4 Water Stress and Social Vulnerability in the Southern United States, 2010–2040

Cassandra Johnson-Gaither, John Schelhas, Wayne Zipperer, Ge Sun, Peter V. Caldwell, and Neelam Poudyal

CONTENTS

Water scarcities are striking in semiarid, subregions of the Southern United States such as Oklahoma and western Texas (Glennon 2009, Sabo et al. 2010). In Texas, water stress has been a constant concern since the 1950s when the state experienced severe drought conditions (Moore 2005). The nearly 2000-mile Rio Grande River, which forms part of the Texas–Mexico border, is the sole source of groundwater for residents and businesses at the far western part of the state. The river also provides water for Ciudad Juarez in Mexico. Because of its strategic location, the Rio Grande is a site of water contestation between United States and Mexican concerns (Szydlowski 2007). To the east, a 3-year, state-level dispute over water rights involved North and South Carolina, as each state struggled to assert rights to the waters of the 225-mile Catawba River, which flows through the two states. The Catawba is a source of domestic water for more than one million residents and provides electricity to nearly double that number of consumers. The dispute was settled amicably in 2010, but these examples illustrate that the oftentimes, taken-for-granted assumptions of freshwater access in industrialized nations are being challenged by decreasing supplies, resulting from both existing and projected climatic changes. Q1

This chapter focuses on the social vulnerability of human communities to water stress in the U.S. South, commencing in 2010 and extending through 2040. One of the primary purposes for including it in this chapter is to highlight the interactions between climate change (in this case, through impacts on water availability) and humans, both in the context of social vulnerability and response drivers. To do so, we examine the intersection of social vulnerability and stresses on freshwater supply at 10-year intervals in the 13 southern states—Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Texas, Tennessee, and Virginia. Using exploratory spatial-data analysis, we assess the spatial association between social vulnerability and water stress at the county level in each of the five subregions in the South— Appalachian–Cumberland highlands, Coastal Plain, Mississippi Alluvial Valley, Mid-South, and Piedmont (Eastern Forest Threat Assessment Center 2011).

We defined socially vulnerable populations as marginal groups with respect to social and human capital and entitlements/endowments—conditions that compromise a population's ability to anticipate, cope with, or recover from environmental hazards (Downing et al. 2005, Intergovernmental Panel on Climate Change 2007, Kelly and Adger 2000). Social vulnerability accounts for expected social inequities among classes, races, ethnic groups, and genders, and also includes processes and movements at scales beyond the local, for instance, immigration/migration and the built environment as they relate to human communities (level of urbanization, growth rate, and economic robustness).

Three primary factors are converging to threaten water resources in the South: increasing risks of water degradation from an expanding human population base, conversion of forests to alternative uses, and climate change (Lockaby et al. in press, Sun et al. 2008). Climate change effects are expected to intensify impacts associated with land cover and population changes in the region over the next century (Stone 2012). Such changes include possible decreases in precipitation and increases in air temperatures, resulting in higher rates of evapotranspiration and increasing demand for crop irrigation (Sun et al. 2008). On average, water stress across the South has been relatively low since European colonization but varies spatially and has been appreciably higher in western Texas (Lockaby et al. in press). In contrast to the westernmost subregions of the South, the humid, subtropical areas farther east have had a relatively abundant water supply. Again, however, population growth and urbanization, continuing forest losses, increasing drought frequencies, and the absence of mechanisms to address future water shortages could lead to a vulnerable situation vis-à-vis water availability.

We take an initial step toward examining the association between water stress and social vulnerability at the county level. As stated, a number of factors are expected to affect water stress over the next several decades. Because of data limitations, however, we are able to examine only the climate-related drivers of water stress for our analysis period (2010–2040). Our water stress variable reflects climate change only; therefore, the analysis should be taken as a screening-level assessment to identify places for further inquiry. For more detailed analysis of the effects of land-use change and population change on water stress, see Chapter 9.

Climate change effects are expected to manifest differently, depending on geography and the ability of populations to anticipate, withstand, and recover from or adapt to the resulting biophysical changes, as reported by the Intergovernmental Panel on Climate Change (2007):

> There are sharp differences across regions and those in the weakest economic position are often the most vulnerable to climate change and are frequently the most susceptible to climate-related damages…. There is increasing evidence of greater vulnerability of specific groups such as the poor and elderly not only in developing but also in developed countries….

The panel concluded that water resources will be among the most "climate-sensitive" systems that are likely to be affected by climate change.

A key factor in social vulnerability is what Adger and Kelly (1999) describe as the "architecture of entitlements"—an individual's access (by rights, knowledge, or both) to the complex web of material, cultural, social, and economic resources. Because entitlements are often disputed and challenged, they are embedded within the political economy both locally and over great distances. Entitlements are controlled primarily at the state level, although local custom can also play a role. Entitlements are typically distributed along sociodemographic lines, for example, according to wealth, caste (race/ethnicity), age, and physical and mental abilities.

K16616_C004.indd 62 6/11/2013 6:58:25 PM

The detection of inequitable access to freshwater sources is much more evident in developing countries where the divide between affluent and impoverished population sectors has been documented at length (Bakker 2007, Mukheibar 2010, Rockström 2003, Vincent 2004, Vörösmarty et al. **Q2** 2005). Limited access to natural and cultural resources and technology, repression of basic freedoms and human rights, generational warfare, and environmental degradation are but a few of the factors that cause or contribute to extreme social vulnerabilities for the poor in the developing world (Wisner et al. 2004).

McCarthy (2002), however, proposes that inequities such as limited access to natural and cultural resources, marginalization of resource-dependent communities, and environmental degradation can also be found in the developed world, albeit at less-intense scales. Central to these inequities is the socially vulnerable or marginal status of resource users whose access is blocked by more powerful, external agents or by competition from those who have stronger connections to resource providers. For instance, the highly controversial "Water Wars" involves demands by Alabama, Florida, and Georgia for freshwater contained in the Apalachicola–Chattahoochee–Flint River Basin. In 1989, the U.S. Army Corps of Engineers announced plans to redistribute 20% of the hydroelectric water supply from Lake Sidney Lanier (headwaters for the basin) to metropolitan Atlanta until 2010 (Feldman 2008). Alabama and Florida responded with lawsuits in 1990. Competing demands actually stem from several sources: (1) the large, urban centers in Georgia (Atlanta) and Alabama (Birmingham) that require more water for domestic consumption; (2) agricultural uses by farmers in southwestern Georgia; (3) Lake Lanier recreation in northern Georgia; and (4) freshwater needs for ecological balance in the Apalachicola Bay estuary, which feeds the economically important oyster industry in the Florida panhandle (Feldman 2008). Perhaps, the most tension has been between Georgia and Florida, specifically, metropolitan Atlanta's demand for increased water retention in northern Georgia versus the need for freshwater flows to Florida's Apalachicola Bay.

This conflict was exacerbated in the summer of 2007 when a severe drought brought water demand to the forefront of southern politics. As the final recipient of water flows from the Apalachicola–Chattahoochee–Flint River Basin, Florida argued that stable flow regimes need to be maintained for ecosystem balance in the Apalachicola River and for species preservation—the freshwater fat three-ridge (*Amblema neislerii*) and the purple bankclimber (*Elliptoideus sloatianus*) are federally protected mollusks found only in the Apalachicola River—and maintenance of crucial saltwater-to-freshwater proportions in the ecologically and economically important Apalachicola Bay, which provides 90% of the oysters harvested in Florida and 10% of those supplied in the United States (Chapin 2003). Importantly, oyster harvesters and others claim that disruptions to the saline–freshwater balance in the bay would also disrupt traditional livelihoods and cultural practices.

The tristate Water Wars have been framed by the media as a contestation between rich, powerful interests in Georgia and poor fishermen in Florida (Williams 2007). This may be hyperbolic, but the strife highlights the potential for uneven access to resources as well the ability of large, urban population centers to control resources that are vital to the livelihood of smaller, resource-dependent communities.

Absent to new water sources or reductions in the rate of population growth, we may infer that disputes over water supplies will increase in coming decades and that socially marginal groups worldwide will be less able to afford this increasingly scarce commodity, whether publicly or privately supplied, or to influence the politics of water allocation (Dellapenna 2005). A U.S. Senate report states that water scarcity in Central Asia is now a national security concern because of the potential for armed conflict over water in the region, and, as economic growth intensifies in India, Africa, and the Middle East, so too does the demand for water and associated conflicts (British Broadcasting Corporation 2008, U.S. Senate Committee on Foreign Relations 2011).

The question then becomes: precisely how would social vulnerabilities exacerbate water stress in the U.S. South into the foreseeable future? There are not likely to be instances in which poor or socially vulnerable households are unable to acquire the resource. Rather, the amplification of water stresses by social vulnerability would be most likely in places where agriculture and other water-dependent economies predominate. For instance, in two Arizona valleys, Vásquez-León (2009) found that Hispanics had less access to institutional safeguards against drought than other farmers and workers, which perpetuated Hispanics' marginal position in agriculture. The study showed an unevenness of social capital and networks linking farmers to agricultural assistance programs (such as crop subsidies, federal disaster relief, and both public and private crop insurance) that had been designed to buffer against the full impact of seasonal floods and droughts. Because Hispanic farmers in the study typically did not produce commodity crops, such as cotton and corn, that qualify for government assistance, they relied on less-formal social networks involving family and friendship circles to help ensure the continuity of their farming operations. Also, their productivity was limited by a combination of factors including social connections, amount of land owned, English language fluency, technological literacy, and selective issuance of federal loans and water distribution. The study suggested that water scarcity, when compounded by social vulnerability can exacerbate the effects of climate vulnerability for a population that already experiences a greater degree of social marginalization and susceptibility than others.

In urban settings, water stress is also compounded by concentrations of socially vulnerable populations, many of whom are likely to be members of racial or ethnic minority groups but also the elderly and very young. But the water stress effect in urban areas is not on water scarcity but extreme precipitation events, for instance floods. Projected climate changes in precipitation and temperature will probably raise the risk of contamination of water used for drinking and recreational purposes (Patz et al. 2001). For instance, high levels of precipitation and runoff can greatly elevate counts of fecal bacteria in local streams and coastal waters (Paul and Meyer 2001). Similarly, increased runoff from extreme rain events can be a concern for cities with combined storm water drainage and sewage systems such as Atlanta, Georgia. Under normal conditions, wastewater treatment facilities handle combined sewage and storm water drainage. Under an extreme event, however, incoming water can exceed the capacity of the facility with overflows being discharged into surface waters. Such events have been linked to incidences of West Nile Virus in Atlanta (Chaves et al. 2009).

With respect to another type of environmental risk (wildfire) and socially vulnerable populations, Collins (2008a,b) found that in the White Mountains of Arizona, state and market institutions such as local fire-protection services and insurance insulated affluent homeowners from potential losses from wildfire. Lower socioeconomic groups, on the other hand, had to absorb the increased wildfire risk created by increasing migration to ecologically vulnerable places. Those with less income had fewer means to purchase or command the type of insulation readily available to higher income groups.

Given these examples from the agricultural, urban ecology, and wildfire risk literature, we suggest that the exacerbation of environmental risk, when social vulnerability is present, depends on the extent to which buffers or insulation from environmental stresses can be employed. Thus, it is the access to various forms of capital (human, social, physical, financial, or natural) that largely determines the extent to which vulnerabilities will intensify environmental stress (Wisner et al. 2004).

CONCEPTUALIZATIONS OF SOCIAL VULNERABILITY

Birkmann (2006) found at least 25 definitions of the term "vulnerability" and six "schools of thought" or analytic models of vulnerability in the literature. Although these definitions may differ with respect to scale and linkages to other crucial concepts such as sustainability, they are similar in that each acknowledges that both endemic and exterior conditions influence the extent of vulnerability. The endemic or interior basis of social vulnerability derives from research on famine and food insecurities (Bohle et al. 1994); in contrast, external vulnerability derives from the hazards literature, which focuses on quantifying risks associated with natural hazards and disaster.

The interior dimension of vulnerability is expressed as the "endpoint" or "outcome" perspective and the external dimension is expressed as the "starting point" or "contextual" framing (Brooks 2003, Kelly and Adger 2000, O'Brien et al. 2007). The outcome perspective constructs vulnerability as a result, as a state of being that arises after exposure and adaptation to some natural disaster or to more incremental forces such as climate change. This perspective makes no assumptions about the temporal or spatial variability of vulnerability.

The definition of vulnerability given by the Intergovernmental Panel on Climate Change (2001)—exposure of a system to climate change and variability, the sensitivity of a system to climate changes, and the ability of the system to adapt to the same—is an example of an outcome perspective on vulnerability. Exposure to hazard refers to the risk of danger (from water stress, wildfires, droughts, or hurricanes) to a population, sensitivity measures the sociodemographic factors associated with place that can either exacerbate or mitigate risk, and adaptive capacity is the ability of a community or population to reach a new equilibrium after all exposures and sensitivities have been accounted for (Polsky et al. 2007, Turner et al. 2003).

Alternatively, contextual vulnerability emphasizes the social conditions of place, identifying the political and cultural context of where environmental threats or risk exists. The focus rests on the larger institutions of place and how communities have greater or lesser access to the system's entitlement structure. Vulnerability is assumed to exist *a priori* to hazard exposure. The socioeconomic, political, and cultural fabric of place acts as a sieve through which biophysical hazards and scarcities are mediated or experienced (Pelling 2001).

Contextual vulnerabilities lie within the social and institutional processes that distribute entitlements across society, with entitlements understood as the differential access to and use of resources. Viewed through this lens, social vulnerability is an inherent or endemic quality of a system that may exist regardless of whether a natural hazard impacts a given locale. Kelly and Adger (2000) use the "wounded soldier" analogy to illustrate this framing: Injuries already existing or sustained in previous battles circumscribe a soldier's ability to withstand any present or future assaults, thus rendering him or her vulnerable. Similarly, a place or system with existing sociodemographic deficiencies would exist in a socially vulnerable state.

However, because human societies are not static, even seemingly immutable inabilities or vulnerabilities can be minimized with a collective effort to be resolute or adapt to environmental stresses over time. Importantly, the vulnerabilities of people and place change continually in response to feedback from the encounters of human and natural systems to physical and social processes (Birkmann 2006, Turner et al. 2003).

Cutter et al. (2003) developed a hazards-of-place model that extends the contextualization of vulnerability beyond sociodemographic variables (those associated with people) to other dimensions of vulnerability—urbanization, geography, growth rates, economic activity of place, and biophysical environment. The authors view social vulnerability in a broader context than poverty or residence in socially marginal geographies. When disaster strikes, wealthier, urbanized areas are considered as vulnerable as poorer places because of high wealth concentrations and the likelihood of large economic losses. Similarly, Brooks (2003) views social vulnerability not only in terms of socioeconomic characteristics but also as a function of the "physical environment as they relate to human systems," using as an example the engineering processes that change the direction and flow of water.

Turner et al. (2003) elaborate on the holistic nature of place by drawing attention to the way that sustainability contributes to vulnerability assessments. Important here is the inevitable interaction between biophysical and social systems (Figure 4.1). Their emphasis is on the vulnerabilities of the "coupled" system rather than looking at the vulnerability of social or biophysical systems in isolation. The model combines elements of both the outcome perspective and contextual framing: vulnerabilities are triggered by exposure to hazards or stressors (outcome), but the ability of the system to cope with the disturbance depends on conditions particular to the human and the natural environments. This means that the responses of systems are not uniform across place but vary according to the capabilities of each subsystem, whether human or physical, and that factors beyond

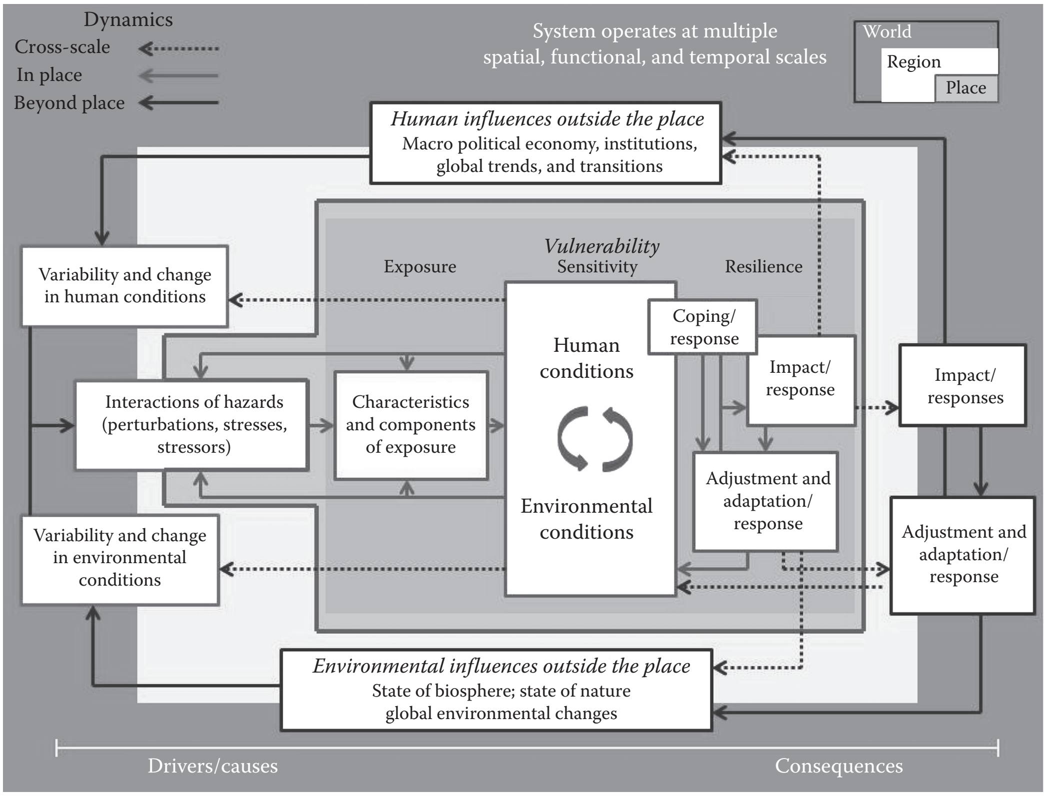

FIGURE 4.1 Schematic showing the components of social vulnerability and how they interact at various scales. (Adapted from Turner, B.L. et al., 2003. *Proceedings of the National Academy of Sciences*, July 8(100), 14:8074–8079.)

place influence the responses of systems and subsystems. Finally, the impacts of hazards are seen in how social and biophysical functions can withstand such impacts. Adaptations in the form of new policies and programs may be offered as a method of resilience; or the impact of the hazards may simply trigger adjustments and adaptations.

The next section describes the methodology used to examine the linkage between social vulnerability and water stress. Subsequently, we discuss findings and offer an alternative method for examining social vulnerability at the community level.

METHODOLOGY

Water Stress

We calculated a water stress value for each decade, 2010 through 2040; first averaging data by decade (2001–2010, 2011–2020, 2021–2030, and 2031–2040) and then averaging across four climate scenarios to develop an ensemble average for each hydrologic unit code (HUC) and decade. HUC codes are eight-digit numbers that identify watersheds addresses (nwis.waterdata.usgs.gov/tutorial/huc_def.html). The climate scenarios were developed by combining four commonly used general circulation models (MIROC3.2, CSIROMK2, CSIROMK3.5, and HadCM3) with two emissions storylines (Intergovernmental Panel on Climate Change 2007): A1B representing low population/high economic growth and high energy use, and B2 representing moderate growth and low energy use. We assumed constant land cover from 1997 levels developed by the U.S. Forest Service for the

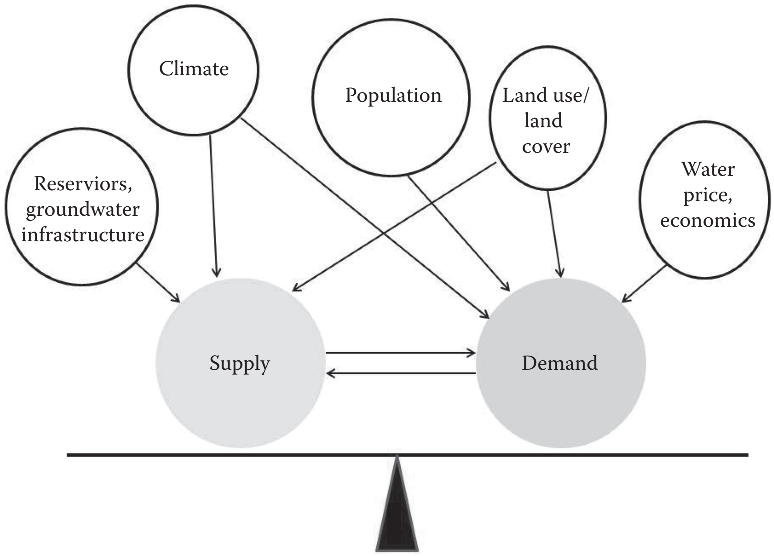

FIGURE 4.2 Factors affecting water supply demand. (Adapted from Sun, G. et al., 2008. *Journal of American Water Resources Association,* 44(6):1441–1457.)

2010 Resources Planning Act Assessment and constant water use from 2005 levels published by the U.S. Geological Survey (U.S. Forest Service 2012). All data were scaled to the county level.

Water stress is measured in terms of a water-accounting model or water supply stress index (WaSSI) (Sun et al. 2008), calculated as water demand divided by water supply. This straightforward explanation conceals the many complex interactions among the variables that constitute the index (Figure 4.2).

Lockaby et al. (in press) elaborate on the model:

> The scale of the water stress model can encompass an entire system from watershed to basin or any portion thereof, depending on the research question and availability of data to examine human water use and demand. The model simulates full monthly water balance, including evapotranspiration, soil moisture content, and water yield. Within each basin, spatially explicit land cover and soil data are used to account for evapotranspiration, infiltration, soil storage, snow accumulation and melt, surface runoff, and baseflow processes; and discharge is routed through the stream network from upstream to downstream watersheds.

Social Vulnerability

As with conceptualizations of social vulnerability, various approaches are available for measuring the construct, including quantitative indices and ethnographic methodologies that provide nuanced explanations of key concepts such as adaptive capacity and resilience (Füssel 2009, Nelson and Finan 2009). Numerous indicators have been developed (Cutter 2003, Eriksen and Kelly 2007, **Q3**
Füssel 2009, Oxfam 2009, Polsky et al. 2007, Rygel, O'Sullivan and Yarnal 2006). Many of these operationalize the definition of social vulnerability given by the third Intergovernmental Panel on Climate Change (2001):

$$\text{Social vulnerability} = \text{exposure} + \text{sensitivity} + \text{adaptive capacity} \tag{4.1}$$

We modified Equation 4.1 to develop a vulnerability equation that keeps the exposure variable but combines sensitivity and adaptive capacity into a *social vulnerability* index. In our model, the hazard occurrence is separated from social vulnerability, and the net effect of sensitivity and adaptive capacity gives social vulnerability. So, *exposure* indicates the degree of hazard occurrence (in the present case, water stress) in Equation 4.1, *sensitivity* measures sociodemographic characteristics at the individual and community scale, and *adaptive capacity* measures sociodemographic characteristics (or resistance) to those variables that would make a population or place more susceptible to environmental stress.

The sensitivity component of social vulnerability was measured with 10 sociodemographic variables from projected decadal estimates provided by Woods and Poole (2009) and from the 2000 U.S. Census. These are the proportion of county residents (1) more than 65-years old, (2) less than 5-years old, (3) female, (4) African American, (5) Hispanic, (6) Native American, (7) employed in farming, (8) employed in "forestry, fishing, related activities and other", (9) below the poverty level, and (10) aged 25 years or older without a high-school diploma. Of these, the first eight were projected to the decades 2010 through 2040 by Woods and Poole (2009). Poverty and education data are from the U.S. Census (2000); these remain constant from 2010 to 2040. U.S. Census 2010 data were not used because they had not yet been scaled to the county level at the time of writing. The adaptive capacity component of social vulnerability was measured by a single variable, the Woods & Poole Wealth Index (Woods and Poole 2009), 2010 through 2040. This index is an indicator of total personal income per capita. It is a summation of three weighted averages: regional per capita income divided by U.S. per capita income (contributing to 80% of the index); regional income from dividends, interest payments, and rent divided by the U.S. income from these sources (10% of index); and U.S. transfer payments divided by regional transfer payments (10% of index).

Each of the social vulnerability variables can have a direct bearing on social vulnerability for both individuals and communities. Age is a critical factor in vulnerability assessments because the elderly and very young are less able to garner resources in the event these become scarce. The same argument can be made for women relative to men. Racial and ethnic minority status, wealth, poverty status, and educational attainment can also play a role in resource acquisition (Collins 2008a,b, Taylor et al. 2007). Employment in agriculture or large-scale resource extraction (such as timber and mining) also bears directly on water stress, as these pursuits require abundant water resources.

All variables contributing to social vulnerability were combined additively to arrive at the social vulnerability index. The index was weighted by a county's reliance on activities relating to farming and fisheries. If 25% or more of the population were employed in farming or 15% or more were employed in fishing, each of these variables (percent employed in farming, percent employed in fishing) was assigned a weight of 0.60 and the remaining variables, except wealth, were assigned a weight of 0.40. If these conditions were not met, percent farming and fishing were assigned a weight of 0.20 and the other variables 0.80. We developed weights to distinguish counties that had stronger ties economically to natural resources, the idea being that resource-based economies would be more sensitive than others to water stresses. Weights were determined based on expert judgment of the impact of farming and fishing on county economies.

We tested for multicollinearity for variables comprising the social vulnerability component of water stress by examining a regression model where water stress was the dependent variable and the social vulnerability variables were predictors. Multicollinearity was detected by indications of inflated standard errors of the predictors. We examined the variance inflation factor (VIF) to detect fluctuating standard errors. Generally, VIF values greater than 10 suggest multicollinearity. VIF values for all predictors were less than 3.5, suggesting low or moderate multicollinearity. Proportions for each social vulnerability indicator were summed to produce the social vulnerability value for a given county in each ecoregion, per decade.

Bivariate Analysis

We examined the association between the two components of vulnerability (water stress and social vulnerability) by using the Local Indicator of Spatial Association (LISA statistic) (Anselin 1995). The LISA statistic indicates how well observations of one variable for a county (i) are associated with observations of a different variable in neighboring or adjacent counties. For our analysis, the variables were water stress for county *i* and social vulnerability in the cluster of counties adjacent to county *i*. A county was defined as being adjacent to county *i* based on a first-order, queen-contiguity weight matrix. Counties adjacent to county *i* that share a common border length or vertex were included in county *i*'s "neighborhood." The LISA statistic compares the average value for water stress in county *i* to the social vulnerability average for counties in the neighborhood of county *i*.

Bivariate LISA statistics were computed using GeoDa™ 0.9.5-I. Our analysis mapped four distinct spatial clusters pairing water stress and social vulnerability at the county level. The clusters, defined in relation to the average value for water stress and social vulnerability, are (1) high water stress–high social vulnerability, defined as a high water stress county adjacent to high social vulnerability neighboring counties; (2) low water stress–low social vulnerability, defined as a low water stress county adjacent to low social vulnerability neighboring counties; (3) low water stress–high social vulnerability, defined as a low water stress county adjacent to high social vulnerability neighboring counties; and (4) high water stress–low social vulnerability, defined as a high water stress county adjacent to low social vulnerability neighboring counties.

We defined high water stress–high social vulnerability counties as "hot spots." Given that we used actual population data rather than a sample, all associations and related LISA statistics were assumed to be significant. However, in keeping with conventional reporting of values significant at $p \leq 0.05$, we mapped only those clusters that met this criterion. Pseudo-*p* values were generated for LISA statistics using the 999-permutation criteria available in GeoDa0.9.5-I.

The calculation of the LISA statistic (Sunderlin et al. 2008) is

$$I_l = z_{xi} \sum_{j=1,\, j \neq i}^{N} w_{ij} z_{yj} \tag{4.2}$$

where I_l is the LISA statistic, *x* is water stress, and *y* is social vulnerability for county *i* and neighborhood *j*. Similarly, z_x represents the standardized value for water stress and z_y represents the standardized value for social vulnerability. The variable w_{ij} is the weight matrix that defines those counties comprising neighborhood *j* (also generated using GeoDa 0.9.5-I).

RESULTS OF UNIVARIATE ANALYSIS

Table 4.1 shows that water stress averages steadily increased in each subregion for the period 2010 through 2040. Table 4.2 shows similar increases for social vulnerability. Figure 4.3 maps water stress and Figure 4.4 maps social vulnerability in terms of its standard deviations from the average for the Coastal Plain in 2010. Figure 4.3 shows that the greatest water stress is in central and southern Florida counties, easternSouth Carolina, and eastern Texas. Relatively, little is seen in southern Georgia and Alabama. Figure 4.4 shows that social vulnerability is highest in an arc-like pattern extending from eastern Virginia through the eastern Carolinas and into southern Georgia, Alabama, much of Mississippi, Louisiana, and eastern Texas. Compared to inland counties, coastal counties show less social vulnerability, as do all the counties in Florida.

SUBREGIONAL RESULTS OF BIVARIATE ANALYSIS

Appalachian–Cumberland Highlands and Piedmont

The Appalachian–Cumberland and Piedmont subregions are both represented in the Southern Appalachian landscape. This landscape encompasses one of the most diverse ecosystems that can be found in a temperate zone (Southern Appalachian Man and the Biosphere 1996). The Appalachian–Cumberland highlands cover approximately 99 million square miles and the Piedmont

TABLE 4.1
Current and Predicted Average WaSSI for the Five Subregions of the Southern United States, 2010 through 2040

Subregion	*N*	2010	2020	2030	2040
Appalachian–Cumberland highlands	252	0.011 s.d. = 0.018 max = 0.144 min = 0.000	0.012 s.d. = 0.019 max = 0.148 min = 0.000	0.013 s.d. = 0.020 max = 0.152 min = 0.000	0.014 s.d. = 0.021 max = 0.154 min = 0.000
Piedmont	177	0.028 s.d = 0.035 max = 0.220 min = 0.001	0.030 s.d. = 0.037 max = 0.226 min = 0.001	0.031 s.d. = 0.037 max = 0.225 min = 0.001	0.032 s.d. = 0.039 max = 0.232 min = 0.001
Coastal Plain	488	0.021 s.d. = 0.030 max = 0.231 min = 0.000	0.023 s.d. = 0.034 max = 0.287 min = 0.000	0.025 s.d. = 0.036 max = 0.317 min = 0.001	0.028 s.d. = 0.040 max = 0.322 min = 0.001
Mississippi Alluvial Valley	64	0.037 s.d. = 0.033 max = 0.166 min = 0.000	0.039 s.d. = 0.034 max = 0.169 min = 0.000	0.042 s.d. = 0.034 max = 0.160 min = 0.000	0.042 s.d. = 0.037 max = 0.187 min = 0.000
Mid-South	330	0.079 s.d. = 0.098 max = 0.60 min = 0.001	0.091 s.d. = 0.107 max = 0.737 min = 0.000	0.100 s.d. = 0.116 max = 0.840 min = 0.001	0.094 s.d. = 0.106 max = 0.652 min = 0.000

Source: Adapted from Vörösmarty, C. J. et al., 2000. *Science,* 289:284–288.
Note: WaSSI is calculated as demand divided by supply: low is >0.1, medium is 0.1–0.2, medium–high is 0.2–0.4, high is ≥0.04. *N* is the number of measurements taken. s.d. is the standard deviation from the mean. max is the highest WaSSI for the subregion. min is the lowest WaSSI for the subregion.

approximately 79 million square miles. These two subregions share similar climatic characteristics and, to some extent, comparable social characteristics. The larger cities and metropolitan areas of the Appalachian–Cumberland highlands and Piedmont have been the epicenters of southern population expansion, economic growth, and cultural diversification over the past 30 years; however, some of the more rural and mountain communities continue to struggle with generational poverty and economic decline.

Figure 4.5a–d shows bivariate LISA clusters for the Appalachian–Cumberland highlands from 2010 to 2040. Three counties were consistently classed as hot spots across the four decades: Macon (North Carolina), Greene (Tennessee), and Washington (Virginia). In terms of social vulnerability, these are all counties with relatively low poverty and small minority populations, relative to their state averages; for Macon and Washington counties, the main drivers of vulnerability center around their low wealth and education indices. A large swath of counties with low water stress–high social vulnerability is located in southeastern Kentucky. These findings are consistent with other mappings of high-poverty counties in this part of Kentucky. Table 4.3 shows the distribution of counties according to cluster type bydecade. In each decade, the percentage of each cluster type remained nearly constant. Only in 2040 did the number of high water stress–high social vulnerability clusters decrease to three from a high of six in 2030. Of the significant counties, the low water stress–high social vulnerability cluster predominated and the hot spots were least prevalent across all decades.

TABLE 4.2
Current and Predicted Average Social Vulnerability (SOVU) for the Five Subregions of the Southern United States, 2010 through 2040

Subregion	*N*	2010	2020	2030	2040
Appalachian–Cumberland highlands	252	0.317 s.d. = 0.238 max = 0.862 min = –0.630	0.342 s.d. = 0.246 max = 0.882 min = –0.761	0.376 s.d. = 0.254 max = 0.917 min = –0.938	0.408 s.d. = 0.258 max = 0.959 min = –0.992
Piedmont	177	0.305 s.d. = 0.348 max = 1.166 min = –0.962	0.348 s.d. = 0.337 max = 1.189 min = –0.948	0.391 s.d. = 0.335 max = 1.20 min = –0.934	0.425 s.d. = 0.339 max = 1.21 min = –0.891
Coastal Plain	488	0.508 s.d. = 0.338 max = 1.407 min = –0.817	0.544 s.d. = 0.334 max = 1.44 min = –0.735	0.580 s.d. = 0.332 max = 1.48 min = –0.653	0.606 s.d = 0.335 max = 1.48 min = –0.723
Mississippi-Alluvial	64	0.667 s.d. = 0.351 max = 1.39 min = 0.058	0.716 s.d. = 0.341 max = 1.41 min = 0.107	0.746 s.d. = 0.333 max = 1.42 min = 0.176	0.761 s.d. = 0.329 max = 1.42 min = 0.188
Mid-South	330	0.386 s.d. = 0.419 max = 1.93 min = –2.85	0.422 s.d. = 0.419 max = 1.93 min = –2.80	0.460 s.d. = 0.418 max = 1.95 min = –2.72	0.478 s.d. = 0.415 max = 1.952 min = –2.357

Source: Adapted from Intergovernmental Panel on Climate Change. 2001. Contribution of Working Groups I, II, and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

Note: SOVU is calculated as the sum of exposure, sensitivity, and adaptive capacity. *N* is the number of measurements taken. s.d. is the standard deviation from the mean. max is the highest WaSSI for the subregion. min is the lowest WaSSI for the subregion.

Figure 4.6a–d shows cluster types for the Piedmont, 2010 through 2040. Counties with the-most consistent high water stress–high social vulnerability clustering are Henry (Virginia), Stokes, Rockingham, Cleveland, and Union (North Carolina); and York and Lancaster (South Carolina). Table 4.4 shows that again for the Piedmont, both the absolute number and percentage of cluster types remainedessentially constant over the 30-year span.

Coastal Plain

The Coastal Plain encompasses land area extending from southern Virginia, down to southern Georgia and Alabama, and into Louisiana and eastern Texas—more than 79 million square miles. The Coastal Plain has also been one of the higher growth areas of the South, including metropolitan areas such as Miami and Houston. A mild climate, proximity to coastal areas, and lower cost of living in many of the rural areas of the Coastal Plain contribute to its attractiveness for migration. Again, however, persistently poor communities also characterize rural Black Belt areas that run through the deep South states of Arkansas, Georgia, Alabama, and Mississippi. The southern Black Belt is comprised of 623 counties spanning from southern Virginia through east Texas that have higher-than-average Black populations. Eighteen percent of the U.S. population is contained in the Black Belt (Allen-Smith et al. 2000; Johnson-Gaither et al. 2011). These counties are mostly adjacent although they span several states.

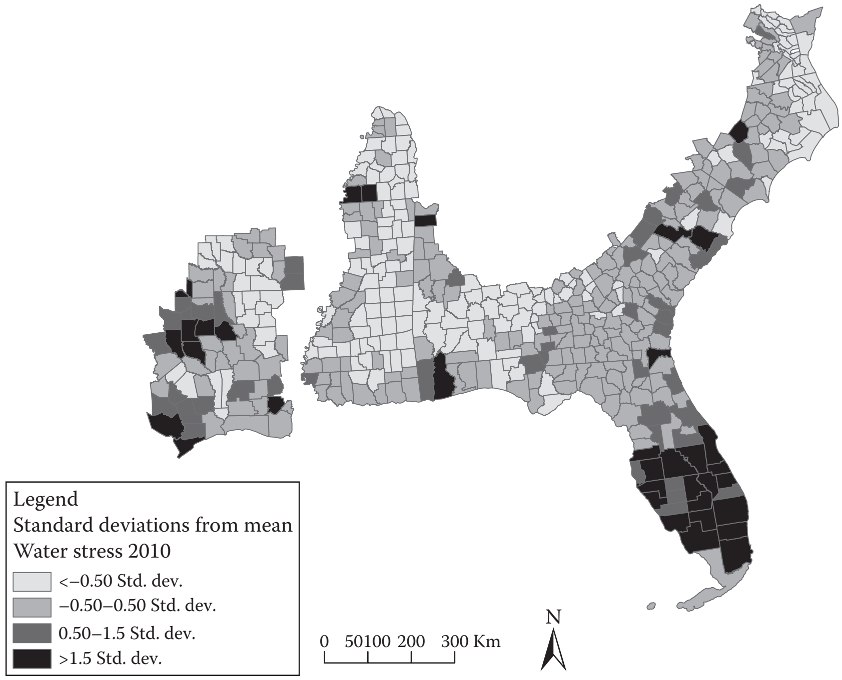

FIGURE 4.3 Water stress, 2010, on the Coastal Plain of the Southern United States, expressed as standard deviations from the mean (water stress is measured by the WaSSI).

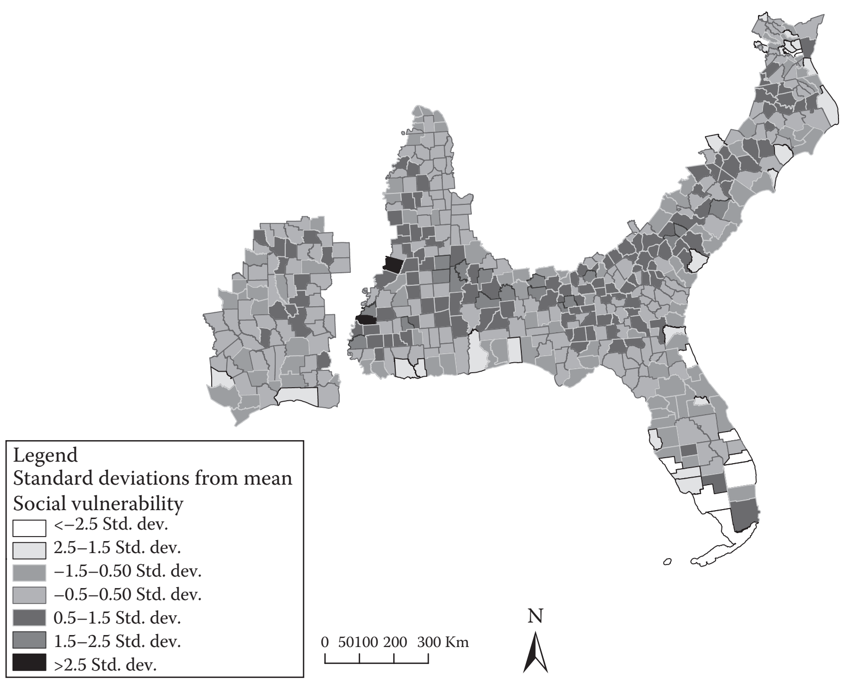

FIGURE 4.4 Social vulnerability, 2010, on the Coastal Plain of the Southern United States, expressed as standard deviations from the mean.

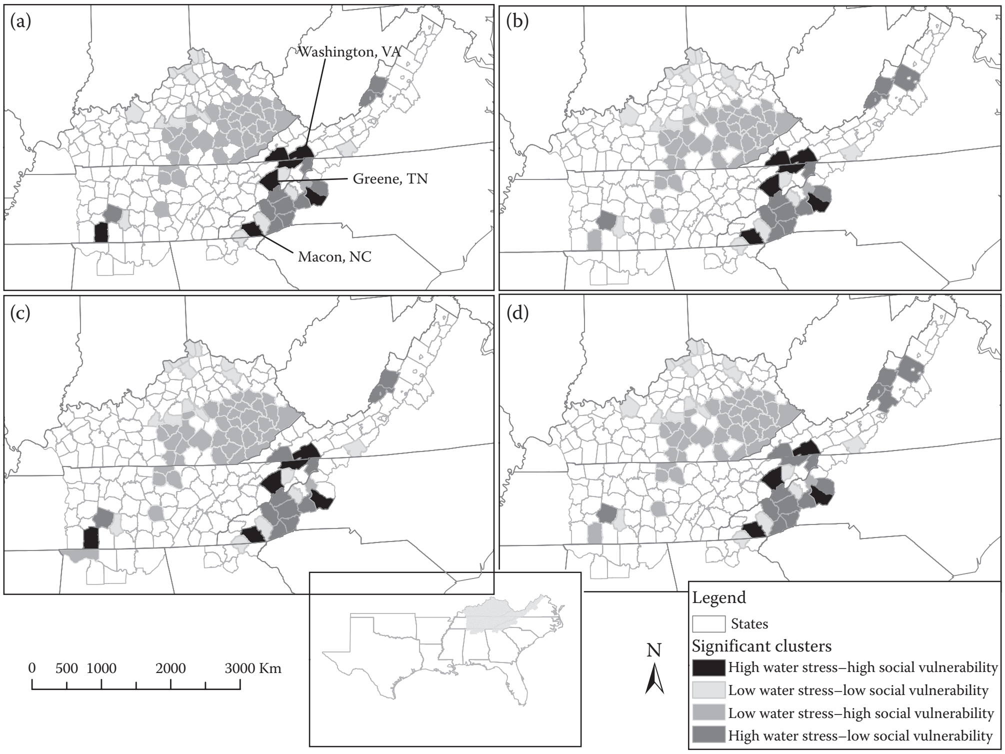

FIGURE 4.5 Convergence of water stress and social vulnerability in Appalachian-Cumberland counties of the Southern United States (a) in 2010 and predicted for (b) 2020, (c) 2030, and (d) 2040.

Figure 4.7a–d depicts clusters for the Coastal Plain. High water stress is indicated in central and southern Florida, accompanied by lower social vulnerability; in southern Alabama andMississippi, higher levels of social vulnerability are prevalent but with little water stress. Hot-spot clusters appear only sporadically for each decade (Table 4.5).

TABLE 4.3
Current and Predicted Distribution of Counties for the Appalachian-Cumberland Highlands of the Southern United States, 2010–2040

	2010		2020		2030		2040	
Condition	**Number**	**%**	**Number**	**%**	**Number**	**%**	**Number**	**%**
High–high[a]	6	2.38	6	2.38	6	2.38	4	1.58
Low–low[b]	19	7.54	20	7.94	19	7.54	20	7.94
Low–high[c]	40	15.87	38	15.08	39	15.48	38	15.08
High–low[d]	12	4.76	12	4.76	11	4.37	15	5.96
Not significant	175	49.72	176	69.84	177	70.24	175	69.44
Total	252	100	252	100	252	100	252	100

[a] High water stress, high social vulnerability.
[b] Low water stress, low social vulnerability.
[c] Low water stress, high social vulnerability.
[d] High water stress, low social vulnerability.

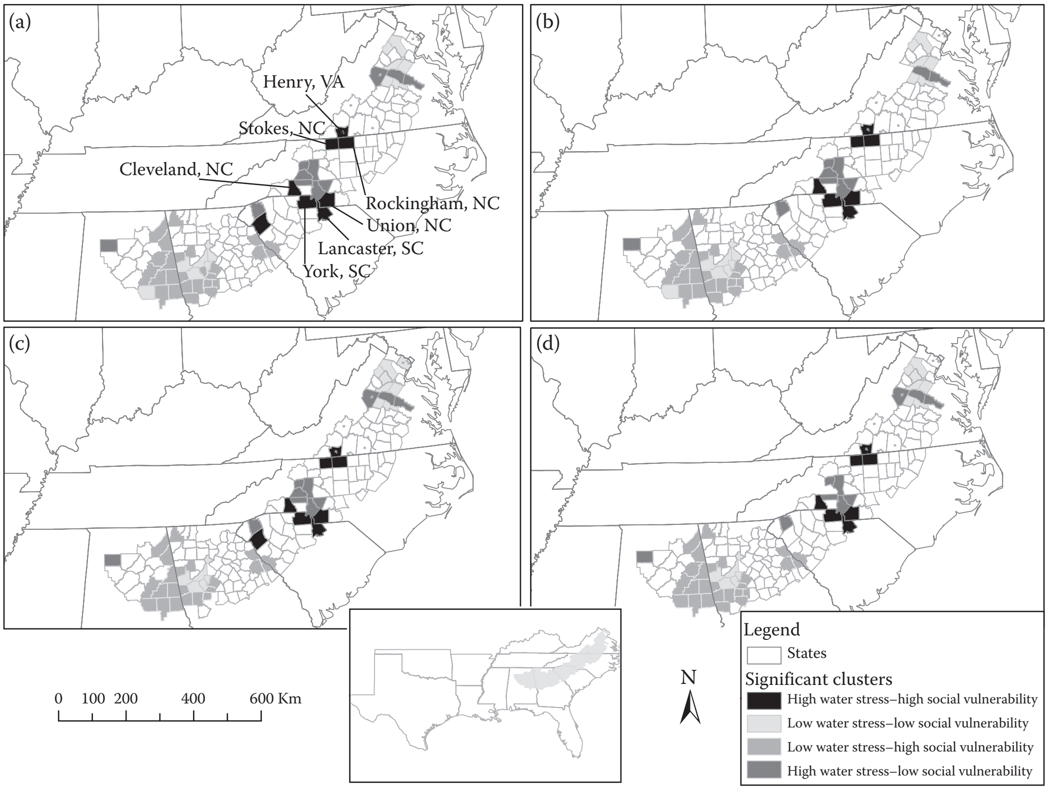

FIGURE 4.6 Convergence of water stress and social vulnerability in Piedmont counties of the Southern United States (a) in 2010 and predicted for (b) 2020, (c) 2030, and (d) 2040.

TABLE 4.4
Current and Predicted Distribution of Counties for the Piedmont of the Southern United States, 2010–2040

	2010		2020		2030		2040	
Condition	**Number**	**%**	**Number**	**%**	**Number**	**%**	**Number**	**%**
High–high[a]	8	4.51	7	3.95	8	4.52	7	3.95
Low–low[b]	12	6.78	13	7.34	13	8.47	12	6.78
Low–high[c]	26	14.69	25	14.12	22	14.69	26	14.69
High–low[d]	11	6.21	10	6.21	11	5.08	10	5.65
Not significant	120	67.80	122	69.49	123	69.49	122	68.93
Total	177	100	177	100	177	100	177	100

[a] High water stress, high social vulnerability.
[b] Low water stress, low social vulnerability.
[c] Low water stress, high social vulnerability.
[d] High water stress, low social vulnerability.

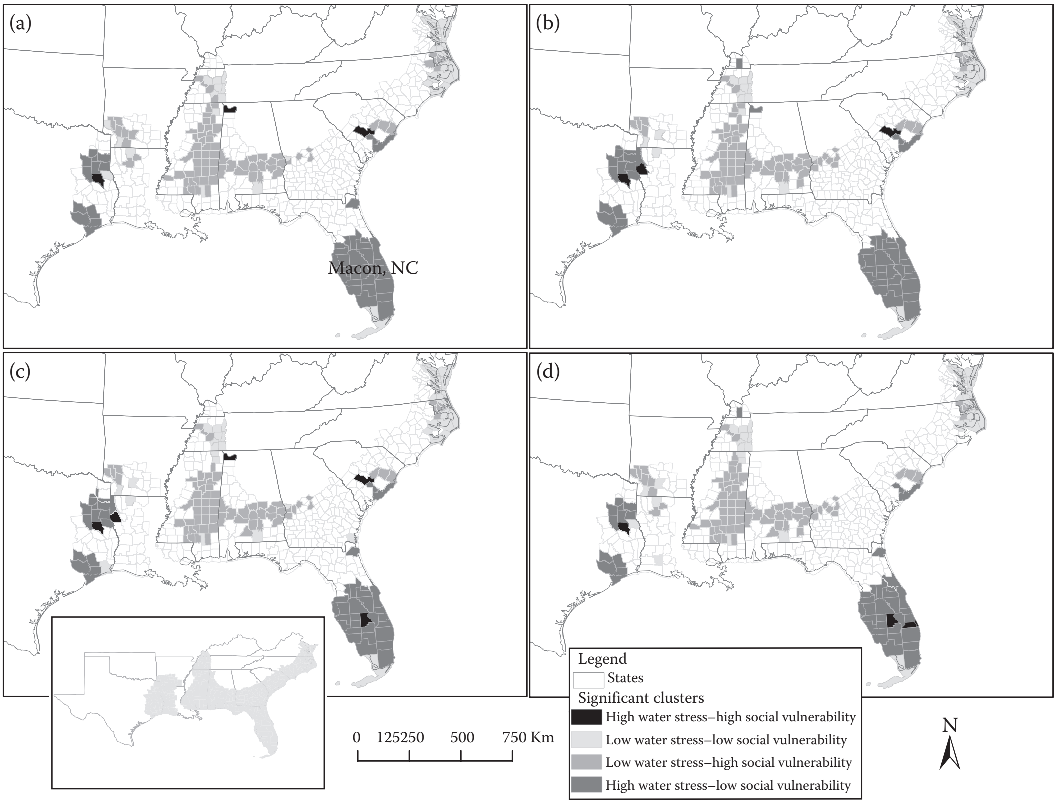

FIGURE 4.7 Convergence of water stress and social vulnerability in Coastal Plain counties of the Southern United States (a) in 2010 and predicted for (b) 2020, (c) 2030, and (d) 2040.

Mississippi Alluvial Valley

The Mississippi Alluvial Valley has its origins at the meeting of the Ohio and Mississippi Rivers in southern Illinois and extends to the Gulf of Mexico. Figure 4.8a–d shows no hot-spot clusters; overall, 11 or fewer counties were found to have a significant association between water stress and social vulnerability (Table 4.6). These results are not surprising given that the Mississippi Alluvial Valley is a riverine ecosystem that has a low-lying physiography and the largest coterminous wetlands system in North America (Omernik and Griffith 2008). Fertile soils make it especially suitable for farming, although flooding is common.

Mid-South

The Mid-South encompasses most of Texas, all of Oklahoma, and much of northwestern Arkansas. Table 4.7 shows that both the absolute number and percentage of cluster types remained virtually constantover the 30-year span. Figure 4.9a–d shows hot-spot clusters mainly in western and southern Texas.

Results are consistent with expectations for these parts of Texas, given that nearly all these hot-spot counties have high water stress (Texas Water Development Board 2008), relatively lower education rates, majority Hispanic populations, and sometimes higher-than-average poverty rates. For the seven counties comprising western Texas (El Paso, Hudspeth, Culberson, Jeff Davis, Presidio, Brewster, and Terrell), overall water demand is expected to increase by only 9% from 2010 to

TABLE 4.5
Current and Predicted Distribution of Counties for the Coastal Plain of the Southern United States, 2010–2040

	2010		2020		2030		2040	
Condition	**Number**	**%**	**Number**	**%**	**Number**	**%**	**Number**	**%**
High–high[a]	3	1.00	3	1.00	5	1.00	3	1.00
Low–low[b]	42	8.62	40	8.21	45	9.24	43	8.83
Low–high[c]	80	16.43	77	15.81	72	14.78	83	17.04
High–low[d]	43	8.83	47	9.65	46	9.45	43	8.83
Not significant	319	82.43	320	65.71	319	65.50	315	64.68
Total	487	100	487	100	487	100	487	100

[a] High water stress, high social vulnerability.
[b] Low water stress, low social vulnerability.
[c] Low water stress, high social vulnerability.
[d] High water stress, low social vulnerability.

2060, but municipal demand is expected to increase by 51% (Texas Water Development Board 2008). High water stress–low social vulnerability counties cluster in northwestern Texas. Low water stress–high social vulnerability counties cluster in eastern Oklahoma and western Arkansas and in some central and southern Texas areas; one extreme example is Cherokee County in Oklahoma, where roughly a third of the population is projected to be Native American in 2020 and the wealth index is only two-thirds the national average.

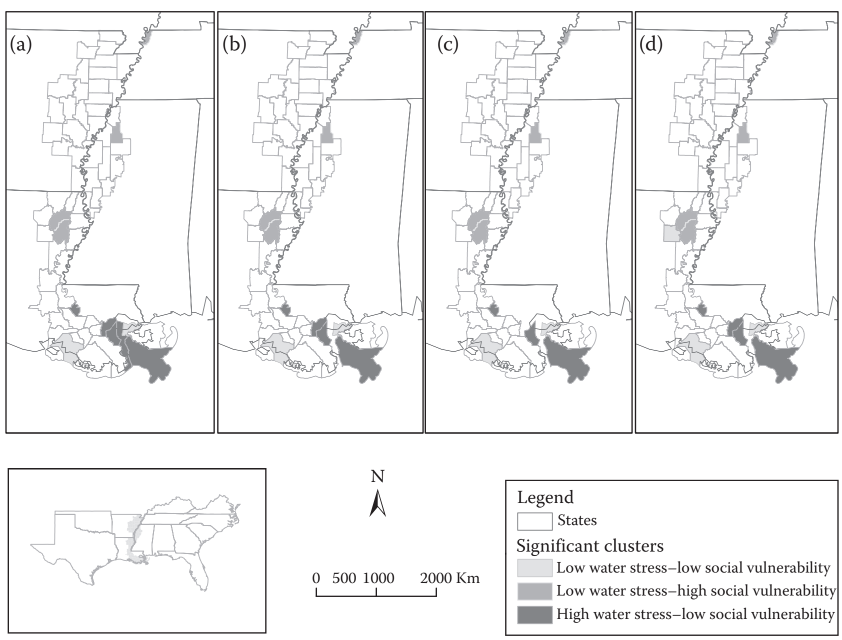

FIGURE 4.8 Convergence of water stress and social vulnerability in Mississippi Alluvial Valley counties of the Southern United States (a) in 2010 and predicted for (b) 2020, (c) 2030, and (d) 2040.

TABLE 4.6
Current and Predicted Distribution of Counties for Mississippi Alluvial Valley of the Southern United States, 2010–2040

	2010		2020		2030		2040	
Condition	**Number**	**%**	**Number**	**%**	**Number**	**%**	**Number**	**%**
High–high[a]	—	—	—	—	—	—	—	—
Low–low[b]	2	3.13	2	3.13	2	3.13	3	4.69
Low–high[c]	4	6.25	4	6.25	4	6.25	4	6.25
High–low[d]	4	6.25	4	7.82	3	4.69	4	6.25
Not significant	54	84.38	54	83.38	55	85.94	53	82.81
Total	64	100	64	100	64	100	64	100

Note: — means zero.
[a] High water stress, high social vulnerability.
[b] Low water stress, low social vulnerability.
[c] Low water stress, high social vulnerability.
[d] High water stress, low social vulnerability.

TABLE 4.7
Current and Predicted Distribution of Counties for the Mid-South of the Southern United States, 2010–2040

	2010		2020		2030		2040	
Condition	**Number**	**%**	**Number**	**%**	**Number**	**%**	**Number**	**%**
High–high[a]	26	7.88	22	6.67	27	8.18	26	7.88
Low–low[b]	56	16.97	55	16.67	53	16.06	54	16.36
Low–high[c]	43	13.03	43	13.03	44	13.33	45	13.63
High–low[d]	23	6.97	27	8.18	19	5.76	24	7.27
Not significant	182	55.15	183	55.45	187	56.67	181	54.85
Total	330	100	330	100	330	100	330	100

[a] High water stress, high social vulnerability.
[b] Low water stress, low social vulnerability.
[c] Low water stress, high social vulnerability.
[d] High water stress, low social vulnerability.

DISCUSSION

Returning to the question posed earlier concerning real-world interplays of social vulnerability and water stress, we offer further discussion along the lines of the relative lack of buffers or insulating factors that act to shield socially vulnerable groups from environmental stresses impacting landownership and improvement. We suggested that the vulnerability of a place is compounded when there are simultaneously environmental stresses (e.g., water scarcity) and socially vulnerable populations. Socially vulnerable populations with significant landownership or whose income depends to a large extent on water availability are typically less likely than those not in socially precarious conditions to be able to protect their ownership interests from environmental stresses such as drought or wildfire (Collins 2008a,b, Johnson-Gaither et al. 2011). A crucial factor in such

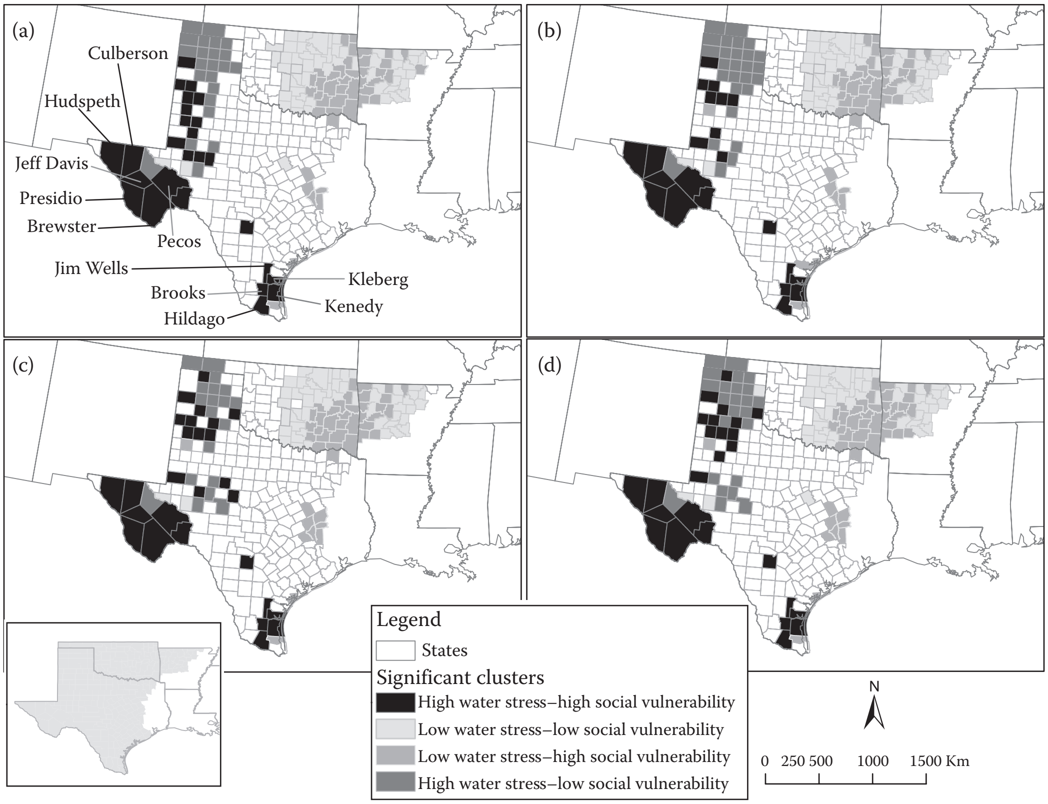

FIGURE 4.9 Convergence of water stress and social vulnerability in Mid-South counties of the Southern United States (a) in 2010 and predicted for (b) 2020, (c) 2030, and (d) 2040.

protection involves the legal status of the land in question. This question also references the problem of entitlements discussed earlier.

"Heir property," fractionation, or tenancy in common is a typical form of landownership in the South, particularly among Black-Belt African Americans but is also prevalent among Appalachian Whites and Native Americans (Deaton et al. 2009; Dyer et al. 2009; Mitchell 2000, 2001; Shoemaker 2003). Heir property describes undivided, real property owned simultaneously by a potentially

Q4

TABLE 4.8
Comparison of Percentages of Selected Vulnerable Populations in Southern Urban Areas and Southern States to the U.S. Average

Population	Urban Areas[a] (%)	States (%)	U.S. Overall[b] (%)
Persons <5 years	6.8	7.6	6.5
Persons ≥65 years and over	10.7	13.1	13.3
African American persons	35.5	20.7	6.8
Persons of Hispanic origin	15.2	15.4	11.0
Persons below the poverty level	20.0	16.9	12.8

[a] Based on the population of the three largest cities (>100,000 individuals) and capitals of the 13 southern states.
[b] National average less southern states.

unlimited number of heirs. No single owner has clear title to land. This type of land acquisition usually comes about in cases where a family member dies intestate or without a will specifying exact amounts and location of ownership accruing to descendants.

In 1978, Graber estimated that one-third of all Black-held land in the rural South could be classed as heir property. Graber (1978) details that "heirs [sic] property is most acute in rural areas and in Q5 counties that are still untouched by heavy industry, by suburban home building, by oil exploration or by extensive resort development." Further, "[t]here is an absence of black real estate (and heir Q6 property) in those counties where large tracts of land are owned by timber or pulp companies, or where a large part of the land mass is in public ownership (i.e., national forests)." Later, Mitchell (2000) offered that 41% of African American-owned land in the southeast could be classed as heir property. Shoemaker (2003, p. 729) also asserts that in "Indian Country today, fractionation has reached crisis proportions," resulting in millions of actual heirs to small land parcels. Today, rights to Native Lands are recognized; however, Shoemaker (2003) writes that "other potential benefits Q7 of the landownership" are lost; and that [h]omelessness and poverty persist within the traditional homeland, and Indian Country continues to face critical obstacles to true economic, cultural, and political security." Q8

The common denominator among these groups with respect to heir property is lack of wealth and education. Socially vulnerable populations are more likely than middle-class or affluent groups to not have wills; and the lack of wills only serves to perpetuate social vulnerabilities. Although Dyer and Bailey (2008) call attention to the cultural significance of heir property for southern African Americans, Dyer et al. (2009) also argue that such landownership is also rife with a number of legal impediments that inhibit the effective use of such properties as collateral for home mortgages, any USDA Rural Development loans available for home building, or the array of farm programs offering protection from environmental hazards, including crop insurance (Dyer et al. 2009; Graber 1978; Shoemaker 2003). Moreover, Deaton et al. (2009) stress that heir property acts as a deterrent to wealth accumulation for individual families because intergenerational transfers of property and income are key to wealth accumulation in the United States.

Specifically, Deaton et al. (2009) write that heir property presents a problem for landowners because of "efficiency and displacement." Efficiency has to do with the underutilization of land and displacement with land loss. With reference to the efficiency difficulty, Deaton et al. (2009) describe heir property as a "tragedy of the anti-commons," meaning that the existence of mul- Q9 tiple landowners can result in an apathetic engagement with privately held resources because of disincentives for land improvement. For example, in three case studies from Appalachia, Deaton et al. (2009) found that the lack of agreement on property management or selling price to an outside party resulted in nothing being done either to utilize resources or improve land, for a significant amount of time. Another problem with heir property is that any cotenant who wishes to realize the cash value of his or her land share can force a court sale of an entire property; the land is then sold to the highest bidder, resulting in the possible dispossession and displacement of actual family members. Graber (1978, p. 278) writes that heir property is land with "greatly diminished value" because of such restrictions; further, heir property "will not finance a home or farm equipment or serve as collateral for an emergency loan." A limited-resource landowner in a water-stressed location in need of a deeply drilled well would find difficulties in obtaining the loan if the intestate properties were intended for collateral. Given the prevalence of heir property among socially vulnerable populations, this form of landownership represents a hindrance to the acquisition of buffers such as property insurance and loans that could protect land from environmental stressors.

Policy and Management Implications

Mapping social vulnerability to environmental change and hazards, as we have done in this chapter, is useful in a number of ways. Social vulnerability indicators that draw from census data enable comprehensive mapping of social vulnerability over large geographic areas with a modest investment of time and little fieldwork. By highlighting vulnerable areas, maps help identify priority places for planning and for focusing responses to sudden environmental disasters, and for targeting mitigation efforts, such as planting trees to reduce urban heat island effects (Cox et al. 2006). However, social vulnerability indicators have limitations, many of which result from using census measures as proxy variables for more complicated social and economic processes that cannot be easily measured and are generally unavailable across large geographic areas.

Although indicators are useful for telling where to target interventions, Ribot (2011) suggests that developing effective interventions also requires a causal analysis of why people are at risk and identification of the potential entry points for risk reduction. As discussed, this would entail an examination of the architecture of entitlements as these relate to climate mitigation. Place-centered causal analysis starts with the unit at risk and the assets or entitlements that are (or are not) present, and then traces the causes of these conditions outward to the larger physical, social, and political–economic environment to understand why and when particular vulnerabilities occur at certain times (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 Q1 surveys. Roncoli et al. (2009) propose that subjective judgment, cultural meanings, and political agendas shape both the awareness of potential climate changes and the responses to climate-related events. Ethnographic methods are needed to understand these patterns, as well as to help identify the processes that shift risks and costs to minority groups as the larger society plans and adapts to climate change.

The mapping presented in this chapter can be used as a first-level indicator of water stress vulnerability. Using the "hot spots" as a guide, research can be directed to a fine-tuned analysis of the contextual vulnerabilities and adaptive capacities within these counties. This step would necessitate collaboration between researchers and county managers (elected officials, extension agents, or human welfare agents) to explore the informal social networks that might operate among limited-resource landowners or farmers, for instance, the goal of which is to understand better how public resources may reinforce water stress alleviation provided by these networks. Informal networks supporting economic activities can include collectives based on friendship, kin, or religious ties. It is these unofficial, invisible webs that can provide the most aid to socially marginal populations in agricultural economies because, again, these populations typically make less use of formal-support networks. Yet, Vásquez-León (2009, p. 291) writes that "Climate-vulnerability studies that focus on the agricultural sector in the United States and Canada rarely look at informal networks or local-level collective strategies." This exploration would provide information on how groups acquire and share information about risk and disaster preparedness and management; further, the analysis would uncover factors impacting competition among groups for resource access and identify specific actions that could be undertaken by county managers to reduce tensions among various groups. While county agents may not be able to address long-standing inequities such as poverty, they may be able to discover why certain groups are routinely excluded from the benefit of state-sponsored buffers such as information delivery and other extension activities. We offer the current work as starting point for looking at the intersection of water stress and social vulnerability in the U.S. South.

REFERENCES

Adger, W.N. and Kelly, P.M. 1999. Social vulnerability to climate change and the architecture of entitlements. *Mitigation and adaptation strategies for global change*, 4:253–266.

Allen-Smith, J.E., Wimberley, R.C., and Morris, L.V. 2000. America's forgotten people and places: Ending the legacy of poverty in the rural south. *Journal of Agricultural and Applied Economics*, 32:319–329.

Anselin, L.1995. Local indicators of spatial association-LISA. *Geographical Analysis*, 27(2):93–115.

Bakker, K. 2007. Trickle down? Private sector participation and the pro-poor water supply debate in Jakarta, Indonesia. *Geoforum*, 38:855–868.

Birkmann, J. 2006. Measuring vulnerability to promote disaster-resilient societies: Conceptual frameworks and definitions. In: Birkmann, J. (ed.), *Measuring Vulnerability to Natural Hazard*, pp. 1–54. New York: United Nations University Press, pp. 524.

Bohle, H.G., Downing, T.E., and Watts, M.J. 1994. Climate change and social vulnerability: Toward a sociology and geography of food insecurity. *Global Environmental Change*, 4(1):37–48.

British Broadcasting Corporation. 2008. Worldwide battle for water. Available online at http://news.bbc.co.uk/2/hi/science/nature/7569453.stm.

Brooks, N. 2003. Vulnerability, Risk and adaptation: A conceptual framework. Working Paper 38. Tyndall Centre for Climate Change Research. Norwich, UK.

Chapin, T. 2003. A population and employment forecast for Franklin County. The Department of Urban and Regional Planning, Florida State University. http://mailer.fsu.edu/~tchapin/garnettchapin/urp5261/FC%20Final%20Report.pdf.

Chaves, L. F., C. L. Keogh, G. M. Vazquez-Prokopec, and U. D. Kitron. 2009. Combined sewage overflow enhances ovipositon of *Culex quinquefasciatus* (Diptera: Culicidae) in urban areas. *Journal of Medical Entomology,* 46:220–226.

Collins, T.W. 2008a. The political ecology of hazard vulnerability: Marginalization, facilitation and the production of differential risk to urban wildfires in Arizona's White mountains. *Journal of Political Ecology*, 15:21–43.

Collins, T. 2008b. What influences hazard mitigation? Household decision making about wildfire risks in Arizona's White Mountains. *The Professional Geographer*, 60:508–526.

Cox, J.R., C. Rosenzweig, W. Solecki, R. Goldberg, and P. Kinney. 2006. *Social Vulnerability to Climate Change: A Neighborhood Analysis of the Northeast U.S. Megaregion. Northeast Climate Impacts Assessment (NECIA)*. Cambridge, MA: Union of Concerned Scientists.

Cutter, S., Boruff, B., and Shirley, W. 2003. Social vulnerability to environmental hazards. *Social Science Quarterly,* 84(1):242–261.

Deaton, B.J., Baxter, J., and Bratt, C.S. 2009. Examining the consequences and character of "heir property." *Ecological Economics*, 68:2344–2353.

Dellapenna, J.W. 2005. Markets for water: Time to put the myth to rest? *Journal of Contemporary Water Research and Education*, 131(1):33–41.

Downing, T., J. Aerts, J. Soussan, S. Bharwani, C. Ionescu, J. Hinkel, R. Klein et al., 2005. Integrating Social Vulnerability into Water Management, NeWater Working Paper No. 5. New Approaches to Adaptive Water Management under Uncertainty. Available online at http://www.pik-potsdam.de/research/research-domains/transdisciplinary-concepts-and-methods/project-archive/favaia/pubs/downing_etal_2005.pdf. Date accessed 16 June 2011.

Dyer, J.F. and Bailey, C. 2008. A place to call home: Cultural understanding of heir property among rural African Americans. *Rural Sociology*, 73(3):317–338.

Dyer, J.F., Bailey, C., Van Tran, N. 2009. Ownership characteristics of heir property in a black belt county: A quantitative approach. *Southern Rural Sociology*, 24(2):192–217.

Eastern Forest Environmental Threat Assessment Center. 2011. CCAMMO Ecoregions. Available online at: http://www.forestthreats.org/current-projects/project-summaries/CCAMMO_ecoregions.png/view. Date accessed 15 November 2011.

Eriksen, S.H. and Kelly, P.M. 2007. Developing credible vulnerability indicators for climate adaptation policy assessment. *Mitigation and Adaptation Strategies for Global Change*, 12:495–524.

Feldman, D.L. 2008. Barriers to adaptive management: Lessons from the Aplachicola-Chattahoochee-Flint compact. *Society and Natural Resources*, 21(6):512–525.

Füssel, Hans-Martin. 2009. Review and quantitative analysis of indices of climate change exposure, adaptive capacity, sensitivity, and impacts. Potsdam Institute for Climate Impact Research. Available online at: http://siteresources.worldbank.org/INTWDR2010/Resources/5287678-1255547194560/WDR2010_BG_Note_Fussel.pdf. Date accessed 9 September 2011.

Intergovernmental Panel on Climate Change. 2001, Contribution of Working Groups I, II, and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press.

Intergovernmental Panel on Climate Change. 2007. Intergovernmental Panel on Climate Change Synthesis Report. Available online at http://www.ipcc.ch/publications_and_data/ar4/syr/en/mains5-2.html. Date accessed 12 September 2011.

Graber, C.S. 1978. Heirs property: The problems and possible solutions. *Clearinghouse Review*, 12:273–284.

Johnson-Gaither, C., Gan, J., Jarret, A., Wyman, M.S., Malone, S., Adams, K.J., Bowker, J.M., and Stein, T.V. 2011. Black Belt Landowners Respond to State-sponsored Wildland Fire Mitigation Policies and Programs. General Technical Report, SRS-139. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station, pp.25.

Kelly, P.M. and Adger, W.N., 2000. Theory and practice in assessing vulnerability to climate change and facilitating adaptation. *Climatic Change*, 47:325–352.

Lockaby, G., Nagy, C., Vose, J.M., Ford, C.R., Sun, G., McNulty, S., Caldwell, P., Cohen, E., and Moore Myers, J. In press. Water and forests. In: *Southern Forest Futures Project*. Southern Research Station, **Q10** Asheville, NC.

Mackun, P. and S. Wilson. 2011. Population Distribution and Change: 2000 to 2010. 2010 Census Briefs. Available online at http://www.census.gov/prod/cen2010/briefs/c2010br-01.pdf. Date accessed, **Q11** unknown.

McCarthy. J. 2002. First world political ecology: Lessons from the wise use movement. *Environment and Planning A*, 34:1281–1302.

Mitchell, T.W. 2000. From Reconstruction to Deconstruction: Undermining Black Landownership, Political Independence, and Community through Partition Sales of Tenancies in Common. Land Tenure Center Research Paper 132. Land Tenure Center, University of Wisconsin-Madison. Available online at: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1544380. Date accessed unknown.

Mitchell, T.W. 2001. From reconstruction to deconstruction: Undermining black landownership, political independence, and community through partition sales of tenancies in common. *Northwestern University Law Review*, 95:505–580.

Moore, J. G. 2005. A half century of water resource planning and policy, 1950–2000. In: Norwine, J., Giardino, J.R., and Krishnamurthy, S. 2005 (eds), *Water for Texas*, pp. 5–16. Texas A & M University Agricultural **Q12** Series, no. 6.

Mukheibir, P. 2010. Water access, water scarcity, and climate change. *Environmental Management*, 45: 1027–1039.

Nelson, D.R. and Finan, T.J. 2009. Praying for drought: Persistent vulnerability and the politics of patronage in Ceará, Brazil. *American Anthropologist*, 111(3):302–316.

Noji, E.K. 1997. The nature of disaster: General characteristics and public health effects. In: Noji, E.K. (ed.) *The Public Health Consequences of Disasters*, pp. 3–20. New York: Oxford University Press.

O'Brien, K., Eriksen, S., Nygaard, L.P., and Schjolden, A. 2007. Why different interpretations of vulnerability matter in climate change discourse. *Climate Policy*, 7:73–88.

Omernik, J.M. and Griffith, G.E. 2008. Ecoregions of the Mississippi Alluvial Plain. *The Encyclopedia of the Earth*. Available at: http://www.eoearth.org/article/Ecoregions_of_the_Mississippi_Alluvial_Plain_(EPA). Date downloaded: 13 October 2011.

Oxfam. 2009. Exposed: Social vulnerability and climate change in the US southeast. Available online at: http://adapt.oxfamamerica.org/resources/Exposed_Report.pdf. Date accessed 8 December 2009.

Patz, J. A., M.A. McGeehin, S.M. Bernard, K.L. Ebi, P.R. Epstein, A. Grambsch, D.J. Gubler et al., 2001. Potential consequences of climate variability and change for human health in the United States. In: N.A.S. Team, (ed.). *Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change*, pp. 437–458. Cambridge: Cambridge University Press.

Paul, M. J. and J. L. Meyer. 2001. Streams in the urban landscape. *Annual Review of Ecology and Systematics*, 32:333–365.

Pelling, M. 2001. Natural disasters?. In: Castree, N. and Braun, B. (eds.), *Social Nature: Theory, Practice and Politics*, pp. 170–188. Oxford: Blackwell.

Polsky, C., Neff, R., and Yarnal, B. 2007. Building comparable global change vulnerability assessments: The vulnerability coping diagram. *Global Environmental Change*, 17(3–4):472–485.

Ribot, J. 2011. Vulnerability before adaptation: Toward transformative climate action. *Global Environmental Change,* 21:1160–1162.

Ribot, J.C. 2009. Vulnerability does not just fall from the sky: Toward multi-scale pro-poor climate policy. In: R. Mearns and A. Norton (eds.), *Social Dimensions of Climate Change: Equity and Vulnerability in a Warming World*, pp. 47–74. Washington, DC: The World Bank.

Rockström, J. 2003. Resilience building and water demand management for drought mitigation. *Physics and Chemistry of the Earth,* 28:869–877.

Rygel, L., O'Sullivan, D., and Yarnal, B. 2006. A method for constructing a social vulnerability index: An application to hurricane storm surges in a developed country. *Mitigation and Adaptation Strategies for Global Change*, 11:741–764.

Sabo, J.L., Sinha, T., Bowling, L.C., Schoups, G.H.W., Wallender, W.W., Campana, M.E., Cherkauer, K.A. et al., 2010. Reclaiming freshwater sustainability in the Cadillac Desert. *Proceedings of the National Academy of Sciences of the United States of America*. Available online at http://www.pnas.org/content/107/50/21263.full.pdf+html. Date accessed 7 September 2011.

Science Daily. 2010. Southeastern U.S., with exception of Florida, likely to have serious water scarcity issues. John Kominoski quoted in *Science Daily*, 13 December 2010. Available online at http://www.sciencedaily.com/releases/2010/12/101213184436.htm. Date accessed 21 November 2011.

Shoemaker, J.A. 2003. Like snow in the spring time: Allotment, fractionation, and the Indian land tenure problem. *Wisconsin Law Review*, 729–788. **Q13**

Southern Appalachian Man and the Biosphere. 1996. The southern Appalachian assessment terrestrial technical report. Atlanta: U.S. Department of Agriculture, Forest Service, Southern Region. 248 p.

Stone, B. 2012. *The City and the Coming Climate Change*. New York: Cambridge University Press.

Sun, G., McNulty, S.G., Moore Myers, J.A., and Cohen, E.C. 2008. Impacts of multiple stresses on water demand and supply across the southeastern United States. *Journal of American Water Resources Association,* 44(6):1441–1457.

Sunderlin, W. D., Dewi, S., Puntodewo, A., Muller, D., Angelsen, A., and Epprecht, M. 2008. Why forests are important for global poverty alleviation: A spatial explanation. *Ecology and Society*, 13(2):24.

Szydlowski, G.F. 2007. Commoditization of water: A look at Canadian bulk water exports, the Texas water dispute, and the ongoing battle under NAFTA for control of water resources. Notes and Comments. *Colorado Journal of Environmental Law and Policy*, 18(3):665–686.

Taylor, W., Floyd, M. F., Whitt-Glover, M., Brooks, J. 2007. Environmental justice: A framework for collaboration between the public health and recreation and parks fields to study disparities and physical activity. *Journal of Physical Activity Health*, 4, S20–S29.

Texas Water Development Board. 2008. *Far West Texas Climate Change Conference: Study Findings and Conference Proceedings*. Available online at http://www.twdb.state.tx.us/publications/reports/climatechange.pdf. Date accessed 24 September 2012.

Turner, B.L., Kasperson, R.E., Matson, P.A., McCarthy, J.J., Corell, R.W., Christensen, L., Eckley, N. et al., 2003. A analysis in sustainability science framework for vulnerability. *Proceedings of the National Academy of Sciences*, July 8(100), 14:8074–8079.

U.S. Census Bureau. 2000. Summary File 3. Detailed Tables for Population, Poverty, Education (which tables are these). Universe Total Population. P6. Data Set: Census 2000 Summary File 3 (SF 3) Sample Data. Available online at http://factfinder.census.gov. Date accessed 7 December 2009.

U.S. Forest Service. 2012. Future of America's Forests and Rangelands: Forest Service 2010 Resources Planning Act Assessment. General Technical Report. WO-87. Washington, DC: 198 p.

U.S. Senate Committee on Foreign Relations. 2011. Avoiding water wars: Water scarcity and Central Asia's growing importance for stability in Afghanistan and Pakistan. Available online at: www.foreign.senate.gov/.

Vásquez-León, M. 2009. Hispanic farmers and farmworkers: Social networks, institutional exclusion, and climate vulnerability in Southeastern Arizona. *American Anthropologist,* 111(3):289–301.

Vincent, K. 2004. Creating an Index of Social Vulnerability to Climate Change for Africa. 2004. Tyndall Centre for Climate Change Research. Working Paper 56.

Vörösmarty, C.J., Douglas, E.M., Green, P.A., and Revenga, C. 2005. Geospatial indicators of emerging water stress: An application to Africa. *Royal Swedish Academy of Sciences*, 34(3):230–236.

Vörösmarty, C. J., Green, P., Salisbury, J., and Lammers, R. B. 2000. Global water resources: Vulnerability from climate change and population growth, *Science*, 289:284–288.

Wear, D. N. In press. Chapter 4: Forecasts of land uses. In: Wear, D. N. and Greis, J. G. (eds.). *The Southern Forest Futures Project*, pp. 123–178. Asheville: USDA Forest Service Southern Research Station.

Williams, D. R., H. W. Neighbors, and J. S. Jackson. 2003. Racial/ethnic discrimination and health: Findings from community studies. *American Journal of Public Health,* 93:200–208.

Williams, M. 2007. Proud, humble oystermen fear loosing a way of life, Cox News Services, Available online at www.lexisnexis.com.proxy-remote.galib.uga.edu/us. Date accessed, unknown.

Wisner, B., Blaikie, P., Cannon, T., and Davis, I. 2004. *At Risk: Natural Hazards, People's Vulnerability and Disasters*. New York: Routledge.

Woods and Poole. 2009. *The 2010. Complete Economic and Demographic Data Source (CEDDS)*. Woods & Poole Economics, Inc. pp. 106.

Cat#:K16616 **Chapter: 004**

TO: CORRESPONDING AUTHOR

AUTHOR QUERIES – TO BE ANSWERED BY THE AUTHOR

The following queries have arisen during the typesetting of your manuscript. Please answer these queries by marking the required corrections at the appropriate point in the text.

Query No.	Query	Response
Q1	The following References are not under reference list. Please provide complete publication details. Glennon (2009); Roncoli et al. (2009)	
Q2	Is it Mukheibir (2010) or Mukheibar (2010)? Please confirm the correct spelling.	
Q3	Is it Cutter et al. (2003) or Cutter (2003)? Please confirm.	
Q4	Please provide in text callout for Table 4.8.	
Q5	Please provide page number for the quote “heirs [sic] property………… development”.	
Q6	Please provide the page number for the quote “[t]here is an ………. national forests)”.	
Q7	Please provide the page number for the quote ‘other potential benefits….’	
Q8	Please check the closing quotes. There is no opening quote for this.	
Q9	Please provide the page number for the quote “tragedy of the anti-commons,”	
Q10	Please update Lockaby et al., in press.	
Q11	The following References are not cited. Please suggest a suitable place for its citation in the text. Mackun, and Wilson. (2011); Noji (1997); Wear (In press); Williams et al. (2003)	
Q12	Please provide place of publication for the following References: Moore (2005); Woods and Poole (2009).	
Q13	Please provide the volume number in Shoemaker (2003).	