

## Social Vulnerability and Environmental Change Along Urban–Rural Interfaces

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### Abstract

As the world becomes increasingly urbanized and interconnected, the distinction between urban and rural areas is diminishing. Creation of new urban–rural interface areas causes immediate changes in local natural and social environments, and these areas are also susceptible to both short-term and long-term environmental changes. Different groups of people have varying levels of exposure to natural hazards and gradual climatic changes, as well as access to different coping and resiliency strategies that create unique sets of assets and vulnerabilities. Social vulnerability to hazards and environmental changes results from a complex mix of environmental, social, and economic factors and is often rooted in poverty and disenfranchisement. Mapping of projected environmental threats and census-based indicators of social vulnerability can signal areas that require more intensive ethnographic research, which can elucidate elements of social vulnerability and adaptive capacity that are difficult or impossible to understand from census data or to measure through surveys. Collaborative management of especially vulnerable urban–rural interface areas can present opportunities to enhance the coping strategies and adaptive capacity of individuals and communities, leading to outcomes that are more ecologically sustainable and socially just.

As world population grows and standards of living improve in developing countries, global demands for natural resources will increase, and the related detrimental effects on the global climatic system will be exacerbated. Simultaneously, as people around the world become more mobile, new areas will continue to be developed, and land use patterns will subsequently change. The world is becoming increasingly urbanized and interconnected (through infrastructure, information media, and global ecological processes), and this leads to new and complex sets of challenges and opportunities. Negotiating these challenges and enhancing these opportunities require attention to both social and environmental factors across spatial and temporal continuums. We must devise long-term, as well as short-term, solutions to the problems presented by increased demand on finite and dwindling natural resources, as many temporary solutions to immediate problems prove later to have unintended (and far more drastic) consequences. Also, we must avoid the pitfalls of believing the fallacy that solutions touted as “win–wins” truly have no winners and losers; explicit and up-front recognition of the trade-offs between economic development and ecological conservation, as well as the differential effects these management pathways have on different populations, can lead to more careful analysis of the complex interplay of

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social and natural processes that occur on local, regional, and global scales (Brosius and Campbell, 2010; Hirsch et al., 2010; McShane et al., 2011; Zia et al., 2011). Finally, we must acknowledge that the distinction between urban and rural areas is diminishing and that more research and policy attention must focus on areas where the two intermingle.

Urban–rural interfaces refer to complex intermixes of land use, where tracts of land more typical of rural areas, such as forests and farms, co-occur with tracts more typical of urban and suburban areas, with concentrations of structures such as dwellings and businesses. There are many different types of urban–rural interface areas, ranging from urban sprawl adjacent to wildland or protected areas, transition areas on the leading edge of development, exurban development where more typical urban residences are interspersed in rural or wildland landscapes, and various types of remnant rural and wildland areas surrounded by urban development (Hermansen and Macie, 2002). There are, however, commonalities across all types of interface areas, including: (i) complex spatial mixes of people with different types of livelihoods, economic status, and values; (ii) a wide range of diverse land uses; and (iii) more complicated natural resource management requirements.

Creation of new interface areas causes immediate changes in local natural and social environments, and these areas are also susceptible to both short-term and long-term environmental changes. Environmental changes can occur rapidly in response to hazards such as fires, drought, or flooding or gradually as a result of global climate change, which will lead to rising temperatures and changes in precipitation. These rapid and gradual changes are interlinked because climate change will lead to more intense and frequent hazard events in many places (Karl et al., 2009; Schneider et al., 2001). However, hazard events will also continue to occur independently of any particular trend in global climate change. While it is important to distinguish between individual events and long-term trends in climate change, many individuals and communities will likely experience global climate change through climatic events. Understanding these different types of environmental changes and how they affect interface areas differently than areas that are distinctly urban or rural requires holistic analysis of a variety of ecological, social, cultural, economic, and political factors.

Environmental changes in urban–rural interfaces occur simultaneously with economic and

social changes and concerns (O'Brien et al., 2007). These changes influence global ecological and economic systems, as well as specific human communities and local ecosystems, so a multiscale approach to studying interface areas is imperative. It is also necessary to acknowledge that some people and places are more vulnerable than others to environmental changes. Social vulnerability to hazards and gradual climatic changes results from a complex mix of environmental, social, and economic factors (Cutter et al., 2003). Social vulnerability is broader than that caused by environmental change, often rooted in social and economic conditions such as poverty and disenfranchisement. Policies and programs can address both the underlying social and economic conditions that create social vulnerability as well as specific environmental stresses that are expected to affect particular places. As we move forward in our efforts to understand and manage urban–rural interfaces, attention should be directed to areas of greater vulnerability. Focusing on the places and people that are likely to be most vulnerable to environmental change presents opportunities to enhance the coping strategies and adaptive capacity of individuals and communities. While the research and literature in this area shows social vulnerability to be complex, it is clear that site-specific research and planning focused on social vulnerability has significant potential for managing urban–rural interfaces in ways that are more ecologically sustainable and socially just.

This chapter will outline a framework for analyzing and understanding social vulnerability to environmental change across urban–rural interfaces and provide examples to stimulate further thinking and work. It begins with a review of the literature on social vulnerability to environmental change, with a discussion of indicator-based and causal approaches. It then reviews projected climate changes that are expected to affect urban, rural, and interface areas, leading to vulnerabilities of different types and magnitudes. Cases from research on social vulnerability for urban, rural, and interface areas illustrate how underlying social vulnerability interacts with environmental change to create specific risks for certain people. The chapter ends with a discussion of how understanding the causes of social vulnerability can guide policy and management.

## **Social Vulnerability**

Social vulnerability is an established research area in human–environment relations, with literature that spans several fields, including

sociology, geography, and anthropology. Vulnerability research has historically been focused on natural hazards, but more recent work extends analysis to slower-moving environmental changes such as climate change. Social vulnerability has been defined by the Intergovernmental Panel on Climate Change (IPCC) as a function of a system's exposure to climatic hazards, its sensitivity to changes in climate (how much it will respond in terms of beneficial and harmful effects), and its adaptive capacity or resilience (the ability to respond to changes by moderating or offsetting the potential for damage or to take advantage of opportunities created by a given change in climate) (Schneider et al., 2001; Eakin and Luers, 2006). While coping and adaptation are not substitutes for the mitigation of climate change, international agreement on mitigation measures has been difficult to achieve, and some form of adaption to both gradual change and new environmental hazards will likely be necessary (Schneider et al., 2001).

The general definition of social vulnerability to environmental change as a function of exposure, sensitivity, and adaptive capacity provides a useful framework for analysis, although this framework is deceptively simple for a number of reasons. The environmental events that cause exposure are uncertain and difficult to predict, particularly under changing climatic conditions. Impacts from exposure are similarly uncertain and can be experienced as gains or losses in different places and by particular groups of people. Resilience and adaptation are complex social phenomena; it is very difficult to untangle the multiple factors that determine resiliency and adaptive capacity in any given place and even more difficult to predict how changes in these factors will affect future capacity to adapt to changing environmental conditions. Adaptation requires balancing risks and uncertainties across different domains and time scales (Roncoli et al., 2009), as there are trade-offs between adaptation to current conditions and future conditions that cannot be easily resolved. Nelson et al. (2007) noted that high adaptiveness to current conditions can be efficient while also creating future vulnerabilities to a changed environment.

Social vulnerability has often been conceptually framed in two different ways in the scientific literature. One framing highlights susceptibility and responses to specific environmental hazards and changes, emphasizing the need to understand likely environmental changes and to prepare responses specific to these changes (O'Brien et al., 2007). The other



**Fig. 11-1. Social vulnerability to hazards, like this tornado damage, results from a complex mix of environmental, social, and economic factors. Photo courtesy of Sarah Hitchner.**

framing stresses a more generalized vulnerability to change where climate hazards and long-term environmental changes coexist with social and economic changes; here, the focus is on helping communities reduce their overall vulnerability, or increase their resilience, in the face of diverse environmental, social, and economic uncertainties (O'Brien et al., 2007). In thinking about social vulnerability and environmental change, these differences may be mostly a matter of emphasis. Clearly, where certain environmental changes are anticipated, specific responses to these changes are warranted. Yet, because climate changes are uncertain and will co-occur with other environmental, social, and economic changes, it also makes sense to identify vulnerable individuals and communities and to undertake programs to increase their resilience and adaptive capacity.

These two conceptual framings mirror a second distinction within social vulnerability research that is more methodological; indicator-based approaches and causal analysis examine different dimensions of social vulnerability (Ribot, 2011). Indicator-based approaches focus on identifying demographic indicators of social vulnerability, such as lower income, racial and ethnic minorities, and single parent households (e.g., Cutter et al., 2003). These indicators can be mapped in ways that show how vulnerability occurs spatially on the landscape, and the maps can suggest where efforts to reduce vulnerability should be targeted (Fig. 11-1). Social vulnerability maps can also be overlaid with maps showing locations of particular current and projected hazards, such as drought, floods, or extreme heat (e.g., Oxfam, 2009). These composite maps are useful for communicating risk and vulnerability (Eakin and Luers, 2006; Ribot, 2011). They can

also bolster support for broader social programs rather than responses to specific anticipated environmental changes, as the effects of environmental risks are highly dependent on the level of vulnerability that already exists in socially and economically disadvantaged populations (Ribot, 2009). Causal analysis, which focuses on understanding what factors produce social vulnerability at particular places, can help guide the development of interventions to reduce vulnerability. For example, while a map based on census data can show areas with high concentrations of immigrant households, the map does not show what particular challenges these families face on a daily basis or what cooperative strategies they may have devised to cope with these challenges. Ethnographic studies of the causes of social vulnerability are necessary if we are to understand how vulnerability can be addressed through policies and programs (Ribot, 2009, 2011). Each approach has its advantages, and used concurrently, they can both inform future policies to reduce vulnerability to environmental changes. This is particularly important in urban–rural interface areas where both vulnerability and environmental risks can be diverse and patchy.

Quantitative measurement of social vulnerability is tricky; however, there is a robust literature on social vulnerability research (e.g., Cutter et al., 2003; Cutter et al., 2008; Wood et al., 2010) from an indicator-based approach. Cutter et al. (2003) constructed and mapped a social vulnerability index for the United States to enable the comparison of social vulnerability to natural hazards in different places. The resulting maps are based on social inequalities including the individual sociodemographic characteristics of people and place-based inequalities such as urbanization, growth rates, and economic vitality. Using statistical procedures, Cutter et al. (2003) identified a set of composite factors that differentiated U.S. counties by social vulnerability:

1. Personal wealth enables communities to quickly absorb and recover from losses, but also means that there may be more material goods at risk in the first place.
2. Age is important because the two demographic groups most affected by disasters are children and elderly.
3. The density of the built environment matters because more structural losses occur in areas of higher residential and commercial density.
4. Single-sector economic dependence is complex. The percentage of rural farm population and percent employment in extractive industries had the highest correlation social

vulnerability. The agricultural sector is susceptible because of its dependence on climate and susceptibility to climate-related hazards, such as flooding, drought, and hail. Boom and bust economies (often associated with extractive industries), such as oil development, fishing, and tourism, can be very productive in good times but fall during hard times.

5. Characteristics of housing and ownership are important. Mobile homes are associated with vulnerability in rural areas because displacement due to damaged dwellings is potentially greater. Areas with many renters were also found to be more vulnerable.
6. Racial and ethnic minorities (African American, Asian, Hispanic, and Native American) contribute to social vulnerability through low levels of access to resources, cultural differences, and the social, economic, and political marginalization that is often associated with racial disparities.
7. Occupation is important in that counties heavily dependent on lower wage service occupations are more vulnerable.
8. Infrastructure dependence takes into account debt/revenue ratio as an indicator of available resources, and employment in infrastructure, which when low suggests fewer local resources.

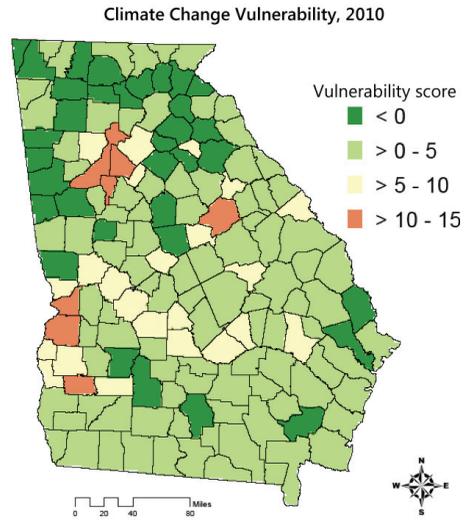
Cutter continued to refine her analysis of the individual and community characteristics that contribute to vulnerability in later studies (for example, in her work with Oxfam, as described below), recognizing the value of weighted analyses tailored to different study sites, as well as the need for subjective judgments of researchers about which factors were most relevant in different areas.

Other work links social vulnerability to specific environmental threats. For example, Wood et al. (2010) mapped social vulnerability to tsunamis in seven coastal counties in Oregon that are part of the state-wide potential inundation zone. This work uses a subset of the variables from Cutter et al. (2003) selected to reflect the ability of individuals to evacuate tsunami-prone areas before inundation (i.e., mobility) and to recover after a tsunami (i.e., access to resources). The mapping was done at a small scale (the census block level) and focused on individual rather than community attributes. Cutter's work for Oxfam (2009) mapped social vulnerability in the U.S. Southeast based on 32 variables—eight of which account for most of the variation: wealth, age, race, gender, ethnicity, rural farm populations, special needs populations, and employment status. The social vulnerability index was

then mapped in relation to four climate hazards—drought, hurricane force winds, sea-level rise, and flooding—likely to be present in this region. Gaither et al. (2011) mapped social vulnerability and wildfire risk in the southeastern United States. They used a simple vulnerability index based on sensitivity factors of race, education, poverty, and housing type and tenancy. Social vulnerability was mapped concurrently with the Wildfire Susceptibility Index to show areas of high and low social vulnerability to wildfire. These maps were then compared with the presence of community wildland fire mitigation programs such as Community Wildfire Protection Plans and Firewise Communities, which are indicators of adaptive capacity. The results indicated that socially vulnerable communities were less engaged with community fire mitigation programs.

It is notable that most indicator approaches cited above do not explicitly follow the IPCC social vulnerability model (i.e., Social Vulnerability as a function of Exposure + Sensitivity + Adaptive Capacity). Yet, the approaches are similar to this model in that the social vulnerability indexes that are used include a mix of variables that indicate both sensitivity (e.g., gender, age, race and ethnicity, housing, single sector economic dependence) and adaptive capacity (access to resources or community capacity-building programs), and social vulnerability is often mapped along with exposure to a particular threat or hazard. The IPCC model explicitly breaks social vulnerability to climate change into different components, thereby providing a framework for organizing and discussing the factors that contribute to social vulnerability as variables. While interactions among these variables across different scales are complex and play a fundamental role in shaping vulnerability, it is useful to review what we know about specific factors and vulnerability.

Exposure is a measure of a physical hazard or long-term change in a climatic variable (e.g., water stress, heat, storms). In general, exposure is determined by examining past history and current conditions and modeling expected futures based on expected changes in various relevant environmental variables. There are many scientific efforts underway to construct models for different environmental hazards or climate changes (e.g., McNulty et al., 2011). In general, such modeling is currently done over large regional scales and does not predict future conditions at local levels (counties or parts of counties). Some scientists are modeling change



**Fig. 11-2. An example of a social vulnerability map. Courtesy of KC, Shepherd, and Johnson (2012, USFS Cooperative Agreement).**

at smaller spatial units through downscaling; these more precise models will help us predict exposure at a spatial scale more relevant to communities and individuals (e.g., Wood et al., 2004). Downscaling climate models is difficult because of the many complex climatic interactions and a high level of unknowns and uncertainties. However, these models are becoming more accurate as understanding increases about how different variables affect local weather patterns, the global climate system, and the interactions between weather and climate and as climate scientists create more sophisticated computerized models that can account for these myriad variables.

The impact of exposure on people will be determined by sensitivity and adaptive capacity. Sensitivity considers what makes a particular person, population, subgroup, or community more or less likely to be impacted by a particular environmental change. Its importance lies in the recognition that not all people will be affected in the same way or to the same extent by any particular environmental change or hazard. One aspect of this is geographical. People living in coastal areas are obviously more vulnerable to sea level rise and hurricanes. People living in or near floodplains will be more vulnerable to extreme rainfall events, and flooding may be exacerbated by other changes such as loss of vegetative cover. But people also have social, economic, and cultural characteristics that can indicate sensitivity, and these can exist at the individual, neighborhood, community, and regional levels (Adger and Kelly, 1999). At the individual level, poverty, age, race

and ethnicity, occupation, and home characteristics have been shown to be relevant indicators of social vulnerability (Cutter et al., 2003; Vásquez-León, 2009). For example, certain characteristics of housing associated with poverty (e.g., lack of air conditioning) may increase exposure to specific environmental changes (in this case, temperature) (Uejio et al., 2011). Indeed, heat waves disproportionately affect the poor and elderly (Adger, 2006). Responses can be second order as well. Poor or minority communities may be more likely to be located in flood plains and thus more susceptible to the flooding that is expected to result from climate change in some places (Dow, 1992). Also, some occupations (or the major economic activity in a community) and those people employed in them may be very susceptible to climatic events and changes; this especially true for the agricultural and forestry sectors (Cutter et al., 2003). However, climate change effects on individuals may be determined not only by their characteristics, but also by the institutions and social networks in which they are embedded. These can include formal mechanisms, like government crop insurance programs or disaster assistance, as well as informal social networks, which provide support based on interpersonal cooperation. These mechanisms may insulate some people from deleterious effects of hazards and environmental changes, although others may be excluded from these desensitizing institutions. Sensitivity is complex and varies with the specific conditions found in different places with different environmental changes and risks. Sensitivity is directly related to adaptive capacity, or the ability of a community to respond to stressors.

Adaptive capacity depends on access to resources, including information, knowledge, technology, and power, and social capital, such as social networks and connections (Cutter et al., 2003). Scale is an important consideration in analyzing how people are able to respond. Strong local social networks (e.g., kin support) can be beneficial on one scale, while the ability to reach across scales (e.g., to access government programs or loans) may increase access to both resources and information. It is important to note that social networks may work differently in response to different stressors. For example, an educated, mobile middle class person may be better able to access government programs or loans in the face of a long-term change, but less able to access local support from kin in the event of a sudden disaster such as a hurricane. Adaptive capacity relates to the ability to access resources both within and outside the community.

It is also important to remember that what is harmed or damaged by an environmental hazard or change is not universal, but instead varies widely across contexts and communities. Basic health and welfare, family and community characteristics, and a variety of culturally determined factors linked to people's different views on quality of life can be threatened (O'Brien et al., 2007). Furthermore, determination of harm is also related to the desirability or satisfactoriness of past and current conditions. For example, resiliency means something different in an impoverished area where residents already desire change than in a wealthier place where residents are for the most part satisfied with current conditions. Ribot (2009) noted that for the poor and marginalized, everyday conditions are already unacceptable, and climate change exacerbates already inadequate conditions. Vulnerability reduction for them must include advances in poverty reduction, basic development, and political empowerment.

Efforts to understand the causality behind social vulnerability generally do not neatly follow the IPCC model or indicator-based approaches. Adger and Kelly (1999) focused on *entitlements*, the ability to cope with and adapt to stress being determined by the extent to which individuals, groups, and communities are "entitled" to make use of resources. Examining social vulnerability to climate change means analyzing: (i) the availability and distribution of entitlements; (ii) how these entitlements are defined, contested, and change with time; and (iii) the role of the wider political economy in the distribution and formation of entitlements (Adger and Kelly, 1999). Their approach focuses on understanding both the level of vulnerability of a population and the factors and processes that shape vulnerability, as well as those that reduce vulnerability and facilitate adaptation. On the basis of the results of a study in Vietnam, Kelly and Adger (2000) reported that poverty reduction and risk-spreading through diversification are important in determining people's adaptive capacity, and that loss of common property and forms of collective action limit the ability to respond. While individual factors play an important role in their approach, they emphasized understanding processes and change over time and showed the value of an ethnographic component. Similarly, Bohle et al. (1994) outlined an approach to social vulnerability that is amenable to modeling but stresses the importance of going beyond reductionist approaches because of the complexity and dynamism of social vulnerability. They outlined a multilayered and multidimensional social space that frames vulnerability

and is defined by three processes: (i) human ecology, or the relations between nature and society; (ii) expanded entitlements, a wider view of access to resources; and (iii) political economy, the larger macrostructure in which individual resource endowments and patterns are embedded. Turner et al. (2003a,b) suggested an approach that begins with assessing how a particular risk or stressor affects a place and then working outward to understand causality; they advocated examining both social and biophysical factors and not bounding the system artificially.

Nelson and Finan's (2009) "In Focus" series of articles in *American Anthropologist* provided additional insights into how an ethnographic approach can help us to understand the causes of social vulnerability. They identified four main themes in the current literature on adaptation to climate change:

1. The process of adaptation is multiscalar in nature.
2. There is a distributive element of socioeconomic inequalities and adaptive capacity at local and national scales.
3. There are interrelated sources of natural stresses and other sources of stress, including economic globalization that either mitigate or aggravate the impacts of a changing climate.
4. Successful adaptation requires effective inclusion and participation of local communities and therefore a focus on institutional adjustments and community reorganization.

Nelson and Finan (2009) emphasized the importance of asking such questions as: What are the goals of adaptation? Who adapts and to what? What values are considered? How do society and culture influence the process of adaptation? They suggested that the key goal is to understand the complexity and constraints of adaptation and how these lead to differential outcomes for particular people, such as the loss of livelihoods, cultures, and identities.

Roncoli et al. (2009) outlined an ethnographic approach to climate change that is rooted in the subtle and nuanced understandings that can be achieved through extensive experience living and working among the study population. They emphasized the importance of culture in framing the way people perceive, understand, experience, and respond to aspects of the world in which they live. Their approach suggests adding to vulnerability analysis the key element of perception and understanding of environmental change by asking research questions like: How do people perceive climate change, and what do they use as evidence that climate is changing?

How do people comprehend what they see based on their mental models and social locations? How are perceptions and knowledge framed by cultural contexts to give them value and shared meanings? How do people respond, individually and collectively, on the basis of meanings and values? Roncoli et al. (2009) emphasized the need for ethnographic research of climate-centered practices in local contexts to understand livelihood significance in ways that are difficult to assess using other methods such as surveys. Ethnographic research can show how subjective judgments, cultural meanings, and political agendas interact to shape representations of and responses to climate change. Careful fieldwork also shows how certain risks and costs may be shifted to less powerful groups and sectors as society adapts to climate change. Understanding adaptive processes for different groups can help us understand the environmental justice implications of societal responses.

Both Nelson et al. (2009) and Roncoli et al. (2009) highlighted the importance of the participation and inclusion of local communities in studies of social vulnerability. Nelson and Finan (2009) used techniques such as participatory GIS to bring communities and policymakers together to discuss current issues and possible futures, including the potential of these techniques to counter the effects of traditional patron-client systems. Roncoli et al. (2009) suggested an engaged ethnography in which researchers participate in policy debates and efforts to build community capacity at all levels, from local communities to global institutions. Careful integration of research and practice can have mutual benefits.

### Environmental Change and Social Vulnerability

Environmental change will affect communities along the urban-rural interface through both gradual climate change and natural hazards. Over the long term, climate change may be more important because it has the potential to change environmental conditions in ways that will exacerbate natural hazards in many places. There is broad scientific consensus that recent observed changes in the global climate—including warmer overall global temperatures, changed rainfall patterns, and increased incidences of certain types of storms—are the result of anthropogenic and natural forcing of climate change (Karl et al., 2009). Global climate change is expected to affect environmental conditions worldwide, including:

(i) melting of Arctic, Antarctic, and Greenland ice sheets and glaciers in mountainous regions, resulting in increased runoff; (ii) rising sea levels (due to melting ice and expansion of ocean water due to warming), leading to coastal erosion, loss of coastal wetlands and mangroves, and increased coastal flooding; (iii) changes in the amount, intensity, frequency, and type of precipitation; (iv) poleward and elevational shifts of plants and animals, and phenological changes such as flowering and leafing out at abnormal times, altered migration timing, and lengthened growing seasons; and (v) possibilities of abrupt climate changes when certain thresholds are met (Karl et al., 2009; Rosenzweig et al., 2007).

Global climate change will have different effects in different places. Karl et al. (2009) summarized ongoing and projected changes from a variety of different global climate models and emission scenarios. Temperatures in the United States have risen from 0.55 to 1.11°C (1–2°F) over the past 50 years, and are expected to rise further—particularly summer temperatures in most of the United States—and lead to longer warm seasons. Precipitation in the United States has increased about 5% over the past 50 years, with northern areas expected to become wetter and southern areas drier (with particular drying in the southwest). Heavy rainfall events have become more common, and extreme weather events such as heat waves and regional droughts have been increasing. Atlantic hurricanes are expected to become stronger and have more destructive energy. Sea levels are expected to rise, particularly on the east and gulf coast (less sea level rise in the west is expected due to geological uplifting).

The effects of climate change will interact with other ecological changes and new environmental conditions brought about by urban and exurban development. Social vulnerability can be magnified by other long-term social and economic changes such as globalization or short-term shocks that produce economic and social dislocations (Nelson et al., 2009; O'Brien et al., 2007). Forest characteristics are changing across the landscape, particularly in interface areas. Larger economic and market conditions, parcelization, difficulties in prescribed burning, and changing attitudes toward timber harvesting all result in less intensive forest management, which in some cases, like southern pine plantations, can reduce forest health and increase fire danger (Duryea and Hermansen, 2002; Monroe, 2002). Increased coverage of impermeable surfaces and decreased

infiltration can lead to larger runoff volumes and flooding (Zipperer, 2002). All of these land use changes exacerbate the threats from natural hazards. Urban development may also affect weather and microclimate. Shepherd et al. (2010) noted that the urban heat island effect, where urban areas are warmer than their surroundings, is well established, but pointed out that less widely known research suggests that urban areas also affect precipitation. Specifically, observed effects include increased precipitation downwind from a number of cities and increased intense rainfall events and lightning in cities. These observations suggest that an urban rainfall effect exists and extends into the urban–rural interface (Shepherd et al., 2010). Although less well understood, there is also evidence that urban areas may split rainfall events and result in more rainfall around the edges of cities while less falls in city centers; increased rainfall in outlying areas can combine with altered runoff and infiltration patterns to intensify flooding there (Shepherd et al., 2010, 2011).

Social vulnerability along the urban–rural interface is complex and dependent on the specific social, economic, cultural, and environmental factors that come together at a particular place. As such, social vulnerability can adequately be understood only through place-based research. Such research will likely include mapping of social vulnerability, both by itself and in association with specific environmental threats, as well as ethnographic work to understand causality. Although there is a need for more place-based research, we can begin to identify specific patterns of vulnerability to environmental change that may occur in urban, rural, and interface areas.

### Urban Social Vulnerability

Social vulnerability in urban areas is strongly influenced by the density of population and structures, as well as by the environmental influence of the built environment. Increased temperatures and heat waves, poor air quality, and possible increase in disease vectors and food- and water-borne diseases due to warming can have significant human health effects in urban areas (Karl et al., 2009; Rosenzweig et al., 2007). Lower income groups are more vulnerable to extremes of heat and cold (Rosenzweig et al., 2007). The high density of people and structure in cities means that environmental changes and hazards have the potential to impact large numbers of people and cause extensive economic damage even in small geographic spaces. At the same

time, the built environment exacerbates the effects of warming, rainfall, and runoff. Coastal cities will be at increased risk from climate change and storms, particularly those that have lost protective mangroves and wetlands (Satterthwaite, 2008).

Risk and resilience will also depend on the quality of housing and infrastructure, the extent to which urban and land use planning have influenced development patterns to avoid natural disasters and mitigate heat effects, and the strength of institutions for emergency response (Satterthwaite, 2008). Urban areas are often characterized by extremes in wealth distribution among the population, increasing social vulnerability (Oxfam, 2009). As was evident following Hurricane Katrina in New Orleans, lower income and minority groups may also be more vulnerable because they may live in the most hazardous environments and have limited coping and resilience ability (Hardoy et al., 2001; Satterthwaite, 2008). Cities often draw on catchments far beyond their boundaries for water, and poorer populations may be more likely to be affected by water scarcity (and resulting higher water prices) if drying occurs (Satterthwaite, 2008).

### Case Study—Urban Heat in the United States

Uejio et al. (2011) studied social vulnerability to extreme heat in Philadelphia, PA and Phoenix, AZ. As mentioned, extreme heat events are expected to increase due to climate change, and heat-related impacts are exacerbated in urban areas due to the urban heat island effect. Heat particularly affects older adults, who are both more sensitive to extreme heat and whose limited mobility makes it more difficult for them to seek a cooler environment or obtain assistance. There is also evidence that African American people have higher heat mortality, in part because they are less likely to have central air conditioning. Vulnerability may also be increased for renters, people living alone, non-English speakers who are linguistically isolated, the mentally ill, and people with existing health problems. In areas of high violent crime, social isolation may be high, and heat-protective behaviors like leaving windows open overnight may be less likely to occur.

Uejio et al. (2011) mapped social vulnerability and heat-related impacts (heat mortality in Philadelphia and heat distress in Phoenix). In Philadelphia, outdoor heat exposure was not related to heat mortality. Rather, heat mortality was more prevalent in neighborhoods with more African American residents and in neighborhoods with more vacant housing. In Phoenix,

the urban heat island effect (measured by impervious surface and maximum nighttime surface temperature) was associated with increased heat distress calls. More heat distress calls were made from neighborhoods with higher proportions of black, Hispanic, linguistically isolated, and renting residents. A higher proportion of vacant households also increased heat distress calls from that neighborhood.

Both study sites had experienced economic stagnation and discriminatory economic practices that discouraged people of color from living in parts of the city that were cooler and safer. The results show that heat risk factors are place-specific and often linked to minority populations and urban decay. Philadelphia has an organized system of Block Captains to identify and check in with at-risk populations during extreme heat events, although this system does not function well in poorer parts of the city where Block Captain positions are often vacant. Social vulnerability analysis can help guide and target efforts to develop heat emergency plans and concentrate efforts to increase coping and resilience to extreme heat events.

### Case Study—Flooding in Guyana

Pelling (1998) studied social and political aspects of hazard vulnerability in two locations in Guyana, one urban and one peri-urban. The analysis was based on the idea that distribution of goods and services in a society is dictated by markets, public institutions, and social networks. Pelling also assessed participatory methodologies, which have been used in an effort to increase the decision-making authority of grassroots actors, with a goal of increasing social cooperation to address flood hazards and make decision-making more inclusive, transparent, and accountable.

Guyana has considerable exposure to flood hazard but weak social institutions. A long period after independence in 1966 was characterized by state-ownership of productive assets and concentrated decision-making, which weakened local social capital and public institutions and led to high collective and individual vulnerability. Democratization and privatization began in 1988 and has included participatory planning and development projects. However, the most marginalized and vulnerable urban populations have generally been excluded from participatory and other decision-making processes. Conflicts among different government agencies with overlapping jurisdictions, combined with competition among political parties for power, have hindered efforts to develop local social capital and

build new community institutions. Ultimately, collective flood mitigation strategies have failed to emerge, and vulnerable households continue to rely on individual mitigation strategies.

The urban cases highlighted here suggest several lessons. The work of Uejio et al. (2011) provides a good example of the links between social and demographic characteristics of individuals and neighborhoods and social vulnerability; they found that minority individuals and areas of urban decay were associated with greater vulnerability. Importantly, the social program utilized to address vulnerability was weaker in these same areas because Block Captain positions were less likely to be filled and functioning. Interestingly, Pelling's (1998) Guyana study found that even nominally participatory programs devised to build grassroots capacity were also less effective among the most vulnerable because they tended to exclude the most vulnerable and because their effects were overshadowed by malfunctions in governance at higher levels. These examples highlight the need for careful causal analysis as the basis for interventions.

### Rural Social Vulnerability

Resource-dependent rural communities are heavily influenced by environmental conditions. Changes in frost occurrences, growing seasons, insect populations, and wildfire occurrence have been observed and have the potential to impact both agriculture and forestry (Rosenzweig et al., 2007). Karl et al. (2009) noted that the effects of environmental change on crops are complex and reflect the interplay of temperature, water resources, and carbon dioxide concentrations. For example, rising night time temperatures can negatively affect grains, soybean [*Glycine max* (L.) Merr.], canola (*Brassica napus* L.), and snap bean (*Phaseolus vulgaris* L.) yields. Crops that do well in heat, such as melon, okra, and sweet potato, will benefit from longer growing seasons, but crops that require cooler conditions, such as potato (*Solanum tuberosum* L.), lettuce (*Lactuca sativa* L.), broccoli (*Brassica oleracea* L. var. *italica* Plenck), and spinach (*Spinacia oleracea* L.), will be negatively affected. As a result, the optimum latitudes for some crops are expected to shift, and farmers will need to adapt. Higher temperatures will increase water stress on plants. Higher carbon dioxide levels cause plants to grow larger, but may alter their nutritional content. Results can be complex. For example, mild winters and early springs may accelerate plant development and blooming, increasing the risk of late-season frosts.

Karl et al. (2009) also explained how changes in precipitation, such as increased heavy storms and droughts, threaten agriculture by increasing flooding and erosion, aggravating heat and water stress, and causing storm-related wind damage. Precipitation changes can also promote disease problems, make harvest difficult, and create conditions that make it difficult to use farm equipment. Weeds generally respond better to higher temperatures and carbon dioxide levels than agricultural crops, and aggressive invasive weeds such as kudzu may spread northward. Warming will aid insects and diseases by allowing greater survivability over winters, increasing the number of generations per year, and reducing the effectiveness of some pesticides. Rising carbon dioxide concentrations will increase forage quantity, but reduce quality by leading to declines in nitrogen and protein concentrations that in turn will affect animal growth, reproduction, and survival. Water shortages and invasive plants may also affect forage, and heat will affect livestock directly.

### Case Study—Farming in Southeastern Arizona

Vásquez-León (2009) studied social vulnerability to climate change among Hispanic and Anglo-American farmers in Arizona, focusing on the role of social capital. The study site included two agricultural valleys in southeastern Arizona, the Safford Valley and the Sulfur Springs Valley, both of which have scarce water resources. The difference is that the Safford Valley has both surface and ground water and the Sulfur Springs Valley relies entirely on groundwater. The Safford Valley produces mostly cotton (*Gossypium hirsutum* L.), and the Sulfur Springs Valley produces corn (*Zea mays* L.), vegetable, and non-citrus fruits. Both have Anglo-American and Hispanic farmers.

In the Safford Valley, early Hispanic settlers used the acequia system of communally managed irrigation canals for subsistence farming and cattle. Later, Mormon settlers began growing cotton, with irrigation water from the San Carlos reservoir becoming linked to land rights in the 1930s. There was a history of water conflict, with Hispanic farmers often being denied their water allocations and eventually selling their land (and along with the land, their water rights). In the Sulfur Springs Valley, cotton farming began in the 1940s, when Anglo farmers from the Midwest arrived, and pumping groundwater for irrigation became feasible. Hispanics soon arrived as laborers in the Bracero program, and many stayed after mechanization of cotton in the

1960s. From the beginning, Anglo farmers had more open social networks that enabled them to obtain legal and institutional support from the federal government and the Mormon Church. While the dense and more closed social networks of Hispanics allowed them to get started in farming, they were outcompeted over time in many areas by the Anglo farmers.

Strategies have changed with time in the two places. As groundwater was overused, farmers in the Sulfur Springs Valley increased irrigation efficiency and diversified cropping systems. In the Safford valley, farmers continued to farm cotton with irrigated water supplemented with groundwater, and, rather than promoting conservation, have engaged in litigation with Indian tribes to obtain more water. Anglo farmers have reduced their vulnerability through access to federal disaster relief and federal and private crop insurance programs, crop subsidies, and bank loans. Largely excluded from these, Hispanic farmers have used kin-based social networks, consolidating farms and water rights in the hands of a few families, producing risky but high value vegetable crops (that are not subsidized by the government), and mobilizing labor and access to markets through ethnic-based social networks.

Hispanic farmers have been more vulnerable due to their lack of institutional support, but they have used dense kin- and ethnic-based networks to mobilize critical farming resources and information that reduce their exposure to climatic and other risks. Anglo farmers, with more open social networks characterized by weak internal ties but bridges to external institutions that provide access to external resources, have been buffered from climate change and market fluctuations. However, while this has worked thus far by buffering them from the effects of climate, it has discouraged them from developing other forms of resilience that may be important in the future if heat and drought conditions continue to worsen.

### Case Study—Mountain Pine Beetle, British Columbia

Parkins and MacKendrick (2007) assessed vulnerability in forest-based communities in British Columbia after a record outbreak of the mountain pine beetle (*Dendroctonus ponderosae*), which has expanded its population and range due to forest aging and above-average seasonal temperatures. There is evidence that the outbreak will continue to spread because climate change is creating conditions more favorable to it. Although

the outbreak has led to larger timber harvests in the short term (due to salvage logging or anticipation of forest loss), in the long term it will reduce economically important timber harvests and will have an aesthetic impact on the landscape. Assessments were done in four communities representing a range of environmental change and social and economic conditions.

The vulnerability assessment began with focus groups, who were asked to discuss: (i) current and future social and economic impacts from the mountain pine beetle, (ii) factors contributing to the community's adaptive capacity, (iii) past hardships in the community that could influence present or future adaptive capacity, (iv) community awareness of the mountain pine beetle, and (v) organizational responses for dealing with social and economic impacts from the mountain pine beetle. Focus group participants emphasized the role of economic diversity and social well-being in reducing vulnerability, while also noting that communities with access to non-pine tree species would also be less vulnerable. Focus group results were then used to develop a quantitative vulnerability assessment tool with four dimensions: physical, social, political, and economic. Researchers then collected data with a household survey to determine vulnerability scores for each dimension.

The results indicated, for example, that one community had high anticipated exposure to mountain pine beetle and low economic diversity and social well-being, but these limitations were mitigated by alternative forest resources, risk awareness, and trust in governments. Other communities had different relationships among the four dimensions. Parkins and MacKendrick (2007) suggested that this type of analysis is helpful in understanding contexts of vulnerability and targeting vulnerability reduction efforts by revealing local variation in vulnerabilities and linking research to action.

These rural cases illustrate the complex relationship between environmental conditions and social, economic, and political factors in determining vulnerability. Vásquez-León's (2009) Arizona case shows how ethnic discrimination and lack of political power over time has forced Hispanic farmers into higher risk agricultural options where they receive little support from government or private sector institutions. At the same time, they have used kin and ethnic social networks to reduce risk and increase resiliency, and actually show greater adaptation to climatic conditions than the well-buffered Anglo farmers. This case shows that there are various ways to

reduce stress and increase resilience; it also highlights the trade-offs that can exist between current productivity and the ability to respond to change, as well as the difficulty in preparing for uncertain future conditions that may lie outside the patterns familiar from the recent past. Parkins and MacKendrick's (2007) mountain pine beetle case shows how complex relationships among environmental, social, economic, and political factors can produce different patterns of vulnerability even among communities in the same region.

### **Urban–Rural Interface Social Vulnerability**

Although it has received less attention in the literature, social vulnerability in urban-rural interfaces is more complex than that of either urban or rural areas alone. As discussed in the introduction, there are multiple types of interfaces undergoing different processes of change. Furthermore, interactions among more typically rural and more typically urban sectors can add new pressures and dynamics to both. Interfaces in developed and lesser developed countries may differ. For example, both Los Angeles and Mexico City are characterized by interfaces with development on steep slopes, and both are subject to wildfires (Wisner and Uitto, 2009). However, many of these areas of Mexico City are inhabited by the poor and the outermost zones with the most fire risk have low population density, while Los Angeles is characterized by wealthier residents with many people living in the midst of highly flammable chaparral vegetation. Many of the specific risks and social vulnerabilities will depend on the particular characteristics of a place, and analysis will require the finer scale data more commonly available for urban areas than rural ones (Freiria and Tavares, 2011). But it is likely that while many interface areas may have a combination of land uses based on agriculture and forestry and an increased density of structures and population that heighten environmental risk, connections to urban areas may increase the economic and human resources available to reduce or respond to risks.

Case Study: Peri-Urban Flood Risk in Mexico  
Eakin et al. (2010) studied a region of the Upper Lerma River Valley in Mexico that has an urban-rural interface comprised of a mosaic of natural ecosystems, agroecosystems, and urban ecosystems. Urban-rural interfaces like this are increasingly common and are characterized by complex intermixes of urban and rural residences and

economic activities, along with institutions that have not adapted to these changes. Their work focused on flooding and water resource management. Flooding along the Lerma River has increased during the past few decades. While there is no evidence of increases in precipitation, there is some evidence that precipitation is more often occurring in short, intense downpours. Climate scenarios indicate that temperature is likely to continue to rise in this region, and flood hazard is expected to increase. Socioeconomic changes, including migration, mean that households are diversifying their livelihoods and participating in urban and rural service economies instead of or along with agriculture. Decentralization has led to local institutions assuming increasing responsibility to manage land use, although many institutions are fragmented along rural-urban lines, and local control does not take a watershed perspective into account.

The research focused on adaptive capacity and perception of flood causes, and qualitative interviews were conducted with public officials and flood-affected households. Officials in the urban sector often did not believe that they had a role in flood prevention and felt they had little control over the expanding urban-rural interface, which largely grows in rural jurisdictions through informal transactions with little oversight. Farmers were more concerned with loss of water to downstream urban areas through urban water projects than with flooding or climate change. In rural areas, household concerns were mostly related to water quality, as the river has become increasingly contaminated as a result of urban development. The results indicated that urban authorities were minimally engaged in flood control because the agrarian sector has traditionally assumed responsibility for flow management. Although development on the interface has changed the nature of this problem, rural water management had not adapted because of their lack of capacity in urban water management.

The results show how municipalities are constrained by their spatial mandates and hindered by political turnover and inexperience with municipal democracy. Urban areas have the institutions to manage urban growth, but most of the growth is taking place in rural areas where land management authority is traditionally local and has shown little attention to the encroaching interface. The combination of rapid change, institutional fragmentation, and lack of perception of the river as an integrated entity results in

inadequate responses to growing flood hazards and thus low adaptive capacity.

### Case Study—Survival and Accumulation in Tanzania

Baker (1995) studied households on the urban–rural interface with particular interest in the ways in which economic strategies draw on both urban and rural sectors. Research was conducted in four villages surrounding a moderate-sized town that served as a regional center. The study focused on household economic success, a principal element of social vulnerability. Village residents had different amounts of land, which was used for agriculture. They grew subsistence and cash crops, but the unreliability of rainfall and difficulties in acquiring fertilizer created the most risk in the agricultural sector. Most households also depended on nonagricultural activities for income, including alcohol production and craftwork at home and employment and asset ownership in town. Most preferred village life to town residence because it was cheaper and people could produce some of their own food, yet most had frequent contact with the urban area. Most households on the interface exploit the benefits of both rural and urban sectors.

The results indicated that households with little land who were primarily laborers were the poorest and most vulnerable. Many households were headed by elderly people, people with little formal education, and some who were divorced or widowed. Labor availability was highly seasonal, leading to the precarious nature of livelihood strategies for this group. Farming-only households were at high risk because of variations in rainfall and regular droughts. Agricultural households who produced and sold alcohol, often selling in town where prices were higher, were much better off. The combination of agriculture and alcohol sales led to a constant flow of cash to meet household needs and ensure survival. Households that combined crop production and sale with non-farm and off-farm income generation were the most economically successful and secure. Many worked in urban jobs such as school teachers, medical personnel, and construction and maintenance workers, or owned urban property that could be rented as shops or dwellings. With their economic success, these households were often able to buy additional agricultural land or urban property, thereby further lessening their vulnerability. The results suggest positive ways that households on the urban–rural interface may exploit their unique location to reduce social vulnerability.

As these two cases highlight, urban–rural interface areas are expected to have more complex vulnerabilities than either urban or rural areas. When land uses and occupancy patterns typical of urban and rural areas are mixed, new vulnerabilities and opportunities are added to those of predominantly urban or rural areas. Eakin et al.'s (2010) Mexico study shows that that policy and management are often as fragmented and patchy in interface areas as are land uses, livelihoods, natural hazards, and awareness. There is a clear need for new strategies to integrate planning and management across the urban–rural interface. Conversely, Baker's (1995) Tanzania study shows how some interface households are able to combine rural and urban livelihood options to achieve greater economic success and reduce vulnerability, while other households remain vulnerable and unable to exploit their unique location.

### Social Vulnerability in Management and Planning

Environmental change and hazards are conditions that have always affected human populations. Flood, drought, fire, and storms have always occurred, although rarely predictably, and human populations can and have developed strategies to reduce their impact and recover after they occur. Historic patterns are useful predictors, although there is evidence that larger and unanticipated changes are afoot as a result of global climate change and human alterations of landscapes. A more densely populated planet intensifies these interactions in a number of ways, while human planning and action can reduce vulnerabilities. Different environmental, social, economic, and political factors come together in unique ways at specific places, and urban–rural interfaces often present unique and highly complex situations. Research (and subsequent planning) must be both local and multiscale to be effective. It must also be interdisciplinary to address interactions across ecological, social, economic, and political domains. Furthermore, it must include analyzing historical patterns of natural variability and hazards, while also anticipating changes due to expanding urban–rural interfaces and climate change.

Mapping social vulnerability to environmental change and hazards is useful in a number of ways. Social vulnerability indicators that draw from census data enable comprehensive mapping of social vulnerability over large geographic regions with a modest investment of

time and little fieldwork. By highlighting vulnerable areas, maps can be used to identify priority places to plan for and focus responses to sudden environmental disasters or events such as heat waves, flooding, and storms (Cox et al., 2006). Maps can also be used to target mitigation efforts such as tree planting programs to reduce urban heat island effects (Cox et al., 2006). Social vulnerability indicators also have limitations, many of which result from the use of existing measures in the census that often serve as proxy variables for more complicated social and economic processes that cannot be easily measured and are generally unavailable comprehensively across large geographic areas.

Ribot (2011) suggested that indicators are useful for suggesting where to target interventions, but that to develop effective interventions they must be complemented by causal analysis focused on why people are at risk to identify the potential entry points for risk reduction. Causal analysis focused on a specific place, starting with the unit at risk, understanding the assets or entitlements that are (or are not) present, and tracing the causes of the conditions outward to the larger physical, social, and political-economic environment can help us understand why particular vulnerabilities occur at certain times and places (Ribot, 2009). This requires detailed, site-specific work for which ethnographic research and participatory planning techniques are well-suited.

Ethnographic research can bring in important elements of human vulnerability and adaptive capacity that are difficult or impossible to understand from census data or to measure through surveys. This work needs to include how people's subjective judgment, cultural meanings, and political agendas shape both their awareness of potential climate changes and their responses to climate-related events (Roncoli et al., 2009). Ethnographic methods are necessary to understand these patterns, as well as to help us identify the



**Fig. 11–3. A community meeting can provide the framework to increase community participation and planning. Photo courtesy of Sarah Hitchner**

ways that risks and costs are often shifted to less powerful groups as the larger society plans and adapts to climate change. Work by Vásquez-León (2009) in southeastern Arizona shows how different ethnic groups have access to different coping and resiliency strategies that create unique sets of assets and vulnerabilities for each group.

Participatory research and planning can be important tools for tapping into local knowledge, for understanding the causes of vulnerability, and for stimulating community preparedness and political action (Nelson et al., 2009; Oliveira Mendes, 2009; Roncoli et al., 2009). Nelson and Finan (2009), working in an area of Northeast Brazil subject to persistent drought vulnerability, used participatory GIS to bring communities and policymakers together to discuss current issues and possible futures and, more importantly, to begin a process to break down disabling patron-client relationships and initiate development of local infrastructure and human capital. Ojerio et al. (2008) provided a toolkit of collaborative techniques, along with case studies of their uses, for engaging low capacity communities vulnerable to wildfires in the United States in collaborative processes to identify vulnerabilities and develop strategies to reduce risk and respond to emergencies. These examples show how mapping can be followed up with ethnographic and participatory techniques to better understand and address social vulnerability. We will need to draw on all the elements of our research and planning toolkits as we prepare for an uncertain future in which urban-rural interfaces become both more common and more complex.

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