Chapter 6

Vulnerable Peoples and Places

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BOXES

FIGURES

TABLES

*This appears in Appendix A at the end of this volume.

Main Messages

Some of the people and places affected by changes in ecosystems and ecosystem services are highly vulnerable to the effects and are particularly likely to experience much of the damage to well-being and loss of life that such changes will entail. Indeed, many of these people and places are already under severe stress from environmental, health, and socioeconomic pressures, as well as new forces involved in globalization. Further threats arising from changes in ecosystems and ecosystem services will interact with these other on-going stresses to threaten the well-being of these groups while many others throughout the world benefit and prosper from human interactions with ecosystems.

The patterns and dynamics of vulnerability in coupled socioenvironmental systems are shaped by drivers operating at scales from the international to the local, all interacting with the specifics of places. The dominant drivers and patterns of vulnerability differ, depending on the threat or perturbation addressed, the scale of analysis selected, and not least the conceptual framework employed. While our existing knowledge of the sources and patterns of vulnerability is still incomplete, substantial progress is being made in this relatively new area of analysis, and vulnerability assessment is proving useful in addressing environmental management and sustainable development.

At a global level, various efforts over the past several decades have defined vulnerability indictors and indexes and have mapped relevant global patterns. Because they use different conceptual frameworks and consider vulnerability to different types of threats, these efforts largely identify different national-scale patterns of vulnerability. Examples in the chapter introduce major efforts to address vulnerability to environmental change broadly defined, as a dimension of environmental sustainability, in respect to climate change and natural hazards. Improvements in the state of knowledge and methodology development are needed generally to deepen understanding of these global patterns and their causes, although the topics of natural hazards, desertification, and food security have received more attention than others, due to the level of societal concern on these issues.

Trends in natural hazards reveal several patterns that are known with high confidence at the national level. The world is experiencing a worsening trend of human suffering and economic losses from natural disasters over the past several decades. In the last 40 years, the number of "great" disasters has increased by a factor of 4 while economic losses have increased by a factor of 10. The significance of these events to the social vulnerability of exposed human populations is of special concern. Even before the December 2004 tsunami, Asia was disproportionately affected, with more than 43% of all natural disasters and 70% of deaths occurring there over the last decade of the twentieth century. The greatest loss of life continues to be highly concentrated in developing countries as a group.

Desertification is another phenomenon that has received extensive attention. Vulnerability to desertification has multiple causes that are highly intermingled; like all vulnerability, it is the product of the interaction between environmental change and social and political systems. The driving forces of environmental change generally have a high patchiness, and effects vary widely with differences in social and geographic scales.

Food insecurity is a third primary area of concern in changes in ecosystem services. Multiple domains of vulnerability exist in food security regimes and livelihood systems. Production, economic exchanges, and nutrition are key elements, along with more-structural issues associated with the political economy. At this point in time, the more generalized, major contributions to knowledge are emerging in the realms of better understanding of driving forces, interactions across biophysical scales and social levels, connections between ecosystems services and human well-being, and differential vulnerability at local levels. While many challenges remain in aggregating diverse case study findings, consistency is emerging around a number of themes:

- Socioeconomic and institutional differences are major factors shaping differential vulnerability. The linkages among environmental change, development, and livelihoods are receiving increasing attention in efforts to identify sources of resilience and increase adaptive capacity, but knowledge in this area is uneven in its coverage of environmental threats and perturbations as they act in relation to different ecosystems and livelihoods.
- Poverty and hazard vulnerability are often closely related, as the poor often lack assets and entitlements that allow them some buffer from environmental degradation and variability.
- The interactions of multiple forms of stress—economic, social, political, and physical—with environmental change can amplify and attenuate vulnerability abruptly or gradually, creating dynamic situations for assessment that have still to be fully captured in research methodologies. Major worldwide trends of population growth, urbanization, the spread of HIV/AIDS, economic development, and globalization are acting to shape patterns of vulnerability at national and local scales. The implications of these processes for climate change are still poorly understood.

The limitations of existing understanding point to the need for a variety of efforts to improve assessment and identify measures to reduce vulnerability. These include the need for a robust and consensual conceptual framework for vulnerability analysis, improved analysis of the human driving forces of vulnerability as well as stresses, clarification of the overlaps and interactions between poverty and vulnerability, the tracking of sequences of stresses and perturbations that produce cumulative vulnerability, the role of institutions in creating and mitigating vulnerability, the need to fill gaps in the knowledge base of global patterns of vulnerability, improved assessment methods and tools, and the need for interventions aimed at reducing vulnerability.

6.1 Introduction

The Third Assessment of the Intergovernmental Panel on Climate Change noted that over the past century average surface temperatures across the globe have increased by 0.6° Celsius and evidence is growing that human activities are responsible for most of this warming (IPCC 2001b). Human activities are also altering ecosystems and ecosystem services in myriad ways, as assessed in other chapters. While both positive and negative effects on human societies are involved, it is unrealistic to expect that they will balance out.

Many of the regions and peoples who will be affected are highly vulnerable and poorly equipped to cope with the major changes in ecosystems that may occur. Further, many people and places are already under severe stress arising from a panoply of environmental and socioeconomic forces, including those emanating from globalization processes. Involved are such diverse drivers of change as population growth, increasing concentrations of populations in megacities, poverty and poor nutrition, accumulating contamination of the atmosphere as well as of land and water, a growing dependence on distant global markets, growing gender and class inequalities, the ravages of wars, the AIDS epidemic, and politically corrupt governments. (See Chapter 3 for further discussion on drivers of change.) Environmental change will produce varied effects that will interact with these other stresses and multiple vulnerabilities, and they will take their toll particularly among the most exposed and poorest people of the world.

The most vulnerable human and ecological systems are not difficult to find. One third to one half of the world's population already lacks adequate clean water, and climate change—involving increased temperature and droughts in many areas—will add to the severity of these issues. As other chapters in this volume establish, environmental degradation affects all ecosystems and ecosystem services to varying degrees. Many developing countries (especially in Africa) are already suffering declines in agricultural production and food security, particularly among small farmers and isolated rural populations. Mountain locations are often fragile or marginal environments for human uses such as agriculture (Jodha 1997, 2002). Increased flooding from sea level rise threatens low-lying coastal areas in many parts of the globe, in both rich and poor countries, with a loss of life and infrastructure damages from more severe storms as well as a loss of wetlands and mangroves. (See Chapters 19 and 23.)

The poor, elderly, and sick in the burgeoning megacities of the world face increased risk of death and illness from growing contamination from toxic materials. Dense populations in developing countries face increased threats from riverine flooding and its associated impacts on nutrition and disease. These threats are only suggestive, of course, of the panoply of pressures that confront the most vulnerable regions of the world. It is the rates and patterns of environmental change and their interaction with place-specific vulnerabilities that are driving local realities in terms of the eventual severities of effects and the potential effectiveness of human coping mitigation and adaptation.

Research on global environmental change and on-going assessments in many locales throughout the world have greatly enriched our understanding of the structure and processes of the biosphere and human interactions with it. At the same time, our knowledge is growing of the effects that changes in ecosystems and ecosystem services have upon human communities. Nonetheless, the knowledge base concerning the vulnerabilities of coupled socioecological systems is uneven and not yet sufficient for systematic quantitative appraisal or validated models of cause-and-effect relationships of emerging vulnerability. Yet what we need to understand is apparent in the questions that researchers are addressing (Turner et al. 2003a): Who and what are vulnerable to the multiple environmental and human changes under way, and where? How are these changes and their consequences attenuated or amplified by interactions with different human and environmental conditions? What can be done to reduce vulnerability to change? How may more resilient and adaptive communities and societies be built?

In this chapter key definitions and concepts used in vulnerability analysis are first considered. Included in this is a clarification of what is meant by the terms "vulnerability" and "resilience." Several of the principal methods and tools used in identifying and assessing vulnerability to environmental change are then examined (but see also Chapter 2). Efforts to identify and map vulnerable places at the global scale are described, followed by three arenas—natural disasters, desertification, and food security—that have received substantial past analyses in vulnerability research and assessment. Several specific case studies that illustrate different key issues that pervade vulnerability assessments are presented and, finally, implications of our current knowledge for efforts to assess and reduce vulnerability and to build greater resilience in coupled socioecological systems are assessed.

6.2 Definitions and Conceptual Framework

The term vulnerability derives from the Latin root *vulnerare,* meaning to wound. Accordingly, vulnerability in simple terms means the capacity to be wounded (Kates 1985). Chambers (1989) elaborated this notion by describing vulnerability as "exposure to contingencies and stress, and the difficulty in coping with them." It is apparent from relating the notion of vulnerability to the broader framework of risk that three major dimensions are involved:

- exposure to stresses, perturbations, and shocks;
- the sensitivity of people, places, and ecosystems to stress or perturbation, including their capacity to anticipate and cope with the stress; and
- the resilience of exposed people, places, and ecosystems in terms of their capacity to absorb shocks and perturbations while maintaining function.

6.2.1 Conceptual Framework for Analyzing Vulnerability

A wide variety of conceptual frameworks have arisen to address the vulnerability of human and ecological systems to perturbations, shocks, and stresses. Here we draw on a recent effort of the Sustainability Science Program to frame vulnerability within the context of coupled socioecological systems (Turner et al. 2003a, 2003b). The framework seeks to capture as much as possible of the totality of the different elements that have been demonstrated in risk, hazards, and vulnerability studies and to frame them in regard to their complex linkages. (See Figure 6.1.)

The framework recognizes that the components and linkages in question vary by the scale of analysis undertaken and that the scale of the assessment may change the specific components but not the overall structure. It identifies two basic parts to the vulnerability problem and assessment: perturbation-stresses and the coupled socioecological system.

Perturbations and stresses can be both human and environmental and are affected by processes often operating at scales larger than the event in question (such as local drought). For example, globally induced climate change triggers increased variation in precipitation in a tropical forest frontier, while political strife elsewhere drives large numbers of immigrants to the frontier. The coupled socioecological system maintains some level of vulnerability to these perturbations and stresses, related to the manner in which they are experienced. This experience is registered first in terms of the nature of the exposure—its intensity, frequency, and duration, for instance—and involves measures that the human and environment subsystems may take to reduce the exposure. The coupled system experiences a degree of harm to exposure (risk and impacts), determined by its sensitivity. The linkage between exposure and impact is not necessarily direct, however, because the coupled system maintains coping mechanisms that permit immediate or near-term adjustments that reduce the harm experienced and, in some cases, changes the sensitivity of the system itself.

If perturbations and stresses persist over time, the types and quality of system resilience change. These changes are potentially irreversible, as the case of ozone depletion illustrates. Change may lead to adaptation (fundamental change) in the coupled system. The role of perception and the social and cultural evaluation of stresses and perturbations is important to both the recognition of stresses and the decisions regarding coping, adaptation, and adjustment. These decisions reflect local and regional differences in perceptions and evaluations. The social subsystem must be altered, or

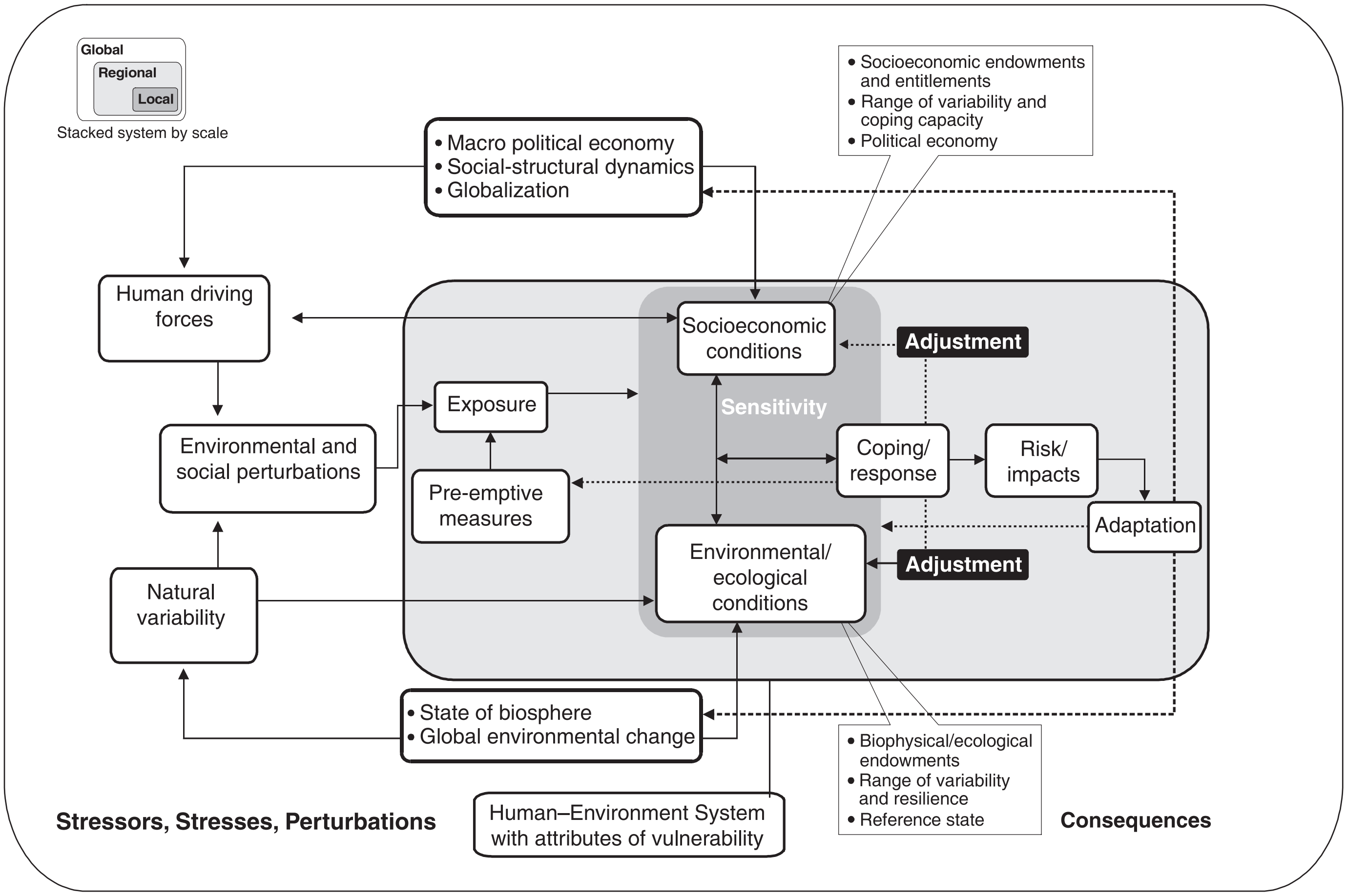

Figure 6.1. A Framework for Analyzing Vulnerability

it ceases to function (a place or region is abandoned, for example); the ecological subsystem changes in climate and vegetation. This process of more fundamental change, sometimes also referred to as ''reorganization,'' may move the coupled socioecological system in a direction of greater sustainability, but perhaps at a cost to those depending on current patterns of ecosystem services. The MA *Policy Responses* volume addresses adjustments and adaptation in ecosystems and with respect to human well-being in greater detail. By definition, no part of a system in this vulnerability framework is unimportant.

6.2.2 The Concept of Resilience

The concept of resilience as applied to integrated socioecological systems may be defined as the amount of disturbance a system can absorb and still remain within the same state or domain of attraction, the degree to which the system is capable of self-organization (versus lack of organization or organization forced by external factors), and the degree to which the system can build and increase its capacity for learning and adaptation (Carpenter et al. 2001). Socioecological systems are complex adaptive systems that are constantly changing, and the resilience of such systems represents the capacity to absorb shocks while maintaining function (Holling 1995, 2001; Gunderson and Holling 2002; Berkes et al. 2002). When a human or ecological system loses resilience, it becomes vulnerable to change that previously could be absorbed (Kasperson and Kasperson 2001).

New insights have been gained during the last 10 years about the essential role of resilience for a prosperous development of human society (Gunderson and Holling 2002). A growing number of case studies have revealed the tight connection between resilience, diversity, and the sustainability of socioecological systems (Berkes and Folke 1998; Adger et al. 2001).

Ecosystems with low resilience may still maintain function and generate resources and ecosystem services—that is, they may seem to be in good shape—but when subject to disturbances and stochastic events, they may reach a critical threshold and slide into a less desirable state. Such shifts may significantly constrain options for social and economic development, reduce options for livelihoods, and create environmental migrants as a consequence of the impact on ecosystem life-support.

In ecological systems, Lawton (2000) and Loreau et al. (2001) synthesized the evidence from many experiments and affirmed that the diversity of functionally different kinds of species affected the rates of stability and increased the reliability of ecosystem processes locally. Furthermore, a number of observations suggest that biodiversity at larger spatial scales, such as landscapes and regions, ensures that appropriate key species for ecosystem functioning are recruited to local systems after disturbance or when environmental conditions change (Peterson et al. 1998; Bengtsson et al. 2003). In this sense, biological diversity provides insurance, flexibility, and risk spreading across scales in the face of uncertainty and thereby contributes to ecosystem resilience (Folke et al. 1996). (See also Chapter 11.)

Ecological resilience typically depends on slowly changing variables such as land use, nutrient stocks, soil properties, and biomass of long-lived organisms (Gunderson and Pritchard 2002), which are in turn altered by human activities and socioeconomic driving forces (Lambin et al. 2001). The increase in social and economic vulnerability as a consequence of reduced resilience through land degradation and drought may cause losses of livelihood and trigger tension and conflict over critical resources such as fresh water or food (Homer-Dixon and Blitt 1998).

Increased vulnerability and fragility places a region on a trajectory of greater risk to the panoply of stresses and shocks that occur over time. Stressed ecosystems are often characterized by a ''distress syndrome'' that is indicated not only by reduced biodiversity and altered primary and secondary productivity but also by increased disease prevalence, reduced efficiency of nutrient cycling, increased dominance of exotic species, and increased dominance by smaller, shorter-lived opportunistic species (Rapport and Whitford 1999). The process is a cumulative one, in which sequences of shocks and stresses punctuate the trends, and the inability to replenish coping resources propels a region and its people to increasing vulnerability (Kasperson et al. 1995).

Key attributes of resilience in ecosystems, flexibility in economic systems, and adaptive capacity in institutions used in assessments include the following:

- Ecological resilience can be assessed by the amount of variability that can be absorbed without patterns changing and controls shifting to another set of keystone processes.
- Key sources of resilience lie in the requisite variety of functional groups; the accumulated financial, physical, human, and natural capital that provides sources for reorganization following disturbances; and the social networks and institutions that provide entitlements to assets as well as coping resources and social capital (Adger 2003).
- In an ecosystem, these key processes can be recognized as the processes that interact and are robust in an overlapping, redundant manner.
- When a system is disrupted, resilience is reestablished through regeneration and renewal that connect that system's present to its past.

Management can destroy or build resilience, depending on how the socioecological system organizes itself in response to management actions (Carpenter et al. 2001; Holling 2001; MA *Policy Responses*). There are many examples of management suppressing natural disturbance regimes or altering slowly changing ecological variables, leading to disastrous changes in soils, waters, landscape configurations, or biodiversity that did not appear until long after the ecosystems were first managed (Holling and Meffe 1996). Similarly, governance can disrupt social memory or remove mechanisms for creative, adaptive response by people in ways that lead to the breakdown of socioecological systems (McIntosh et al. 2000; Redman 1999). By contrast, management that builds resilience can sustain socioecological systems in the face of surprise, unpredictability, and complexity. Successful ecosystem management for human well-being requires monitoring and institutional and organizational capacity to respond to environmental feedback and surprises (Berkes and Folke 1998; Danter et al. 2000), a subject treated at the conclusion of this chapter.

6.3 Methods and Tools for Vulnerability Analysis

Many tools and methods exist for undertaking vulnerability analysis, as described in Chapter 2. This section describes several tools more specific to assessing vulnerability issues and outcomes. The vulnerability toolkit described here and in Chapter 2 is considerable, ranging from qualitative to quantitative methods, with various levels of integration among disciplines, and it is suitable for participation of stakeholders. Matching the types of analytical approaches in a toolkit to the characteristics of a specific assessment is a necessary step in scoping projects.

6.3.1 The Syndromes Approach

The syndromes approach aims to ''assess and monitor a multitude of coupled processes taking place on different (spatial and temporal) scales with different specificities'' (Petschel-Held 2002). The goal of the syndromes approach is to identify where intervention can help contribute to sustainable development pathways. In order to achieve this, similarities between regions are found by looking for functional patterns that are called ''syndromes'' (Schellnhuber et al. 1997). An assessment of these patterns of relationships is achieved by combining qualitative and quantitative approaches. Some 16 syndromes of global change are grouped according to the dominant logic: utilization of resources, economic development, and environmental sinks. The results enable critical regions to be identified for different syndromes, so that future development can set priorities for key areas necessary for establishing more-sustainable systems.

The syndromes approach recognizes the need to examine human-environment interactions, as global change is a function of how society responds to natural changes and vice versa. It is therefore important that the socioecological system is seen as a whole. Within this context, archetypal patterns are most relevant to representing the process of global change. For example, the Sahel syndrome (Lüdeke et al. 1999), characterizes a set of processes that result in the overuse of agriculturally marginal land. (Note that the names of syndromes represent an archetype rather than a specific location, event, or situation; for more detailed analysis of environmental change in the Sahel itself, see Chapter 22.)

The Sahel syndrome can be located in certain parts of the world and characterized by a number of factors. Its driving forces or core mechanisms include impoverishment, intensification of agriculture, and soil erosion, which in turn lead to productivity loss. Various factors might contribute to the disposition toward this syndrome, including socioeconomic dimensions, such as high dependence on fuelwood, and natural dimensions, such as aridity and poor soils. The core mechanisms can be quantitatively assessed to determine which areas of the world experience the syndrome most extensively and intensively. The syndromes approach is a transdisciplinary tool, drawing on both quantitative and qualitative assessments of dynamic patterns at a variety of scales, and by identifying patterns of unsustainable development, it can be used to target future development priorities aimed at enabling sustainable development.

6.3.2 Multiagent Modeling

Multiagent behavioral systems seek to model socioecological interactions as dynamic processes (Moss et al. 2001). Human actors are represented as software agents with rules for their own behavior, interactions with other social agents, and responses to the environment. Physical processes (such as soil erosion) and institutions or organizations (such as an environmental regulator) may also be represented as agents. A multiagent system could represent multiple scales of vulnerability and produce indicators of multiple dimensions of vulnerability for different populations.

Multiagent behavioral systems have an intuitive appeal in participatory integrated assessment. Stakeholders may identify with ''their'' agents and be able to validate a model in qualitative ways that is difficult to do for econometric or complex dynamic simulation models. However, such systems require significant computational resources (proportional to the number of agents), and a paucity of data for validation of individual behavior is a constraint.

6.3.3 Vulnerability and Risk Maps

The development of indicators and indices of vulnerability and the production of global maps are prominent vulnerability assessments techniques at the global level, although these approaches are still being developed to better capture the full concept of vulnerability. Global assessments using these techniques are described later in this chapter.

In order to bring conceptual understanding of vulnerability closer to their cartographic representations, vulnerability and risk mapping efforts are working to resolve several methodological challenges. Generally, risk maps are explicitly concerned with the human dimensions of vulnerability, such as the risks to human health and well-being associated with the impacts from natural hazards.

Given the common focus on human well-being at an aggregate level, vulnerability is quantified in terms of either single or multiple outcomes, such as water scarcity and hunger. Two exceptions are the hotspots of biodiversity (Myers et al. 2000) and the GLOBIO analysis (Nellemann et al. 2001), which are concerned with the vulnerability of biodiversity. For example, the hotspots of biodiversity identify areas featuring exceptional concentrations of endemic species and experiencing exceptional loss of habitat. The GLOBIO analysis relates infrastructure density and predicted expansion of infrastructure to human pressure on ecosystems in terms of the reduced abundance of wildlife. Limited progress, however, has been made as yet in integrating analyses of the vulnerability of human and ecological systems.

Many of the risk maps have been generated from remotely sensed data or information held in national data libraries. The maps are generally developed and displayed using a geographic information system. The analytical and display capabilities of GIS can draw attention to priority areas that require further analysis or urgent attention. Interactive risk mapping is presently in its infancy. The PreView project (UNEP-GRID 2003) is an interactive Internet map server presently under development that aims to illustrate the risk associated with natural disasters at the global level.

For the most part, risk maps have tended to be scale-specific snapshots at a particular time, rarely depicting cumulative and long-term risk. A challenge is linking global and local scales in order to relate indirect drivers (which operate at global, national, and other broad levels and which originate from societal, economic, demographic, technological, political, and cultural factors) to direct drivers (the physical expressions of indirect drivers that affect human and natural systems at regional or local scales). Temporally, risk maps generally depict short-term assessments of risk. The accuracy of these maps is rarely assessed, and risk maps are usually not validated empirically. Two exceptions are the fire maps and the maps of the risk of land cover change. The uncertainty that surrounds the input risk data needs to be explicit and should also be mapped.

A challenging problem for the effective mapping of risk is to move from solely identifying areas of stress or likely increased stress to mapping the resistance or sensitivity of the receptor system. This would highlight regions where the ability to resist is low or declining and the sensitivity of the receptor systems is high. The difficulty here lies in quantifying the ability to resist external pressures. Quantifying resistance, at least in ecological systems, is presently largely intractable as it requires information on the effects of different levels of severity of threats, which is usually species-specific, as well as ways of integrating this information across assemblages of species or areas of interest.

A further challenge to risk mapping is the analysis of multiple and sequential stressors. Generally, single threats or stressors are analyzed and multiple stressors are rarely treated. The ProVention Consortium (2003) aims to assess risk, exposure, and vulnerability to multiple natural hazards. Possible limitations to undertaking a multiple hazard assessment of this kind include accounting for the different ways of measuring hazards (for example, in terms of frequency, intensity, duration, spatial extent), different currencies of measurement, varied data quality, and differences in uncertainty between varying hazard assessments.

Scale and how to represent significant variation within populations of regions are common challenges for global mapping exercises, with broad implications for vulnerability assessment (German Advisory Council on Global Change 1997). Political and social marginalization, gendered relationships, and physiological differences are commonly identified variables influencing vulnerability, but incorporating this conceptual understanding in global mapping remains a challenge. Global-scale maps may consider vulnerability of the total population, or they may consider the situation of specific groups believed to be particularly vulnerable. Because many indigenous peoples are less integrated into political and social support systems and rely more directly on ecosystem services, they are likely to be more sensitive to the consequences of environmental change and have less access to support from wider social levels.

Women and children are also often reported to be more vulnerable than men to environmental changes and hazards (Cutter 1995). Because the gendered division of labor within many societies places responsibility for routine care of the household with women, degradation of ecosystem services—such as water quality or quantity, fuelwood, agricultural or rangeland productivity—often results in increased labor demands on women. These increased demands on women's time to cope with loss of ecosystem services can affect the larger household by diverting time from food preparation, child care, and other beneficial activities. While women's contributions are critical to the resilience of households, women are sometimes the focus of vulnerability studies because during pregnancy or lactation their physiology is more sensitive and their ill health bears on the well-being of children in their care. Children and elderly people are also often identified as particularly vulnerable primarily because of their physiological status.

Measures of human well-being and their relationship to ecosystems services also often incorporate data on the sensitivity and resilience dimensions of vulnerability, expressed as assets, capabilities, or security. These measures are discussed in greater detail in Chapter 5.

6.4 Assessing Vulnerability

The causes and consequences of human-induced change in ecosystems and ecosystem services are not evenly distributed throughout the world but converge in certain regions and places. For some time, for example, Russian geographers prepared "red data maps" to show the locations of what they regarded as "critical environmental situations" (Mather and Sdasyuk 1991). The National Geographical Society (1989) created a map of "environmentally endangered areas" depicting areas of natural hazards, pollution sources, and other environmental stresses. Nonetheless, it is only in recent years that concerted efforts have been made to develop indices and generate maps that depict the global distribution of people and places highly vulnerable to environmental stresses.

As noted earlier, several challenges remain in developing indicators, indices, and maps that capture all the dimensions of vulnerability, but this section reviews major notable efforts that address vulnerability in the context of human security, as an aspect of environmental sustainability, and natural disasters and that point to environmental health issues addressed further in Chapter 14.

Although modest progress has occurred in identifying and mapping vulnerable places and peoples, the state of knowledge and methodology are still significantly limited. Few of the analyses presented here integrate ecological and human systems. They rarely treat multiple stresses, interacting events, or cumulative change. Indicators continue to be chosen without an adequate underlying conceptual framework and are typically not validated against empirical cases. For the most part, they are scale-specific and snapshots in time. Disaggregated data are lacking, and much remains to be done before a robust knowledge base at the global scale will exist.

In a demonstration project, the Global Environmental Change and Human Security Project of the International Human Dimensions Programme on Global Environmental Change (Lonergan 1998) mapped regions of ecological stress and human vulnerability, using an ''index of vulnerability'' composed from 12 indicators:

- food import dependency ratio,
- water scarcity,
- energy imports as percentage of consumption,
- access to safe water,
- expenditures on defense versus health and education,
- human freedoms,
- urban population growth,
- child mortality,
- maternal mortality,
- income per capita,
- degree of democratization, and
- fertility rates.

The criteria used in selecting indicators were that data were readily available, that the resulting ''index'' consisted of a small number of indictors, and that the indicators covered six major categories—ecological and resource indicators, economic indicators, health indicators, social and demographic indicators, political/social indicators, and food security indicators. Through cluster analysis, a vulnerability ''index'' was derived and then used to map estimated vulnerability patterns, such as one for Africa. (See Figure 6.2.)

The work of the Intergovernmental Panel on Climate Change (IPCC 2001a) has made clear that ongoing and future climate changes will alter nature's life-support systems for human societies in many parts of the globe. Significant threats to human populations, as well as some potential benefits, are involved. (See Box 6.1.) As the example on the Arctic region illustrates, changes that benefit some may harm others in the same area. (See also Chapter 25.)

But it is unrealistic to assume that positive and negative effects will balance out, particularly in certain regions and places. Many of the regions and human groups, the IPCC makes clear, will be highly vulnerable and poorly equipped to cope with the major changes in climate that may occur. Many people and places are already under severe stresses arising from other environmental degradation and human driving forces, including population growth, urbanization, poverty and poor nutrition, accumulating environmental contamination, growing class and gender inequalities, the ravages of war, AIDS/HIV, and politically corrupt governments. The IPCC points to the most vulnerable socioecological systems: one third to one half of the world's population lack adequate clean water; many developing countries are likely to suffer future declines in agricultural production and food security; sea level rise is likely to greatly affect low-lying coastal areas; small-island states face potential abandonment of island homes and relocation; and the poor and sick in growing megacities face increased risk for death and illness associated with severe heat and humidity.

In preparation for the World Summit on Sustainable Development in 2002, the Global Leaders for Tomorrow Environment Task Force (2002) of the World Economic Forum to created a global Environmental Sustainability Index. It has five major components developed from globally available national data, including one on reducing human vulnerability. (See Table 6.1.) While it would be desirable to display regional differences within countries, finer-scale information is not consistently available for many types of data.

Human vulnerability seeks to measure the interaction between humans and their environment, with a focus on how environmental change affects livelihoods. Two major issues are included in the vulnerability component (one of the five components in the overall index): basic human sustenance and environmental health. The index is based on five indicators: proportion undernourished in the total population, percentage of population with access to improved drinking water supply, child death rate from respiratory diseases, death rate from intestinal infectious diseases, and the under-five mortality rate. The standardized values for each indicator were calculated and converted to a standard percentile indicator for ease of interpretation. The indicators were unweighted. Country scores were then derived to demarcate global patterns, as shown in Table 6.2.

The United Nations Environment Programme (UNEP 2003) has also assessed definitions, concepts, and dimensions of vulnerability to environmental change in different areas of the world. In particular, it calls attention to the importance of environmental health in the vulnerability of different regions and places. It notes, for example, that every year thousands of people die from a range of disasters, but the fate of many of these people is never reported. The International Red Cross Federation (IFRC 2000) has shown that the death toll from infectious diseases (such as HIV/AIDS, malaria, respiratory diseases, and diarrhea) was 160 times the number of people killed in natural disasters in 1999. And this situation is becoming worse rapidly. It is estimated, for example, that over the next decade HIV/AIDS will kill more people in sub-Saharan Africa than died in all wars of the twentieth century.

The United Nations Development Programme, in *Reducing Disaster Risk: A Challenge for Development* (UNDP 2004), undertakes the formulation of a ''disaster risk index,'' which it then uses to assess global patterns of natural disasters and their relationship to development. The Disaster Risk Index calculates the relative vulnerability of a country to a given hazard (such as earthquakes or floods) by dividing the number of people killed by the number of people exposed to the hazard. The analysts then compared the risk of the hazard (the number of people actually killed by the hazard in a country) with 26 indicators of vulnerability, selected through expert opinion. Analyzing a series of statistical analyses, a number of findings concerning the impact of development on disaster risk emerge:

- The growth of informal settlements and inner city slums has led to the growth of unstable living environments, often located in ravines, on steep slopes, along floodplains, or adjacent to noxious industrial and transport facilities.

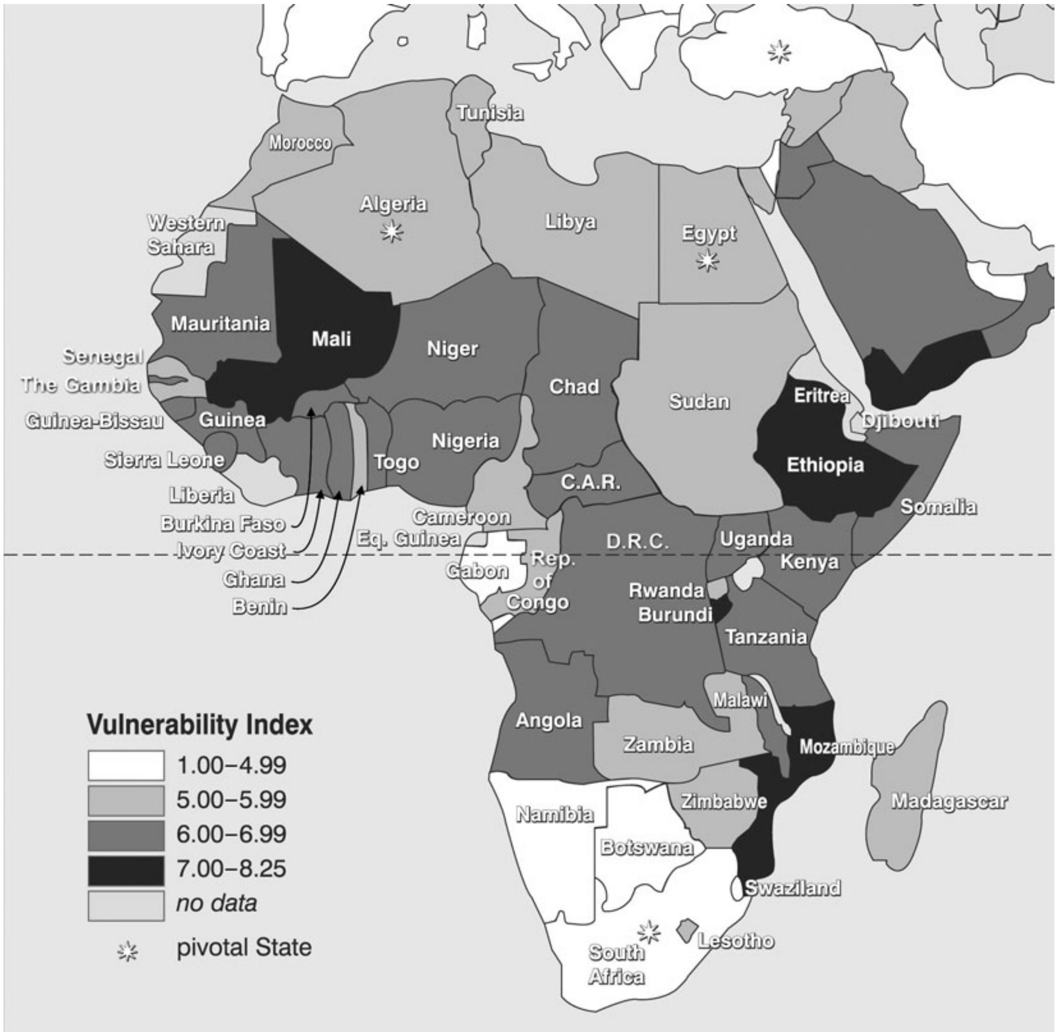

Figure 6.2. Vulnerability Index for African Countries (Lonergan 1998)

- Rural livelihoods are put at risk by the local impacts of global climate change or environmental degradation.
- Coping capacities for some people have been undermined by the need to compete in a globalizing economy, which presently rewards productive specialization and intensification over diversity and sustainability (UNDP 2004, p. 2).

6.5 Natural Hazards and Vulnerability

Natural hazards and disasters are products of both natural variability and human-environment interactions, and vulnerability to them has received substantial past attention. (See also Chapter 16.) The extremes of environmental variability are defined as hazards when they represent threats to people and what they value and defined as disasters when an event overwhelms local capacity to cope. Natural hazards offer a particularly dramatic view of the role of vulnerability in explaining patterns of losses among people and places. Indeed, research on this topic was the first realm to document the vast differences in the magnitude of losses among people and places experiencing the same types of events (White 1974). Since the 1970s, researchers have consistently reported greater loss of life among poorer populations and countries than in industrial countries, along with the inverse relationship for economic damage.

Natural hazards and disasters have always been a part of human history. Yet human relationships to hazards have evolved as the power of humans to shape natural landscapes and their biogeochemical processes has grown. Over the centuries, humans have changed from relatively powerless victims in the face of natural hazards and disasters to active participants shaping natural hazards and our vulnerability to them. Only recently has policy recognized that natural hazards are not ''Acts of God'' and begun to shift hazard management from a model of response and relief to an active engagement with mitigation, prevention, and integration of hazard management into development planning (ISDR 2002).

It is well established that the impacts of natural disasters continue to create uneven patterns of loss in populations around the world. The rising economic costs, the relative significance of those costs to the budgets of developing countries, the increasing numbers of people affected, and the decreasing loss of life demonstrate the dynamics of vulnerability across scales and experienced in local places.

6.5.1 Trends in Natural Hazards and Vulnerability

The best available data on a global scale (e.g., Swiss Re 2000; Munich Re 2003; CRED 2002) indicate that the world is witnessing a worsening trend of human suffering and economic loss

BOX 6.1

Threats and Potential Benefits of Climate Change to Human Societies (IPCC 2001a)

Threats

- Reduced potential crop yields in some tropical and sub-tropical regions and many mid-latitude regions
- Decreased water availability for populations in many water-scarce regions, particularly those with inadequate management systems
- An increase in the number of people exposed to vector-borne diseases (such as malaria) and waterborne diseases (such as cholera)
- Increases in the number of people dying from heat stress, particularly in large cities in developing countries
- A widespread increase in the risk of flooding for many human settlements throughout the world
- Severe threats to millions of people living on low-lying islands and atolls
- Threats to aboriginals living in Arctic and high mountains (for example, through the breakup of ice fields preventing people from reaching their traditional hunting and fishing grounds)

Potential Benefits

- Increased potential crop yields in some mid-latitude regions
- A potential increase in global timber supply from appropriately managed forests
- Increased water availability for populations in some water scarce regions (such as parts of South East Asia)
- Reduced winter mortality in mid- and high latitudes
- Improved marine transportation in the Arctic

Table 6.1. Components of Environmental Sustainability (Global Leaders for Tomorrow Environmental Task Force 2002)

Component	Logic
Environmental systems	A country is environmentally sustainable to the extent that its vital environmental systems are maintained at healthy levels and to the extent to which levels are improving rather than deteriorating.
Reducing environmental stresses	A country is environmentally sustainable if the levels of anthropogenic stress are low enough to engender no demonstrable harm to its environmental systems.
Reducing human vulnerability	A country is environmentally sustainable to the extent that people and social systems are not vulnerable (in the way of basic needs such as health and nutrition) to environmental disturbances; becoming less vulnerable is a sign that a society is on a track to greater sustainability.
Social and institutional capacity	A country is environmentally sustainable to the extent that it has in place institutions and underlying social patterns of skills, attitudes, and networks that foster effective responses to environmental challenges.
Global stewardship	A country is environmentally sustainable if it cooperates with other countries to manage common environmental problems, and if it reduces negative transboundary environmental impacts on other countries to levels that cause no serious harm.

to natural disasters over recent decades.(Data available at the time this chapter was written do not include losses caused by the 2004 tsunami.) While the general trend is clear, the precise estimates vary somewhat, due to improvements in reporting over time, data gathering practices, and definitional differences across organizations. (See Chapter 16 for more detailed description of the limitations and variations among data sets.)

During the past four decades, the number of ''great'' catastrophes—when the ability of a region to help itself is distinctly overtaxed, making interregional or international assistance necessary—has increased about four times, while economic losses have increased over 10 times. (Munich Re 2000) (See Table 6.3.) This trend reflects the increasing economic costs of disasters, lives lost, and the unequal ability of nations to cope with the impacts. Natural disasters affected twice as many people in the 1990s as in the 1980s (CRED 2003). The annual average losses for all disasters over the 1990s were 62,000 deaths, 200 million affected, and $69 billion in economic losses (IFRC 2001). Although comprehensive global databases do not exist for smaller-scale natural hazard events, the significance of these more common events to the social vulnerability of exposed human populations is also a major concern (ISDR 2002; Wisner et al. 2004).

Throughout the twentieth century, three general observations can be drawn from global trends: the number of disasters has increased, economic losses from disasters have increased (primarily in industrial countries), and the ratio of loss of life to total population affected has decreased, although this decline has also been heavily concentrated in industrial societies. (See Figure 6.3 in Appendix A.)

The global trends in natural disaster occurrences and impacts suggest several important patterns of vulnerability among people and places at the same time that they mask considerable geographic variation. Asia is disproportionately affected, with more than 43% of all natural disasters in the last decade of the twentieth century. During the same period, Asia accounted for almost 70% of all lives lost due to natural hazards. In China alone, floods affected more than 100 million people on average each year (IFRC 2002).

Variation among types of natural hazards is also significant. Over the decade 1991–2000, the number of hydro-meteorological disasters doubled, accounting for approximately 70% of lives lost from natural disasters (IFRC 2001). Floods and windstorms were the most common disaster events globally, but not consistently the cause of greatest losses. Disasters causing the greatest number of deaths varied among regions, with floods causing the most deaths in the Americas and Africa, drought or famine the most in Asia, earthquakes the most in Europe, and avalanches or landslides narrowly exceeded windstorms or cyclones in Oceania. Chapter 16 provides a more comprehensive description of flood and fire hazards.

While the economic loss per event is much larger in industrial countries, the greatest losses still occur in developing nations in absolute numbers of lives as well as in relative impact as measured by percentage of GDP represented by disaster losses. (See Figure 6.4.)

Considering lack of resources and capacity to prevent or cope with the impacts, it is clear that the poor are the most vulnerable to natural disasters. Among the poorest countries, 24 of 49 face a

Table 6.2. Reducing Human Vulnerability: Country Scores (Global Leaders for Tomorrow Environmental Task Force 2002)

1.	Austria	85.1
2.	Netherlands	85.1
3.	Sweden	85.0
4.	Canada	85.0
5.	Slovenia	85.0
6.	Australia	84.9
7.	Finland	84.9
8.	United Kingdom	84.8
9.	Norway	84.8
10.	Hungary	84.3
11.	Slovakia	84.3
12.	Switzerland	84.3
13.	Ireland	83.9
14.	Iceland	83.6
15.	Italy	82.7
16.	New Zealand	82.2
17.	France	82.2
18.	Japan	82.1
19.	Denmark	82.0
20.	Greece	81.9
21.	South Korea	81.7
22.	Uruguay	81.1
23.	Germany	80.9
24.	Belgium	80.8
25.	Spain	80.6
26.	Israel	80.4
27.	United States	80.4
28.	Chile	79.9
29.	Russia	79.7
30.	Czech Republic	79.7
31.	Belarus	79.3
32.	Bulgaria	79.1
33.	Costa Rica	79.1
34.	Portugal	78.9
35.	Poland	78.5
36.	Moldova	77.3
37.	Croatia	76.6
38.	Kuwait	76.5
39.	Estonia	76.3
40.	Saudi Arabia	76.2
41.	Argentina	75.2
42.	United Arab Emirates	75.0
43.	Lebanon	74.8
44.	Latvia	74.8
45.	Macedonia	73.8
46.	Ukraine	73.6
47.	Malaysia	73.0
48.	Cuba	72.6
49.	Colombia	71.7
50.	Trinidad and Tobago	71.4
51.	Jordan	70.9
52.	Iran	70.7
53.	Kazakhstan	70.6
54.	Tunisia	68.8
55.	Syria	68.1
56.	Mexico	67.2
57.	Turkey	66.8
58.	Panama	66.2
59.	Brazil	66.0
60.	Lithuania	64.8
61.	Algeria	64.2
62.	Bosnia and Herzegovina	63.7
63.	Romania	62.7
64.	Libya	62.2
65.	Egypt	62.1
66.	China	61.9
67.	Jamaica	61.4
68.	Honduras	61.3
69.	Ecuador	61.2
70.	Paraguay	60.7
71.	Morocco	60.4
72.	Uzbekistan	60.3
73.	Albania	59.8
74.	Thailand	58.9
75.	North Korea	57.9
76.	Venezuela	57.8
77.	South Africa	57.7
78.	Indonesia	57.5
79.	Philippines	56.4
80.	Sri Lanka	56.3
81.	Kyrgyzstan	52.3
82.	Guatemala	52.3
83.	Dominican Republic	51.5
84.	Peru	51.1
85.	Botswana	51.0
86.	Armenia	51.0
87.	Viet Nam	50.5
88.	El Salvador	48.8
89.	Azerbaijan	47.6
90.	Nicaragua	45.6
91.	India	43.8
92.	Bolivia	43.5
93.	Turkmenistan	42.0
94.	Pakistan	41.5
95.	Oman	41.0
96.	Bangladesh	40.3
97.	Zimbabwe	39.2
98.	Namibia	38.5
99.	Gambia	37.3
100.	Laos	35.3
101.	Iraq	33.8
102.	Mongolia	32.8
103.	Myanmar (Burma)	32.6
104.	Ghana	32.3
105.	Nepal	31.5
106.	Bhutan	31.4
107.	Senegal	30.6
108.	Sudan	29.5
109.	Gabon	25.6
110.	Congo	25.1
111.	Côte d'Ivoire	22.4
112.	Tajikistan	21.6
113.	Benin	21.0
114.	Togo	18.3
115.	Nigeria	18.2
116.	Papua New Guinea	18.0
117.	Uganda	15.4
118.	Cameroon	15.1
119.	Burkina Faso	10.3
120.	Kenya	10.2
121.	Tanzania	9.9
122.	Mauritania	9.7
123.	Central African Rep.	9.4
124.	Mali	9.3
125.	Cambodia	8.2
126.	Guinea	8.1
127.	Madagascar	7.9
128.	Haiti	7.9
129.	Malawi	7.4
130.	Zambia	6.9
131.	Burundi	6.4
132.	Rwanda	6.1
133.	Mozambique	5.4
134.	Niger	5.1
135.	Guinea-Bissau	5.1
136.	Liberia	3.9
137.	Chad	3.8
138.	Somalia	3.5
139.	Zaire	2.7
140.	Ethiopia	2.4
141.	Sierra Leone	2.2
142.	Angola	1.9

high level of disaster risk; at least 6 countries have been affected by two to eight major disasters per year in the past 15 years, with long-term consequences for human development (UNEP 2002). Ninety percent of natural disaster–related loss of life occurs in the developing world. When countries are grouped according to the UNDP Human Development Index, socioeconomic differences are strongly reflected in disaster losses (IFRC 2001). For the 1990s, countries of low human development experienced about 20% of the hazard events and reported over 50% of the deaths and just 5% of economic losses. High human development countries accounted for over 50% of the total economic losses and less than 2% of the deaths.

In assessing the distribution of vulnerability, several limitations to existing research need to be considered. First, economic valuations do not reflect the difference in relative value of losses among wealthier and poorer populations or the reversibility of environmental damages incurred. Similarly, land degradation due to landslides, flooding, or saline inundation from coastal events can diminish the natural capital resources of livelihoods, further compounding recovery challenges. The meaning of the economic value of these losses of ecosystem services is also difficult to capture and is seldom included in conventional economic assessments.

Second, because of the definitions of disaster used, local-scale disasters of significance to the affected community are often not reflected in these disaster statistics. If those losses were included, the figures on damages could easily be much higher.

Finally, there is the tendency to treat natural hazards in separate categories and to treat disasters as discrete, individual events.

Table 6.3. Great Natural Catastrophes and Economic Losses: Comparison of Decades, 1950–99 (Munich Re 2000)

Catastrophes and Losses	1950–59	1960–69	1970–79	1980–89	1990–99
Number	20	27	47	63	82
Economic losses (bill. 1998 dollars)	38.5	69.0	124.2	192.9	535.8
Insured losses (bill. 1998 dollars)	unknown	6.6	11.3	23.9	98.9

Note: Natural catastrophes are classified as "great" if the ability of the region to help itself is distinctly overtaxed, making interregional or international assistance necessary.

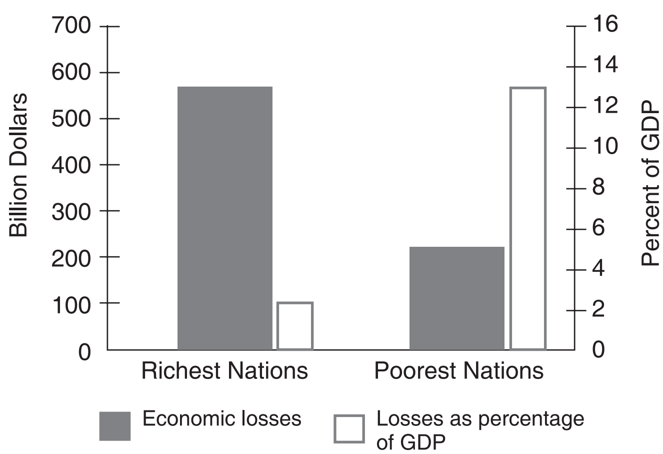

Figure 6.4. Disaster Losses, Total and as Share of GDP, in 10 Richest and Poorest Nations, 1985–99 (Abramovitz 2002)

This accounting practice limits insights into the consequences of threats from multiple hazards in one place and of sequences of disasters following upon one another. Over time, multiple and recurring hazards exacerbate vulnerability, and across scales, vulnerability is generally greater during the recovery period, when systems are already damaged. These patterns of differential impact affect efforts to cope with the impacts of environmental variability and degradation, as described earlier.

6.5.2 Explaining Vulnerability to Natural Hazards

Human-driven transformation of hydrological systems, population growth (especially in developing countries), and movements of people and capital into harm's way are major driving forces underlying the increasing numbers of disasters (Mitchell 2003). Conflict among people contributes further to vulnerability (Hewitt 1997). The causal reasons relate to basic characteristics of economy and political system but also to the perceptions, knowledge, and behavior of local managers and institutions (Hewitt 1997).

In some regions, significant environmental changes have resulted in the degradation of ecological services that mediated the effects of hydro-climatological events. Two common forms of ecological change—desertification and deforestation—can exacerbate the impacts of drought in some areas by reducing the moisture-holding capacity of the soil and contribute to increased flooding through reducing infiltration. (See Chapter 16.) In Honduras, deforestation contributed losses through increasing flooding as well as landslides following Hurricane Mitch in 1998. In other areas, efforts at river or flood control have reduced vulnerability to smaller hazard events, but increased losses when larger events overwhelmed dams, dykes, or levees and damaged the usually protected area.

The growth in numbers of people affected is a particularly important measure, as it provides an indication of the potential increase of exposure and sensitivity of people to environmental variability. The global annual average number of people affected has increased over the last decade, although the number of deaths due to disasters has declined. This shift highlights the potential for changes in pattern of vulnerability though adaptations. (See also MA *Policy Responses,* Chapter 11.) The greatest proportion of people affected resides in countries of medium human development, which include the large-population countries of Brazil, China, India, and Indonesia (IFRC 2001).

In addition to changing exposure, socioeconomic changes are shaping the overall patterns of vulnerability. First, while poverty is not synonymous with vulnerability, it is a strong indicator of sensitivity, indicating a lack of capability to reduce threats and recover from harm. The number of people living in poverty is increasing (UNDP 2002a). The greater number of people affected in medium human development countries may also reflect their experience with the additional challenges of transition, a situation somewhat akin to recovery, in which infrastructure and support systems, both physical and social, may be disrupted by the processes of change and be unable to contribute to reducing vulnerability.

Urbanization creates particular problems in disaster vulnerability. Due to the concentrations of people and complex infrastructure systems involved, the repercussions of an event in cities can spread quickly and widely, and the scale of resources needed for effective response is often challenging for national or international coordination. In many cases, these cities also draw in vast numbers of people seeking better lives, but they are often unable to keep up with the demand for planning, housing, infrastructure, and jobs. The informal housing that immigrants create is often located in marginal areas, such as hill slopes and floodplains, and accessible construction options cannot address the site limitations (Wisner et al. 2004). In 1950, just under 30% of the world's population (of 2.5 billion) lived in cities; by 2025 it is projected to be over 60% (of an estimated 8.3 billion) (UNDP 2002b). This rapid urbanization trend is particularly pronounced in countries with low per capita income. (See also Chapter 27.)

Globalization is contributing to natural hazard vulnerability as it is changing the sensitivity and coping options available (Adger and Brooks 1003; Pelling 2003). On an international scale, increasing connectedness is causing societies to become more dependent on services and infrastructure "lifelines." In such a connected world, the consequences of natural disaster reach far beyond the area physically damaged. It has been estimated that the possible extent of damage caused by a extreme natural catastrophe in one of the megacities or industrial centers of the world has already attained a level that could result in the collapse of the economic system of entire countries and may even be capable of affecting financial markets worldwide (Munich Re 2000, 2002). Globalization has also increased the risks faced by marginalized indigenous peoples; many of these are developmental effects that will become apparent over only the long term. Traditional coping mechanisms have come under severe pressure, and adaptation strategies, at one time effective, can no longer cope (Pelling 2003).

Data on global trends do not report on the social differentiation among victims, but case study evidence and other synthesis efforts indicate some social groups are continually disproportionately represented among those harmed the most (Wisner et al. 2004). These are often people who are marginalized within society, due to combinations of prejudice, lack of or ignored rights, and lack of access to social supports or personal resources or due to distance from concentrations of services and power. Indigenous peoples, such as the Inuit, Sami, and others from northern regions, represent the vulnerability of this type of situation well. (See Chapter 25 for further details). These circumstances often apply to poor people, women, children, elderly individuals, and ethnic minorities in affected areas. In addition, the elderly, children, women, and handicapped people are more likely to have physical limitations or special needs that reduce their ability to cope with disaster.

6.6 Desertification: Lessons for Vulnerability Assessment

Desertification—land degradation in drylands—has been a subject of interest for over 30 years, with numerous technical assessments and policy analyses, and it is a good example of changes in a coupled socioecological system that threaten livelihoods across large swaths of Earth. It is also a good example of understanding vulnerability. (See Downing and Lüdeke (2002) and Chapter 22 for more on drylands and desertification and a useful set of maps.)

Local to global studies of social vulnerability to desertification suggest at least three lessons for vulnerability from past experience:

- *Vulnerability is dynamic.* Desertification arises from the interactions of the environment and social, political, and economic systems—through the actions of stakeholders and the vulnerable themselves (Downing and Lüdeke 2002).
- *Vulnerability takes different forms at different scales.* Similar constellations of institutions have diverse effects at different social or geographic scales. The patchiness of driving forces, often represented in global scenarios, precludes developing a simple hierarchy from local vulnerability to global maps of desertification risks.
- *Vulnerability cannot be differentiated into different causes.* At the level of human livelihoods and systems, exposure to desertification is entangled with poverty, drought, water, food and other threats and stresses.

One example of the close coupling of social and environmental systems related to desertification is apparent in the syndromes approach developed by the Potsdam Institute for Climate Impact Research, which depicts the close linkages and components involved in the coupling. The basic idea behind syndromes is "not to describe Global Change by regions or sectors, but by archetypical, dynamic, co-evolutionary patterns of civilization–nature interactions" (Petschel-Held et al. 1999, p. 296). Syndromes are charted in dynamic process models that link state variables that change over time and between states. The scale is intermediate, reflecting processes that occur between household and national/macro scales. The typology of syndromes reflects expert opinion, modified over time based on modeling. Local case examples are used to generalize to mechanisms in the modeling and also to validate the syndrome results. Desertification is a case of several syndromes operating independently, reflecting the internal dynamics of places, resources, economies, and populations.

The syndrome approach illustrates how concepts of dynamic vulnerability might be implemented to understand multiple stresses arising from the human use of ecosystem services. It takes the analysis one stage beyond purely biophysical explanations to examine linkages with human systems. The next steps might be integrated analysis at the level of different users of ecosystem services, and how they interact with each other in markets and in governance.

6.7 Food Insecurity

The arena of food security has been a third primary focus of vulnerability analysis. The severe famines in the 1980s in Africa saw the launch of dozens of famine early warning schemes. These implemented various designs, but all expanded beyond the simple monitoring of agricultural production. By the mid-1980s, Amartya Sen's entitlement theory (Sen 1981), which emphasized factors influencing the distribution of food as well as the absolute levels of available food, was widely circulated and implemented in food security monitoring. Attention to the socioeconomic failures that limit access to global food supplies became a substantial component of these efforts. More recently, more holistic approaches have sought to focus on livelihood security, to include food security, thereby widening the conceptual framing of vulnerability still further.

Much of the literature on food security focuses on human vulnerability; ecosystem services are limited to crop production, grazing for livestock, and to a lesser extent wild foods. While vulnerability assessment is maturing as an analytical tool, the need exists for assessments that are more dynamic and actor-oriented. An essential way forward in vulnerability analysis is to adopt a more precise terminology and nomenclature (see, e.g., the papers in Smith et al., 2003).

6.7.1 Methodology

Methodological lessons learned in vulnerability assessment over the past several decades reinforce the general messages of this chapter: food security is a relative measure that can be captured in various quantitative and semi-quantitative ways, but it is not an absolute condition that can be measured objectively. Food security is multidimensional and it integrates exposure to stresses beyond more narrow treatment of the production or availability of food. (See Chapters 8 and 18 for a further description of food provisioning services.) It is also clear that indicators of food security need to represent an explicit conceptual framework, such as that offered earlier in this chapter. The collation of indicators into profiles and aggregated indexes needs also to reflect the causal structure of food insecurity, going beyond the indiscriminate adding up of available indicators into a single index (see Downing et al. 2001).

A common feature of almost all food security (and livelihood) analyses is the recognition of multiple domains of vulnerability. Operational assessments commonly treat production, economic exchanges, and nutrition, while longer-term and more structural analyses include some measure of the political economy that underlies the more immediate dimensions of food security. Examples of operational assessments include India (MSSRF 2001) and Kenya (Haan et al. 2001). Figure 6.5 charts three domains of rural food insecurity for states in India.

A more heuristic illustration of the multiple dimensions of food security, related to climate change, is shown in Figure 6.6 (in Appendix A). The Figure is speculative, based on a subjective assessment of food security and climatic risks. Nevertheless, it clearly shows that global food production is of less concern than

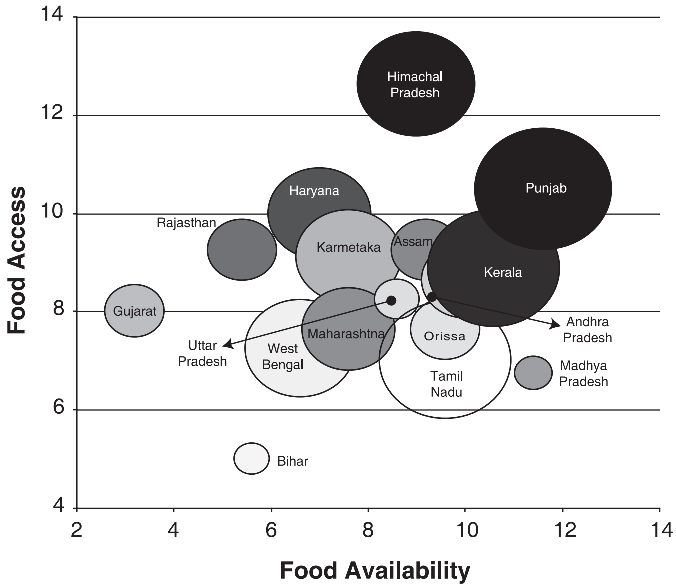

Figure 6.5. Food Insecurity Indicators of Rural India. Compiled at the state level, the MS Swaminathan Research Foundation aggregated food insecurity into three dimensions—food availability and production (x-axis), economic access (y-axis), and nutritional utilization (size of the circles, where larger is better-off). (MS Swaminathan Research Foundation 2001)

the impacts of droughts, which are already economically and socially significant for some livelihoods.

6.7.2 Wild Foods at the Local Scale

While a myriad of propositions regarding food security are possible, relating to different elements of causal structure, from the nature of the hungry themselves to the global political economy of food trade, here the case of wild foods and their role in food security is examined. (See also Chapters 5, 8, and 18 for food production and hunger issues.)

The most common approaches to food security are designed to balance consumption and production at the household level—including such indicators as expected yields of major foods (related to rainfall, soil quality, and pests, for instance), economic exchanges (such as terms of trade for agricultural sales or access to off-farm employment), hunting of wild foods, and some measures of entitlement through remittances from kin, official food relief, and relief work schemes. Set against the total of available food is the expected consumption, from meeting the FAO calorie standards to various levels of deprivation and starvation resulting in measurable effects on health. Aggregating to a regional or national level, such food balances guide policies for imports and exports, for targeted relief, and for declaration of a food crisis.

Notably absent from such food balances is the role of off-farm food collection—the gathering of wild foods either for consumption or sales. (See Chapter 8 for a more detailed description of the role of wild foods, including game, fish, and plants, in diets and for the underestimation in accounting in food balances.) In forest regions, these are called non-wood forest products and can be a major livelihood activity. Equally, few monitoring schemes include direct measures of ecosystem services such as charcoal sales, increased burdens of water shortages, or even effects of vegetation and land cover on livestock and pests. Nevertheless, for some marginal communities, such ecosystem services are essential and particularly important for surviving food shortages (Ericksen 2003).

Investigations of two dryland sites in Kenya and Tanzania found that indigenous plants were an important source of raw material in the majority of coping mechanisms when alternative sources of food or income were required, such as when the harvest failed or sudden expenses had to be met. Such coping mechanisms included making use of trees for making and hanging beehives (flowering trees are also a source of nectar); of fuelwood for sale, burning bricks, or producing charcoal; of reeds, fibers, and wood for handicrafts such as mats or tools; and of fruit, vegetables, and tubers for food and sale. Indigenous plant-based coping mechanisms are particularly important for the most vulnerable, who have little access to formal employment or market opportunities, thus providing a crucial safety net in times of hardship. Wild fruits provide important nutrients to children during times when meals are reduced at home in many parts of Africa and South Asia (Brown et al. 1999), for example.

Such raw materials can often be acquired from communal land or from neighbors without cash transactions, and they are available at critical times of the year due to the climatic resilience of indigenous plants. In addition, the sale of livestock and poultry and engaging in casual labor, which are critical sources of cash during crises, often depend on ecosystem services, such as grazing land and fodder or forest products for fencing, construction, and other typical casual labor tasks. Table 6.4 shows the high percentage of households that depended on indigenous plant-based coping mechanisms in the Kenya and Tanzania site (Eriksen 2000), and Figure 6.7 illustrates the relative importance of indigenous foods. While the findings refer to a particular point in time (the 1996 drought), the widespread use of forest products as a source of food and income figures is consistent with findings from numerous other studies (Arnold 1995; Brown et al. 1999).

6.7.3 Global Influence on Local Food Balance

The literature on food security has a long tradition recognizing that local food balances are embedded in national economies and global flows of food trade and aid (for one representation, see Kates et al. 1988). A fictitious illustration captures the notion of global exposure:

> *During a drought, a farm household suffers a loss of yields in one of its fields of maize and beans. The field is primarily used for domestic consumption, cultivated by the women. Rainfall shortages are apparent with the delay in the onset of the rains—although the field is planted and later weeded by the women, the family does not apply expensive pesticides and fertilizers, expecting low returns during a poor season. Another field has a different problem. The head of the household acquired it as part of a community-based irrigation scheme*

Table 6.4. Households That Depended on Indigenous Plant-based Coping Mechanisms in Kenya and Tanzania (Eriksen 2000)

Activities that Involve Use of Indigenous Plants	Share of Households, Kenya site	Share of Households, Tanzania site
	(percent)	
All use	94	94
Food use	69	54
Non-food use	40	42

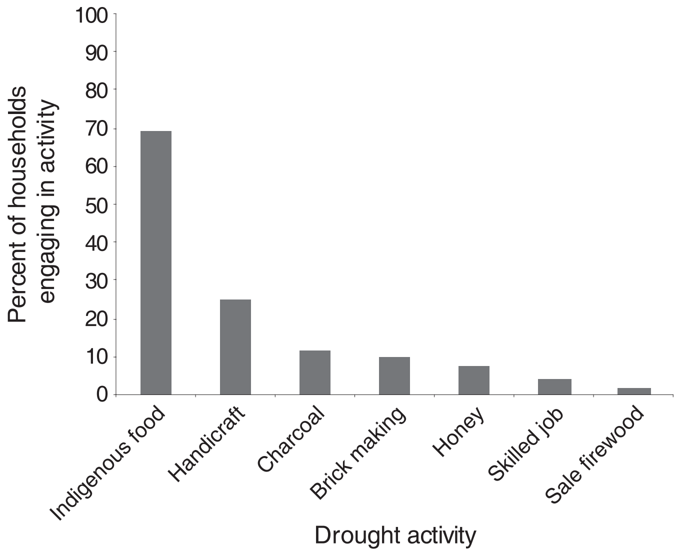

Figure 6.7. Use of Indigenous Plants in Mbitini, Kenya, by Activity during the 1996 Drought. "Skilled job" entailed tailoring, stone masonry/construction of houses, and woodcarving. Total number of households is 52. (Eriksen 2000)

that he joined a few years ago. He plants it this year with a cash crop of tomatoes and invests in fertilizer and pesticide. Halfway through the season, however, the drought restricts the availability of irrigation water. As a "junior" member of the scheme, his supply is reduced earlier than expected and his yields and quality are poor. When he tries to sell his crop to the local factory for processing into tomato juice, he discovers that there is a glut in the market due to a relaxation of import controls. Good conditions in a nearby country and export subsidies have produced a surplus, and the factory cannot afford to purchase local produce.

The fictitious example is not unrealistic—farmers have to contend with local conditions, with social, economic, and environmental relations in their community, and with the global and national food system. This global nature of vulnerability makes it impossible to clearly "bound" exposure, and it is often misleading to adopt a single spatial scale, as is often attempted in mapping vulnerability (as noted earlier regarding tools and methods).

6.7.4 Reporting Vulnerability

An essential way forward in food security analysis is to use at least a more precise terminology and nomenclature. A fairly simple scheme is proposed here, which makes clear four fundamental considerations that are not consistently reported: who is exposed, what the stresses are, what time frame is considered, and what consequences evaluated (see Downing et al. 2004). The notation below calls for reporting vulnerability (V) as specific to time frame (t); the sector, such as agriculture (s); the group, such as small-scale farmers, women farmers, or residents of peri-urban areas (g); and the consequences evaluated, such as food production, change in food purchasing power, nutritional levels or hunger (c).

$$ {}^{t}V_{s,g}^{\;c} $$

(where s = sector, g = group, c = consequence, t = time frame and V = vulnerability)

For instance, an examination of climate change vulnerability in agriculture could offer greater utility to future comparisons and policy by specifying differences as follows:

- Climate change vulnerability (T = climate change, no other terms specified)
- Drought (T) vulnerability for food systems (s)
- Drought (T) vulnerability for smallholder (g) agriculturalists (s)
- Drought (T) vulnerability for smallholder (g) agriculturalists (s) at risk of starvation (c = health effects of reduced food consumption)

These four different statements about climate change vulnerability suggest the range of potential differences in assessment findings. The process of conducting a vulnerability assessment can be labeled VA. If the indicators are mapped, this is extended to a vulnerability assessment map, a VAM. A database of vulnerability indictors used in a VA (or VAM) can be labeled VI. Greater precision and analytical comparability could be gained by assigning a nomenclature to individual indicators (VI_x), such as:

t = time period (historical, present or specific projection)
g = group of people if specific to a vulnerable population
r = region (or geographic pixel)
* = transformed indictors, as in standard scores

This basic set of relationships can be extended into a variety of assessment tools and facilitate comparison of case studies.

6.8 Exploring Vulnerability Concepts: Three Case Studies

The broad patterns of vulnerability apparent in the patterns and trends of natural disasters, the assessment of desertification, and the lessons from food security studies all demarcate important aspects of the sources and outcomes of stresses and perturbations on coupled socioecological systems. But it is well known that these interactions are highly place-specific. Thus it is useful to turn to particular cases to explore these issues in greater depth.

This section considers three specific examples. First, the situation of two types of resource-poor farmers in northeastern Argentina is examined, illustrating how vulnerability can take different forms with different types of farming systems. Second, we look at how shifting the scale of analysis or vulnerability and resilience yields quite different insights on the sources of vulnerability and the potential effectiveness of resilience-building strategies, using a case study from Southern Africa. Finally, efforts to reduce vulnerability and the challenges involved in assessing the benefits of different types of interventions are examined through a case study from the one of the poorest areas of India.

6.8.1 Resource-poor Farmers in Northeastern Argentina

The Misiones region, in a hilly area of northeastern Argentina, has a sub-tropical wet climate where about 60% of the original vegetation (sub-tropical forest) has now been replaced by agriculture, despite the fact that soils are fragile, ill-suited for continuous cropping, and subject to nutrient depletion and erosion (Rosenfeld 1998).

Subsistence farming is common in the region, and two major types of farmers can be distinguished. Both have a similar farm structure in terms of land, capital, and labor; both are very poor; and both types often cannot meet their basic needs (Cáceres 2003). But they have designed very different farming systems and developed contrasting strategies to interact with the wider context within which they operate. On the one hand, agroecological farmers have developed farming systems of very high diversity, use few external inputs, rely mostly on local markets, and are part of representative peasant farmer organizations. Tobacco growers, by contrast, manage less diverse agroecosystems, rely on external inputs provided by the tobacco industry, have a weak participation in local organizations, and are closely linked to external markets. (See Table 6.5.)

6.8.1.1 Agrobiodiversity

The number of domesticated animals and cultivated plants (agrobiodiversity) maintained by the two types of farmers is strikingly different. On average, agroecological farmers grow or raise three times as many species within a single farm as tobacco growers do. The total number of species in all surveyed farms is also very different: 97 species in the case of agroecological farmers and 41 species for tobacco growers. This indicates that agrecological farmers maintain a higher degree of heterogeneity among farms and a higher agrobiodiversity at the landscape-to-region level. Horticultural, aromatic, and medicinal crops and fruit trees are the most diverse categories both within and among farms.

Agrobiodiversity has a direct impact on food security (Altieri 1995). The more diverse farms are, the more likely they are to meet subsistence food needs. The opposite occurs in the case of farmers specialized in the production of commodities (such as tobacco), since most of the farm resources are allocated to a goal that does not strengthen local food security (Dewey 1979; Fleuret and Fleuret 1980). This situation is clearly observed in this case, where agroecological farmers grow more than three times as many species for food as tobacco growers do.

6.8.1.2 Technology

Agroecological farmers and tobacco growers also differ strongly in terms of farm technology. Although both draw on the same technological matrix (draft power and the use of fire to clear up land), the ''final'' technologies used in their farms are very different (Cáceres 2003). In order to produce their cash crop, tobacco growers rely on modern technology and a conventional approach to farming. This involves the use of high external input technology (chemical pesticides and fertilizers and high-yield seeds) and monocropping. Nearly all the inputs needed for tobacco production come from the market. Because tobacco growers have an extremely limited financial capacity, they rely on the credit provided by tobacco companies, which in turn buy the tobacco leaves from them, in a typical contract-farming relationship.

In contrast, the technology used by agroecological farmers rests mostly on the understanding and management of natural processes and cycles. Rather than relying on external inputs, they maximize the use of both local and agroecological knowledge and resources that are locally available. As a consequence of both their traditions and the extension work of development agencies, the use of raised beds, composting practices, intercropping, biological pest control, and crop rotation is common among the agroecological farmers (Rosenfeld 1998). In order to gain access to this technology, these farmers do not need to develop a heavy reliance on the market, nor do they require the financial support of the agroindustry.

6.8.1.3 Scale Interactions

The socioeconomic and institutional context, in particular of markets and organization, is another key element shaping the vulnerability of rural societies. Tobacco growers in the Misiones have a less diversified relationship with the markets, since the tobacco companies are the main social actor with whom they interact. This is the highly asymmetrical relationship that typically develops in contract farming (Watts 1990). Tobacco growers are unable to make the most important farming decisions (such as how many tobacco plants to have, or which varieties), negotiate the quality and price of their tobacco with the agroindustry, or even decide which company to sell their product to.

The contacts of agroecological farmers with the agroindustry, on the other hand, are weak, and they are mostly linked to NGOs and governmental programs fostering rural sustainable development. Agroecological farmers have substantial control over the productive decisions concerning their farms and have developed a more diversified relationship with the market. They sell their production through different channels, of which the organic farmers' markets is the main one. In these markets, farmers and consumers meet once a week, when they set the price and other aspects of the commercial transactions. The wider range of products that agroecological farmers bring to the market also allows more spreading of commercial risks and thereby has a favorable impact on the stability of their cash flow.

The differences among these two types of farmers are even more noteworthy in terms of their participation in local organizations. Agroecological farmers not only relate with a higher number of organizations, they are also part of a larger number of grassroots representative organizations committed to peasant interests and civil rights. In contrast, tobacco growers are almost exclusively related to the Tobacco Growers' Association of Misiones, a highly bureaucratized organization that primarily represents tobacco company-interests (Schiavoni 2001). Yet the participation of tobacco growers in this organization is compulsory in order to be able to sell their tobacco to the agroindustry.

6.8.1.4 Synthesis: Differential Vulnerability

Agroecological farmers and tobacco growers share many key social and productive features. Both types of farmers and the envi-

Table 6.5. Differences between Agroecological Farmers and Tobacco Growers in Terms of Agrobiodiversity, Food Safety, Links with Markets, and Representative Organizations ($P < 0.001$, Mann-Witney U test for independent samples) (Cáceres 2003)

	Agroecological Farmers			Tobacco Growers		
Variable	**Median**	**Minimum**	**Maximum**	**Median**	**Minimum**	**222**
Total number of plant and animal species grown or raised on the farm	40	21	54	14	7	82
Number of species grown or raised for family consumption	28	18	42	10	4	11
Number of species sold in the market	5	3	10	2	1	1
Participation in organizations (number)	2	1	5	1	1	1

ronment in which they develop their farming strategies may be regarded as "vulnerable." However, as this case illustrates, factors shaping vulnerability can come together in a variety of ways that result in substantial variations in the magnitude and types of vulnerability, even among a group such as small-scale farmers, who are often assumed to be homogeneous.

Given these differences in vulnerability, the agroecological farmers appear less vulnerable overall than tobacco growers. Differences in agrobiodiversity, technology, and articulation to the wider context are the main factors underpinning this contrast. On the one hand, agroecological farmers appear to have developed more autonomous and resilient livelihood strategies. They manage more diverse and stable agroecosystems, produce more food, and show a stronger negotiating capacity within the political process. The strategy of tobacco growers, in contrast, depends far more on the agroindustry. They produce less food, have very limited negotiation power, and are more exposed to the control of tobacco companies and the fluctuations of tobacco prices and industry.

All this suggests that livelihood strategies used by different groups can dramatically increase or decrease their level of vulnerability. Since the articulation to the wider context is a key aspect in determining the vulnerability of poor farmers, the latter can change drastically due to external factors, no matter how "sensible" the within-farm decisions. This suggests that vulnerability involves the amplification and attenuation of a variety of conditions that depend on both internal and external circumstances, and that vulnerability changes over time with changing stresses or needs in households or with wider socioeconomic and political changes that increase or decrease access to various assets and opportunities.

6.8.2 Vulnerability and Resilience in Southern Africa: Perspectives from Three Spatial Scales

The southern African region is currently facing a suite of complex emergencies driven by a mix of factors, including HIV/AIDS, conflict, land tenure, governance, and lack of access to resources, coupled with climate risks—not least of which is the emergence of floods as a serious hazard (Mano et al. 2003; Vogel and Smith 2002; IPCC 2001a). Existing adaptive capacity is also, arguably, being increasingly eroded and undermined by such factors. The World Food Programme has recently estimated that around 14 million people in the region are in a heightened food insecurity situation (Morris 2002). Contributing factors emerging from this situation include, among others, low opening stocks of cereals from previous years, low grain reserves in some countries, low levels of preparedness for such food insecurity, and inappropriate and constraining policies that contributed to market failures (Mano et al. 2003).

This case examines the multiple roles of global environmental change as part of a complex suite of stressors (such as climate, governance, and health) and adaptation to such stressors in South Africa, using the 2002/03 famine situation in the Southern African Development Community as a backdrop. The theme of resilience and adaptation in the face of global change (Adger 2000) is analyzed at three spatial scales, moving from the regional (SADC) level to the district and community levels, focusing particularly on the role of information as a potential input into building sustainability. The greatest priority in such an investigation is less one of describing the problem than it is interactively crafting appropriate sustainable interventions. (No suitable "sustainable" interventions can be designed in isolation of the institutions and stakeholders involved.)

6.8.2.1 The SADC Region 2002/03 Season: Coping with Complex Environmental Stress

The contributions of various socioeconomic and political factors, often generated outside the region, have long been acknowledged to contribute to the complexities associated with climate stress and food insecurity facing Southern Africa (Benson and Clay 1998). Several of these myriad of factors usually become particularly important during a severe dry spell, flood, or other climate-driven event.

In response to the droughts of the 1970s, 1980s, and 1990s, international organizations, bilateral donors, African governments and NGOs established numerous early warning systems and enlarged institutional capacity to manage food security and risks (Moseley and Logan 2001). These entities have been actively undertaking efforts to reduce vulnerability to a number of risk factors in the region. A clear activity has been to examine current risks and threats primarily relating to drought-induced production deficits and to provide improved climate information to serve the agricultural sector (see, e.g., Archer 2003).

Another priority has been not only to increase the understanding of food provision and production but also to improve assessments of food procurement and access to food by households in the region (e.g., see Devereux 2000; Vogel and Smith 2002) and the factors (such as institutions, governance, and policy issues) that enhance or constrain access to food. The contributions of adverse synergies, including natural triggers (such as drought) and politics (such as civil stress) that have precipitated famines (Devereux 2000), have in some cases become more prevalent and endemic in sub-Saharan Africa.

A number of interesting adaptive measures have emerged from assessments undertaken of the 2002/03 famine in the region (see www.fews.net). Vulnerability assessments show, for example, that cereal production is sometimes not a key activity in procuring food in risk-prone households. Rather, it is food purchases and other inputs (remittances, gifts, and so on) that enable households to obtain food. Such insight on adaptation practices has only emerged from detailed food economy investigations. Such studies reveal and question the role of "food relief" as an intervention strategy in reducing the impacts of the crisis. Furthermore, the role of HIV/AIDS in aggravating the situation in several households is also emerging as a strong and negative factor (SADC FANR Vulnerability Assessment Committee 2003).

With the background of this regional scale, vulnerabilities to a similar suite of risks (including climate, management, and other factors) can be understood at the scale of South Africa and Limpopo Province. These case studies clearly show that, similar to the regional examples described earlier, a well-intentioned focus on early warning can do little to enhance resilience to risks if it is not coupled with a careful examination of the wider socioeconomic environment in which such activities operate (such as the policy environment, or institutional strengths and weaknesses), consistent with the northern Argentina case.

6.8.2.2 South Africa, 2002/03 Season—The National Scale

An unusually dry 2002/03 summer rainfall season caused widespread livestock mortality and water scarcity for growing crops in Limpopo, Mpumalanga, and North West Provinces in South Africa. In Limpopo, the provincial government requested 40 million rand in drought relief from the National Department of Agriculture, in addition to 6 million rand of provincial emergency funding that was made available (largely for subsidized fodder). Official estimates were that drought-related cattle mortalities exceeded 18,000.

A range of potentially valuable mechanisms to promote drought mitigation and risk reduction was, however, in place. Institutions and mechanisms included the Agricultural Risk Management Directorate, whose Early Warning Subdirectorate was substantively involved in improving awareness of early warning in the agricultural sector. The Early Warning Subdirectorate was established to improve forecast dissemination to smallholder farmers after forecasters and decision-makers realized that the information did not reach any further than provincial departments of agriculture (Archer and Easterling 2004). In addition, the National Agrometeorological Committee was established as a forum for reviewing updated seasonal outlook and provincial reports regularly throughout the season.

Essentially, the seasonal warning advisory was developed and disseminated at least to the provincial level in South Africa for the 2002/03 season. In spite of this, the adverse effects of climatic risk were substantial. Accepting that further investigation is required (and is planned), some preliminary observations on the 2002/03 season at the national scale in South Africa are possible.

As is well documented in a variety of case studies, forecasts, warnings, and information were in themselves insufficient to ensure action to improve resilience to environmental stress. In this case study, failures may have occurred in dissemination (for example, forecast information may not have been disseminated to extension officers or farmers). There may also have been failures in response capacity—even had farmers heard the seasonal warning, they may, for a variety of reasons, have been constrained in their ability to take anticipatory action (such as destocking). Last, there may have been weaknesses in institutional capability as well as weaknesses of ''fit'' and ''interplay'' between what institutions are providing and what is required (see, e.g., Folke et al. 1998; Berkes and Folke 1998; Orlove and Tosteson 1999; Raskin et al. 2002). Even with effective information dissemination, provincial, municipal, and local institutions may themselves be constrained in their ability to either recommend or support appropriate actions to improve resilience.

6.8.2.3 Vhembe District, Limpopo Province, 2002/03 Season

Results from research at the district and local level in Vhembe district of Limpopo Province show where gaps and weaknesses existed with regard to improved resilience to climatic risk in the 2002/03 season. It appears that this was the first season that the surveyed community (first surveyed in 2000/01) had exposure to seasonal forecast information. The Vhembe District Department of Agriculture and the District Department of Water Affairs and Forestry also received the forecast. Yet both at the community level and at the district institutional level, little response was apparent. Identifying the reasons for the lack of action is key to understanding the adverse drought effects at the national and provincial level described earlier.

First, it is clear that the forecast alone was insufficient, both for the needs of farmers and for district institutions. Both farmers and institutions explicitly asked for more guidance in terms of what actions might be appropriate in the light of the forecast or warning information. Farmers requested, for example, that when the seasonal forecast (or severe weather warning) was broadcast over the radio, the announcement needed to be coupled with an advisory. Such an advisory could include a wide range of general advice at various scales—at the district level, for instance, information on planting dates; at the farm level, very specific information on cultivars and planting. The District Department of Agriculture asked that the existing agricultural advisory be further developed and refined for local district conditions. The District Department of Water Affairs and Forestry requested that the agricultural advisory be adapted for the water sector (and for other climate-sensitive sectors as well, such as health).

Second, farmers themselves may have been constrained in their ability to respond to information about climatic stress. The most commonly documented constraint on response capacity was resource limitation, including lack of access to credit, supplemental irrigation, land, and markets as well as lack of decision-making power (particularly in the case of women farmers) (Archer 2003). Further research in the area is seeking to understand the precise role of resource limitations and misdirected inputs (such as inappropriate irrigation infrastructure) in constraining both the ability to respond to forecasts and warnings and, more important, the ability to increase resilience and adaptive capacity.

There are also, however, encouraging signs in Vhembe district and at the national scale in South Africa of building adaptive capacity under conditions of climatic (and environmental) stress. Progress has been made in the dissemination of the forecast to district institutions and to the community level. And intermediary mechanisms described at the national scale (such as the programs under the Directorate of Agricultural Risk Management) show promise. There are signs that research on ways to improve adaptive capacity in South Africa is becoming increasingly well positioned to produce generalized recommendations that may inform policy.

6.8.2.4 Synthesis: Cross-scale Interactions and Multiple Stressors

The results from this case suggest that although gaps and weaknesses were evident in the ability of entities at different scales to decrease vulnerability to the emergence of multiple stressors, success stories were also apparent. In this example it is clear that the spatial scale is a valuable unit of analysis. The level of interplay, however, between scales of ''intervention'' is equally important (e.g., Orlove and Tosteson 1999).

This example illustrates the ''misfit'' between scales of research and intervention, between what is investigated and what is required. This example points to a greater understanding of these complex issues, particularly in a region undergoing complex shocks and stressors, and the deeper interrogation that is required of the range of institutional responses that may be needed to manage these systems effectively. The South African Weather Service, as the official national forecast producer, works with other forecast producers at the international and national levels to derive a multiple-sourced seasonal outlook, containing three-month rainfall and temperature forecasts. The forecast, looking specifically at the agricultural sector, is disseminated to the National Department of Agriculture and from there to provincial, district, ward extension, and finally farm level.

The process of sub-provincial dissemination of the forecast is still in progress. There are three areas of on-going activity to improve the system: the process of combining multiple source forecasts, the role of the National Disaster Management Centre in receiving forecasts and coordinating response in appropriate areas and sectors, and the sub-provincial receipt of, and response to, the forecasts.

At present, however, there remains a misfit between what is currently being provided by the forecast producers and the suggested requirements from the agricultural sector within the provincial levels. From the province down to ward level extension, suggested forecast information differs from the three-month temperature and rainfall forecasts provided from the national and international levels. Finer levels suggest information be provided on seasonal quality (such as information on intra-seasonal variability), advisories coupled to forecasts, retroactive forecast applications, and impact-specific interpretation of forecasts (Orlove and Tosteson 1999). To reiterate, the system is highly dynamic and should be seen as evolving. The key question remains how to best intervene to aid a system in building resilience to sustain socioecological systems under conditions of environmental stress and surprise.

6.8.3 The Benefits of Reducing Vulnerability in Bundelkhand, India

The Bundelkhand region in the central highlands of India consists of semiarid plateau land. Rising population, subsequent agricultural expansion, and increased demand for wood has led to rapid deforestation in the region, which together with poor land management practices and government-approved commercial logging has aggravated soil erosion and ecological degradation. Erratic rainfall coupled with soil erosion has further reduced soil productivity and contributed to crop failure, and the area is now highly degraded (EcoTech Services 1997). (This paper draws on EcoTech Services 1999; the study was carried out to support the Uttar Pradesh state government initiatives in the area, under a grant from the Government of the Netherlands.)

The region has some of the lowest levels of per capita income and human development in India. Illiteracy and infant mortality rates were high, and local inhabitants depended on rain-fed single-crop agriculture and small-scale livestock production. The forests that were the traditional source of livelihood have largely disappeared.

Lalitpur district lies at the heart of the Bundelkhand region. The main monsoon crops grown in the district are maize, gram, and groundnut, while the main winter crops are wheat, peas, and gram. Most people collect green fodder from their own land during kharif and feed harvest remains to the animals in rabi and summer. Harvest is sold as dry fodder. Most households use the same well through the year, and it takes approximately two hours per household to collect water each day. Nonavailability of potable water is a major problem across the district (EcoTech Services 1997).

6.8.3.1 Watershed Management

A technical plan for the Donda Nala watershed in Lalitpur district was drawn up, aimed at land treatment and drainage line treatment measures (EcoTech Services 1997). Land treatment measures sought to reduce the loss of topsoil and to augment rainwater retention and biomass production. Measures such as embankments, earthen gully (channel) plugs, and agroforestry were deemed applicable to cultivated land, while silvipasture was deemed applicable to uncultivated lands. Drainage treatments suggested by the plan included mechanical measures such as the construction of dams and surface water storage tanks. Long-term benefits envisioned from these measures were retention of topsoil and an increase in the moisture-retaining capacity of soil. The technical plan estimated that the high-grade lands in the watershed would show increased crop yields by about 50% in the first five years as a result of such improvements.

6.8.3.2 Quantifying Benefits

Benefits projected from the watershed management activities included increased productivity of land, improvement in the health of animals due to increased fodder availability, better access to drinking water, increased employment, lower rates of soil erosion, and stabilizing environmental degradation. For the economic analysis in the plan, the benefits were summarized as irrigation benefits, benefits from vegetative treatments, drinking water benefits, and employment benefits. (The assessment did not attempt to evaluate environmental and health benefits, which are more complex to quantify.)

Farmers realized benefits from cultivation in the form of increased profits. The incremental net profit was computed as the difference between current profits and potential future profits from cultivation. Assuming that prices would remain constant, profits in the future were estimated on the present value of future cultivation. It was estimated that the average annual incremental profit would be 3,910,700 rupees (or 1,450 rupees per acre) as a result of additional water on existing farmlands. It was estimated that there would be additional benefits due to cultivation on marginal lands due to a further 257 hectares coming under cultivation during monsoon and 90 hectares in winter. This value was estimated as 1,681,000 rupees.

Vegetative treatments led to increased biomass in the form of fodder, firewood, and timber. Locally accepted species were identified for long-term community-managed common land. The estimates from increased fodder availability were based on fodder collection amounts. The incremental production of dry fodder or crop residues was valued at the existing market rate and estimated at 777,800 rupees for the watershed as a whole. A detailed cost-benefit estimation of silvipastural treatments planned in the wastelands for a period of 30 years was also assessed to compute the net present value of the future stream of benefits. Some 420 hectares of land were to be covered under the afforestation plan.

The potential benefits from better access to drinking water were valued by using the opportunity cost of time saved in water collection for women. Three open wells were proposed in the villages of Agar, Dhurwara, and Ghisoli. These sought to enhance women's participation in the project and to benefit families who lacked easy access to drinking water. The new wells were typically located near a cluster so that these families would not have to go more than a quarter of a kilometer. The estimated cost of digging wells in the watershed was 304,065 rupees, and the total value of time savings was 45,090 rupees for the year. The value of this is projected to rise over time as daily wages increase.

Given the labor requirements for each type of project activity, the market and opportunity costs for labor were determined. The benefits were calculated from activity-specific labor components of the technical work plan. Total incremental benefits from employment were valued at the prevailing wage rate. The employment benefits disbursed in the first two years of project activities were estimated at 5,480,000 rupees.

The projected present value of the future stream of the total annual benefits from each of the estimated components provides the overall value for the stream of benefits accruing from the project. The average projected present value of benefits per hectare was 47,461 rupees as opposed to an average project activity cost of 7,500 rupees per hectare. (See Table 6.6.) Assuming a 30-year horizon, the present projected value of the estimated benefits were computed using a 12% discount rate. The net present value of total benefits worked out to be over 100 million rupees for the entire watershed.

6.8.3.3 Synthesis: Distributional Issues

Most of the village community of Lalitpur district consists of small farmers and landless people. While the benefits from additional employment and access to drinking water are projected to directly enhance their quality of life, benefits from irrigation and green fodder production (which are the major source of benefits) are

Table 6.6. Total Benefits for Donda Nala Watershed (EcoTech Services 1997)

Project Activity	Total Undiscounted Benefits	Total Discounted Benefits
	(Rs crores)	
Irrigation	16.5620	3.5799
Digging wells	0.1300	0.0281
Employment	0.5476	0.4132
Silvipasture	24.4177	6.0871
Forestry	5.5876	0.3949
Total benefits	**47.2449**	**10.5320**

likely to accrue to those with land or cattle. The benefits will reach poorer households only if the access to treated wastelands and to harvest can be assured.

6.9 Implications for Assessment and Policy

The discussion and cases in this chapter emphasize that the patterns and dynamics that shape the vulnerability of coupled socio-ecological systems are composed of a multitude of linkages and processes. As such, assessments of vulnerability need to be comprehensive, sensitive to driving forces at different scales, but also appreciative of the differences among places.

A number of observations relevant to attempts to assess and reduce vulnerability and to build resilience may be offered. First, conceptual frameworks of vulnerability have improved, representing human and biophysical vulnerabilities as a coupled socio-ecological system. However, the relationships across scales and the role of specific actors (as drivers of systems) are poorly represented in most frameworks, and the existing state of knowledge is still weak. Different components of the coupled socioecological system may have quite different vulnerabilities and may experience exposure to stresses and perturbations quite differently. Diverse impacts are likely as a result; broad frameworks should not be taken as reliable guides to local conditions. The term vulnerability is still used in disparate ways in many assessments; a clear nomenclature is required to make assessments more consistent and coherent.

Second, the driving conditions of vulnerability have been well characterized at least at a general level. Human alterations of ecosystems and ecosystem services shape both the threats to which people and places are exposed and their vulnerabilities to the threats. The same alterations of environment can have very different consequences, depending on the differential vulnerability of the receptor systems.

Third, poverty and hazard vulnerability are linked and often mutually reinforcing by creating circumstances in which the poor and those with limited assets have few options but to exploit environmental resources for survival. At the same time, poverty and vulnerability are overlapping but distinct conditions, and they require analysis to determine overlaps and interactions.

Fourth, vulnerability can also be increased by the interaction of stresses over time. In particular, sequences of stresses that erode coping capacity or lengthen recovery periods can have long-term impacts that still often are not adequately treated in many assessments. Capturing these dynamics of vulnerability in assessment is an ongoing challenge.

Fifth, socioeconomic and institutional differences are major contributors to patterns of differential vulnerability. The linkages among environmental change, development, and livelihood are attracting increasing attention as a nexus in building resilient communities and strengthening adaptive capacity, but existing knowledge is still uneven and not well developed.

Sixth, despite this general level of explanation, it is still difficult to document adequately the effects of different changes upon different human groups with precision. While environmental changes and natural disasters are affecting increasing numbers of people, the existing knowledge base of vulnerability and resilience is highly uneven, with much known about some situations and very little about others. Some of the most vulnerable peoples and places are those about which the least is known. New vulnerabilities may be realized in the future, as in the dramatic increase of flooding damages in Africa or the effects of HIV/AIDS as a compounding factor in livelihood security. Filling the major gaps is a high priority in improving current assessments.

Seventh, assessment methods are improving. Entering vulnerability assessments at different scales of analysis, and particularly the local scales of place-based assessments, holds potential for greater depth and understanding of the complexity and dynamics of changing vulnerability.

Finally, despite the limitations of theory, data, and methods, sufficient knowledge exists in most regions to apply vulnerability analysis to contemporary problems of ecosystem management and sustainable development in order to provide useful information to decision-makers and practitioners.

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