of women and children, with 64 percent of the migrants adopting circular patterns during this period. This study recommends development and migration policies and describes the characteristics of migrations like these. Available online by subscription.


Conceptual models of climate change–driven migrations are presented at an intermediate level. The article explores linkages between these concepts, using two mechanisms that will be intensified with changes in climate: floods and sea level rise. Available online for purchase or by subscription.


This paper explores the mechanisms that link vulnerability with migration and recommends the use of knowledge acquired from migrations caused by development, disasters, and conflict. Various case studies, in Mozambique, Egypt, and Vietnam, are used in conjunction with multidisciplinary literature. Available online for purchase or by subscription.

**GENDER INEQUALITIES**

Early-21st-century literature about gender dimensions of climate change emphasizes pervasive gender inequality as a driver of many types of vulnerabilities. Women and girls tend to constitute a significant portion of poor and disadvantaged communities. The collected volumes Masika 2002 and Aboud 2011 present articles reviewing the literature related to climate change and gender inequality. Women’s vulnerabilities are related to many factors, such as residence location, culture, accessibility of resources, and participation in decision making. As vulnerability is reduced, women become more pro-environment. For example, Aurora-Jonsson 2011 explores how women from the Southern Hemisphere are compared with the women of the North. Also, specific case studies on how women react to and cope with climatic changes in different sectors are available in the following articles: Codjoe, et al. 2012; Jungehûlsing 2010; and Lambrou and Nelson 2010.


This collection of resources displays existing publications on gender and climate change. The report includes policy briefings, practical tools, case studies, advocacy documents, and research papers from a variety of regions.


This article contrasts poor women of the Southern Hemisphere with pro-environmentalist women of the Northern Hemisphere.
The author discusses gender assumptions and the danger of attributing by gender responsibility for environmental change. Available online for purchase or by subscription.


This paper assesses adaptation strategies by gender during extreme events for workers in farming, fishing, and charcoal production among communities with limited resources in Ghana. A vast majority of climate change adaptation in West Africa will take place at the community and household scale. Assessments presented will usefully support adaptation implementation at these scales.


This study was conducted in the southern part of Chiapas, Mexico, a region that is already experiencing an increased occurrence of extreme events. Results showed gender differences in terms of migration strategies, vulnerabilities, and impacts from climate change.


A report that is based on a project conducted in Andhra Pradesh, India. The report addresses gender-sensitive aspects of coping with climate variability and long-term changes in the areas of farming-based livelihoods and food security.


In this collection of articles, the authors explore the linkages between poverty, gender, and climate variability and debate how these issues are important to the climate change policy process.

**ECONOMIC VULNERABILITIES**

Economic vulnerabilities in the context of climate change offer unique challenges for economists. Zhang 2004 discusses diversification as a vehicle in helping reduce vulnerabilities to climate change. A lack of economic diversification increases vulnerability when the principal economic sector is directly influenced by climate. Tourism, a primary economic sector for many countries, is known to be affected by climate variations. Berritella, et al. 2006 studies direct climate change impacts for the tourism industry; in contrast, Hamilton, et al. 2005 takes an international approach, analyzing how impacts on the tourist industry in one country would affect other countries. Studies regarding the impacts of climate change on tourism are important for reducing economic vulnerability in these countries. Economic impacts in various sectors and how to reduce costs of coping are considered in Ruth, et al. 2007 and Yohe and Schlesinger 2002. Controversially, Stern 2007 presents climate change as a market failure and a challenge for economists. According to Stern, the economist’s challenge is to answer questions such as, How well do we understand the risks and costs of climate change impacts? What economic paths would make countries less vulnerable to these changes? Who should finance these paths? and What types of economic opportunities do these actions and new technologies bring?

Berritella, Maria, Andrea Bigano, Roberto Roson, and Richard S. J. Tol. “A General Equilibrium Analysis of Climate Change...

Berrittella and colleagues analyze how future supply and demand of tourism services could be affected by climate changes, using a computable general equilibrium model. Only direct effects of climate change on tourism were considered in this study, whereas side effects, such as sea level rise, were ignored (as acknowledged by the authors). Available online for purchase or by subscription.


This paper presents a simulation model of tourism demand in 207 countries. An analysis at the international level is pursued because tourism demands in one place change relative to competitors’ impacts and variations. These demands are studied in the context of climatic, population, and per capita income changes. Available online for purchase or by subscription.


The authors introduce the double exposure framework concept, under the general assumption that globalization and climate change affect a region simultaneously, and using as an example the large farms in California’s Central Valley. Available online for purchase or by subscription.

Ruth, Matthias, Dana Coelho, and Daria Karetnikov. The US Economic Impacts of Climate Change and the Costs of Inaction: A Review and Assessment by the Center for Integrative Environmental Research (CIER) at the University of Maryland. College Park, MD: Center for Integrative Environmental Research, 2007.

This review explores the economic impacts that climate change would cause on different regions of the United States. Regional and sectoral case studies are provided. Information for each section includes an overview, major impacts, infrastructures, and missing information and research needs.


Economists give mixed reactions toward approaches and conclusions in *The Stern Review*. Its international approach implies that climate change is the greatest example of market failure and thus represents a unique challenge for economics. The review contains numbers on costs of impacts, emissions reduction, and implementation. A combination of human and economic costs is calculated, demonstrating supramonetary cost.


These authors discuss three case studies that evidence the value of reducing the costs of climate change impacts. The study uses an approach that analyzes vulnerabilities to climate change explicitly reflecting geographic diversity and uncertainty. Available online for purchase or by subscription.

Zhang, Le-Yin. *Economic Diversification in the Context of Climate Change*. Paper presented at the UNFCCC Workshop on...
Economic Diversification, Tehran, Iran, 18–19 October 2003.
This is a background paper that examines negative effects of climate change on creating needs and options for economic diversification in least-developed countries and small island developing states. How humans respond to climatic change could affect economic diversification and increase vulnerability for these regions.

POLITICS AND CLIMATE CHANGE

Climate change increases probabilities for conflict because of scarcity of resources and poverty. When addressing climate change policy, conflicts of interest and power are inevitable. As presented in Devitt and Toll 2012, armed conflicts could reduce development and increase vulnerabilities. Similarly, Mason, et al. 2011 discusses how a region already experiencing armed conflicts copes with climatic changes, in an effort to shed light on future climatic change–related controversies. Hinkel 2011 indicates that vulnerability assessment has moved from an academic exercise to a political necessity, increasing the need for improved communication between science and policy. In a political context some of the most powerful groups have done well from ongoing frameworks and are hesitant to change existing conditions. Meadowcroft 2009 talks about the importance of governance in climate change topics. Stronger, national-level approaches are needed, as suggested by Giddens 2009, as lack of action and organization at this level would undermine any advancement at global scales.

This book presents approaches taken by local communities using adaptive governance, in an effort to address climate change issues. An analysis of past climate change policies and political decisions is discussed, fortifying the argument for adaptive governance.

Devitt and colleagues examine how sub-Saharan Africa could be affected by interactions between projected climate changes, civil war, and development. A model that employs, as a baseline, the *Intergovernmental Panel on Climate Change Special Report on Emission Scenarios* (SRES), is used to study how climate change induces civil war, which in turn reduces development, creating more vulnerabilities. Available online for purchase or by subscription.

Although Giddens recognizes the importance of creating international policy, this publication focuses on national-level public policy in developed countries. This emphasis reflects a need for developed countries to change internally, owing to their contribution to climate change. No international policy approach will reduce vulnerabilities to climate change if internal policies are not in place to mitigate changes.

Vulnerability indicators are a popular instrument in bridging academia and political needs. However, the author believes that these indicators could be an example of failed communication between science and policy. A conceptual framework is offered, in an effort to increase efficiency in this type of communication. Available online for purchase or by subscription.

Since the 1970s the Gaza Strip has been experiencing an increase in average temperature. Coupled with conflicts in the region, this increase causes vulnerabilities for the population. The authors suggest vulnerability assessment as a useful approach for understanding how climatic risks are experienced within conditions of conflicts.


This paper examines long-term, national-level governance responses to climate change. Analyzing advantages and disadvantages of particular policies is not the focus of this paper; rather its concern is with overall systems of governance for climatic changes.

### Mapping Vulnerabilities

Traditionally, vulnerability has been examined in isolation from other stressors. Moreover, organized methodology to operationalize vulnerability in the context of multiple stressors remains scarce (O’Brien, et al. 2004, cited under Social Vulnerability). Spatially and temporally explicit information regarding place vulnerability can be assessed and effectively communicated with the use of mapping tools and various types of data, ranging from biophysical to socioeconomic, at different spatial and temporal scales (Antwi-Agyei, et al. 2012). Mapping vulnerabilities to climate changes remains a relatively new and complex process that needs further critical assessment. Key challenges are inherent in the high degree of spatial and temporal heterogeneity associated with socioeconomic, physical, cultural, and societal judgments and diverse perceptions (Brooks, et al. 2005; Preston 2011). A specific example is Brody, et al. 2008; in this publication, vulnerabilities induced by gender inequalities and a linkage with knowledge gaps are mapped. An attempt at mapping population vulnerabilities to climate change that captures spatial differences at a global scale and that incorporates human density, demographic change, and climate change forecasts is reported in Samson, et al. 2011.


This study takes a multiscalar and multi-indicator approach to determining and mapping the vulnerability of crop production to drought in sub-Saharan Africa and proposes a series of methodological steps to improve vulnerability assessments in dynamic farming systems under stress climatically, socioeconomically, and politically. Available online for purchase or by subscription.


This draft report identifies gaps in the gender and climate change literature, outlines key connections, reviews best practices, and provides recommendations for future research. The paper’s main focus is women’s participation in decision making.


This article presents indicators of vulnerability and adaptive capacity in the face of climate variability and change that the authors derive through a novel, national-level data aggregation technique, on decadal time scales. Using eleven key indicators and data on mortality associated with climate disasters, the authors show that adaptive capacity is associated primarily with literacy, governance, and civil and political rights. Available online for purchase or by subscription.


Preston and colleagues review climate change vulnerability mapping in the context of four fundamental topics for assessment design: goals, framework (vulnerability of what and to what), methods, and participants. Available online for purchase or by subscription.


This study takes a spatially explicit approach to modeling present and future population vulnerabilities to climate change. The authors use human population density, forecasted climate change data, and demographic data to map vulnerability hot spots at a global scale and introduce the concept of moral hazard in climate change policies. Available online for purchase or by subscription.

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