Chapter 3: Socioeconomic Impacts of Climate Change on Rural Communities in the United States

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Introduction

Climate change refers to any distinct change in measures of climate such as temperature, rainfall, snow, or wind patterns lasting for decades or longer (USEPA 2009). In the last decade, there has been a clear consensus among scientists that the world is experiencing a rapid global climate change, much of it attributable to anthropogenic activities. The extent of climate change effects (e.g., future temperature increase) is difficult to project with certainty, as scientific knowledge of the processes is incomplete and the socioeconomic factors that will influence the magnitude of such increases are difficult to predict (IPCC 2001). However, even if greenhouse gas (GHG) emissions are reduced significantly over the coming years, significant increases in temperature and sea level rise may still occur.

The impacts of climate change can be broadly grouped under three headings: ecological, social, and economic. The ecological impacts of climate change include shifts of vegetation types and associated impacts on biodiversity; change in forest density and agricultural production; expansion of arid land; decline in water quantity and quality; and stresses from pests, diseases, and wildfire. Salient social impacts may include changes in employment, equity, risk distribution, and human health, and relocations of populations. Economic impacts include increased risk and uncertainty of forest or agricultural production, alteration in productivity for crops and forest products, reduction in supply of ecosystem goods and services, increased cost of utilities and services, and altered energy needs.

Climate change will most likely affect populations through impacts on the necessities and comforts of life such as water, energy, housing, transportation, food, natural ecosystems, and health systems. Considerable uncertainty remains about the nature and magnitude of climate change impacts, particularly those related to rural communities, in view of (1) the complex nature of farm decisionmaking, in which there are many nonclimatic issues to manage; (2) the likely diversity of responses within and between regions; (3) the difficulties that might arise if climate changes are nonlinear or increase climate extremes; (4) timelags in responses of communities; and (5) the possible interactions among different adaptation options and economic, institutional, and cultural barriers that inhibit such strategies. In light of these uncertainties, there is a need to increase our understanding of how ecosystems, social and economic systems, human health, and infrastructure will be affected by climate change in the context of other stresses.

The climate change literature specifically addressing social and economic effects of climate change in rural versus urban areas is limited. Although potential threats to urban and rural populations have been described in recent reports (e.g., USGCRP 2009), information delineating the impacts of climate change specifically on rural communities is scarce. The research has largely been sector-specific, such as delineating impacts on agriculture, health, transportation, demography, energy, etc., and has rarely addressed how these impacts might differ across urban or rural communities.[1] Similarly, knowledge of the comparative impacts of climate change in different geographical regions is limited. Because much of the climate change literature does not specifically address social and economic effects of climate change, we make inferences about these effects from national or sector assessments dealing largely with biophysical impacts. In addition, very few studies have attempted to delineate impacts across different spatial scales in terms of severity. Also, it is difficult to compare severity of impacts in light of future uncertainties. The capacity of the community to act in response to climate change and community resilience has been largely absent in climate change research (Flint and Luloff 2005). However, delineating the impacts of climate change on rural populations is critical, as they tend to depend on climate-sensitive livelihoods and are especially vulnerable to climate change events.

One difficulty in analyzing the impacts of climate change on rural communities, is the lack of a clear demarcation between rural and urban areas, as evidenced by the wide variety of definitions of "rural" employed by researchers and policymakers. For example, the USDA Economic Research Service (USDA ERS 2010g) lists as many as nine definitions for "rural." Whether an area is categorized as rural or urban depends in large part on how urban spaces are demarcated, i.e., whether urban spaces are defined in terms of administrative boundaries, land use patterns, or economic influence, and the minimum population thresholds established for delineating areas as urban or rural (Cromartie and Bucholtz 2008). Administrative definitions identify urban space along municipal or other jurisdictional boundaries. Definitions based on land use demarcate urban areas based on population density, whereas economic definitions incorporate the influence of cities beyond densely settled cores and demarcate based on broader commuting areas. The Office of Management and Budget (OMB) identifies counties as rural if they are not core counties (core counties contain one or more urban areas of 50,000 people or more) or economically tied to the core counties, as measured by the share of the employed population that commutes to and from core counties. For the purpose of this study,

[1] The literature that focuses on indigenous communities tends to be more developed than the literature on rural areas in general.

we follow the OMB definition and discuss impacts of climate change on nonmetro (rural) areas comprising about 2,052 counties lying outside metro boundaries.

Vulnerability of Rural Communities

Rural regions contain about 17 percent of the U.S. population but extend across 80 percent of the land area (fig. 3-1). The communities residing in these areas differ from their urban counterparts in terms of demography, occupations, earnings, literacy, poverty incidence, dependency on government funds, housing stress, mortality rates, etc. These differences tend to reshape economic and sociocultural conditions across rural counties and can provide insights as to why rural populations might have different vulnerabilities[2] to climate change than their urban counterparts. Vulnerability is a function of the character, magnitude, and variability rate of climate change to which a community is exposed, and the community's sensitivity and adaptive capacity (IPCC 2007). The community adjusts (adapts) in response to actual or expected climatic stimuli or their effects, in order to mitigate (moderate) adverse impacts or exploit beneficial opportunities. The higher a community's adaptive capacity, the lower is its vulnerability to climate change.

[2] Vulnerability is defined as the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes (IPCC 2007).

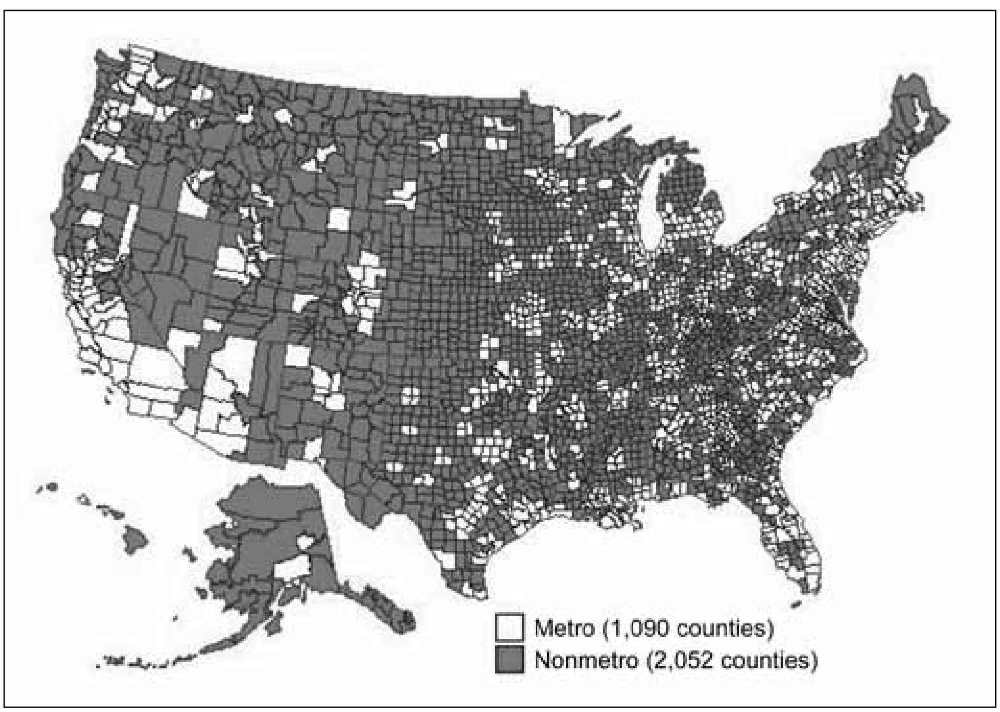

Figure 3-1—Nonmetro and metro counties, 2003. Source: USDA ERS 2010f.

Because 19.6 percent of nonmetro countries are farm dependent[3] as compared to just 3.4 percent of metro counties (USDA ERS 2010d) (fig. 3-2), rural communities are expected to disproportionately experience the brunt of the climatic impacts on agriculture. However, the specific impacts will vary across the United States. For example, the Midwest and Great Plains regions where farming is the predominant land use should experience larger impacts compared to other regions such as the Southeast, Northeast, or Lake States.

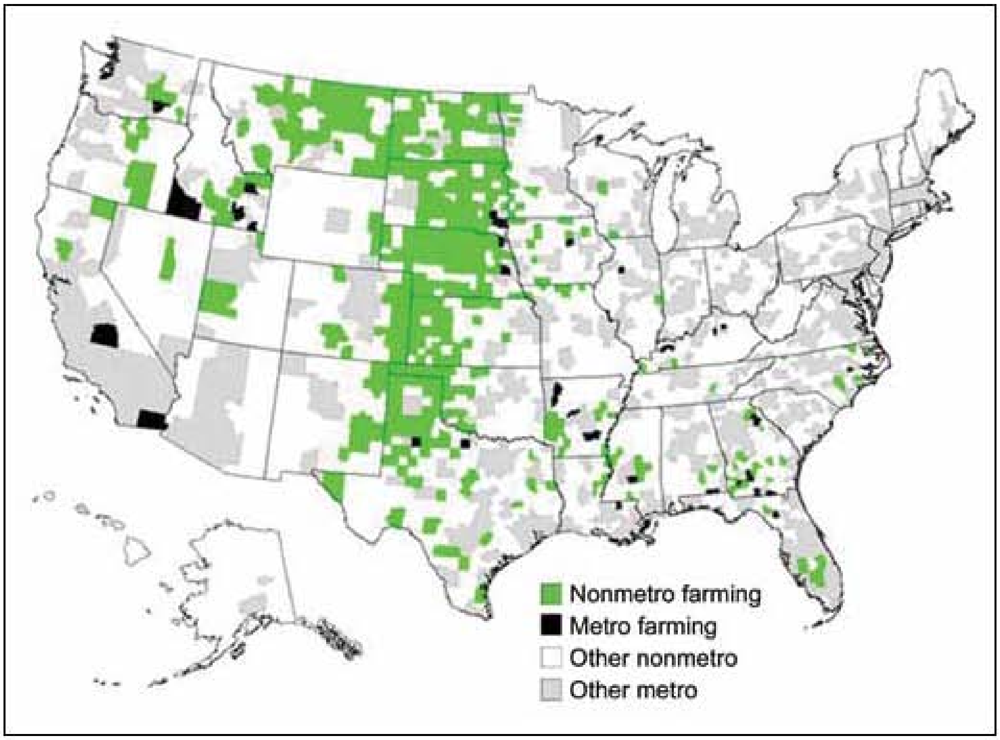

Figure 3-2—Farming-dependent counties, 1998–2000. Source: USDA ERS 2010c.

Rural counties tend to be poorer than their urban counterparts, as shown in figure 3-3. The per capita income in urban areas ($32,077) far exceeded per capita income in micropolitans ($23,338) (counties with cities of 10,000 to 49,999 residents and socioeconomic ties to adjacent counties), and noncore counties with neither a city over 10,000 residents nor socioeconomic ties to a city of that size, ($21,005) (USDA ERS 2010j). Among rural counties, per capita income is generally higher in the Northeast than in the Southeast or Southwest. The lower rural earning levels indicate lower shares of highly skilled jobs and lower returns to college degrees in rural labor markets (USDA ERS 2010l). Unemployment is also often higher in rural

[3] Farming-dependent counties have either (1) 15 percent or more of average annual labor and proprietors' earnings derived from farming or (2) 15 percent or more of employed residents who work in farm occupations. See USDA ERS 2010e for details.

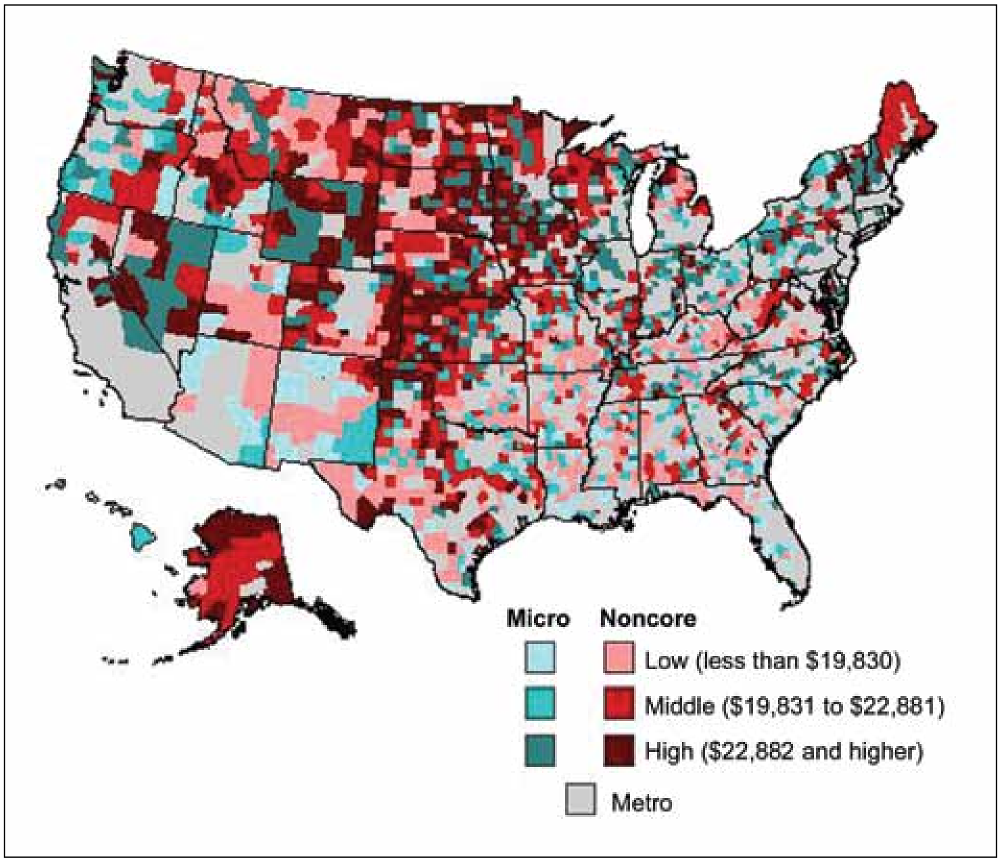

Figure 3-3—Per capita income in micropolitan and noncore counties, 2001. Source: USDA ERS 2010j.

areas. For example, 396 of the 460 counties classified as having low employment[4] were rural (Whitener and Parker 2007). The rural regions in the Southeast stand out as being plagued by high unemployment. Higher unemployment suggests a higher sensitivity and lower capacity to cope with the adverse impacts of climate change.

The rural-urban income gap has been widening recently (USDA ERS 2010j). For example, between 1993 and 2004, rural areas averaged 0.5 percent annual growth in real earnings compared to 1.2 percent per year in urban areas (USDA ERS 2010h). The rural-urban income gap is associated with lower costs of living in rural areas, lower educational attainment, less competition for workers among employers, and fewer highly skilled jobs in the rural occupational mix. As vulnerability to climate change is directly related to income levels (Yohe and Tol 2002), the rural communities' vulnerability to climate-related risk is expected to be higher than that of urban communities. Incidence of poverty is another factor that will influence a community's vulnerability to climate change. Turner et al. (2003)

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[4] Less than 65 percent of residents 21 to 64 years old were employed in 2000. See USDA ERS 2010e for details.

suggested that the poor and marginalized in Canada and the United States have historically been most at risk from weather shocks. Rural communities also tend to suffer from higher incidence of persistent poverty as evidenced by the data for counties[5] (fig. 3-4).

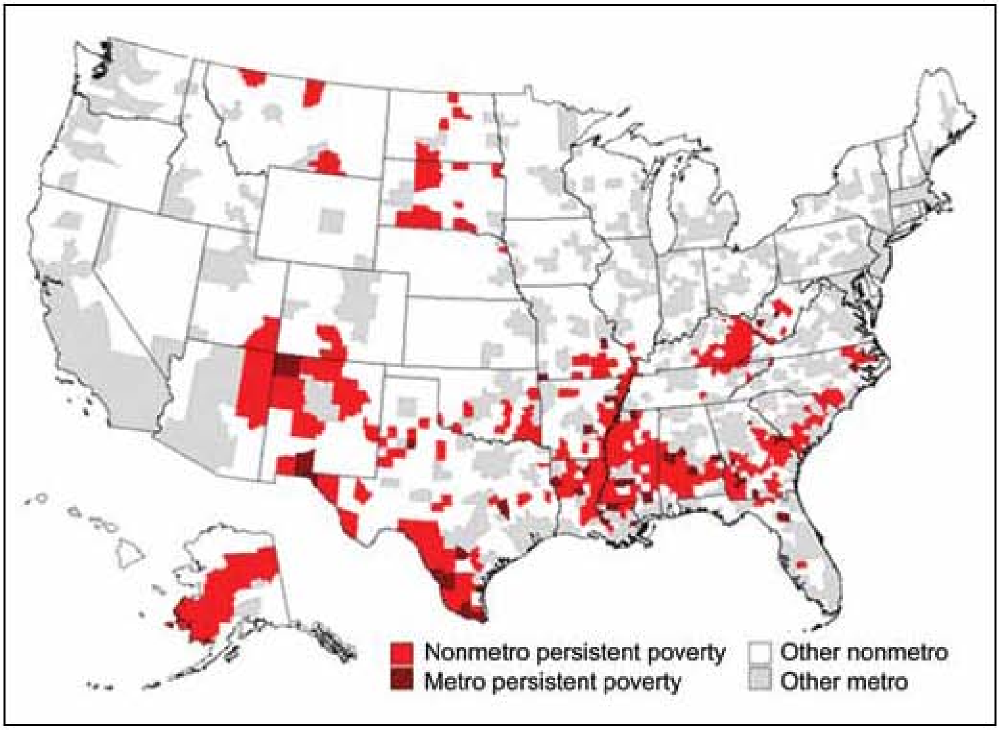

Figure 3-4—Persistent poverty counties, 1970–2000. Source: USDA ERS 2010i.

Rural communities tend to be less ethnically diverse than urban areas (USDA ERS 2010i). Of the 442 rural counties categorized as high-poverty counties in 2000, three-fourths were classified as predominately Black, Hispanic, or Native American counties. There were 210 predominantly Black high-poverty counties, mostly in the Southeast; 72 Hispanic high-poverty counties, mostly in Texas and New Mexico; and 40 high-poverty counties dominated by Native Americans primarily in Alaska, New Mexico, Utah, Arizona, Oklahoma, Montana, South Dakota, and North Dakota. Of the remaining one-fourth of high-poverty counties, most (91 counties) are in the southern highlands of eastern Kentucky, West Virginia, and parts of Missouri and Oklahoma and are dominated by non-Hispanic Whites. The remainder of the high-poverty counties (27) includes thinly populated farming areas in the northern Great Plains, where annual income levels range widely depending on

[5] Counties in which 20 percent or more residents were poor as measured by last four censuses, 1970–2000. See USDA ERS (2010e) for details.

wheat and cattle prices and output, and two high-poverty counties where Asians are the dominant ethnic group.

The Intergovernmental Panel for Climate Change (IPCC) identifies economic wealth, technology, information and skills, infrastructure, institutions, and equity as significant features of adaptive capacity (Smit et al. 2001). Wealthier communities tend to have greater access to technology, information, developed infrastructure, and stable institutions (Easterling et al. 2007) and thus possess higher adaptive capacity for climate change. According to the USDA Economic Research Service (2010i), rural communities in the South and West account for approximately 59 percent of the total rural population in the country and have the highest poverty rates in the country. Thus, we would expect these areas to have generally lower adaptive capacity to cope with future climate risks (fig. 3-5). Just because a community may have high socioeconomic status, however, does not mean it is effective at making collective decisions and meeting the needs of the broader population. Social relations are difficult to quantify and compare across communities and regions. In this paper, we primarily use socioeconomic status, technology, infrastructure, and skills to make inferences about the relative adaptive capacity of communities.

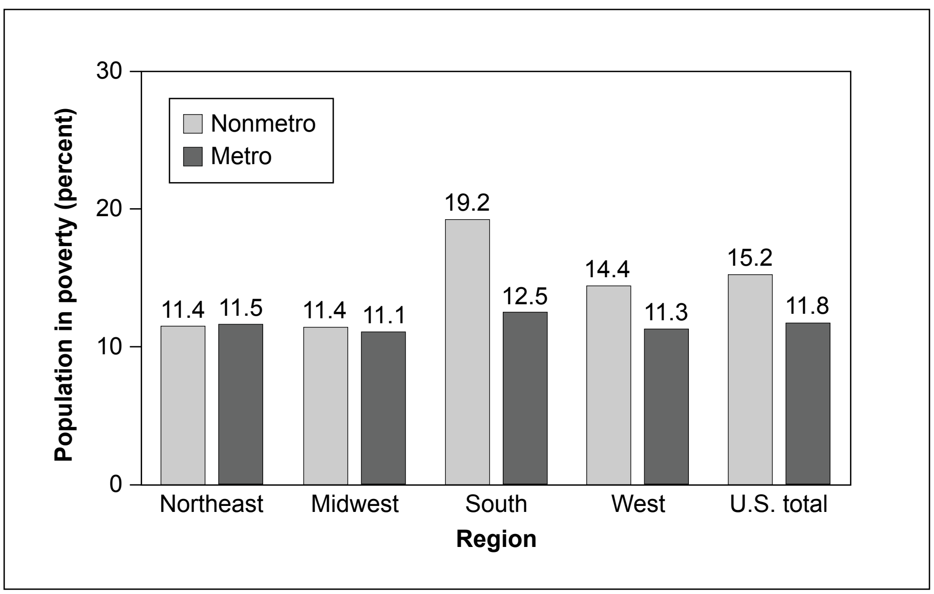

Figure 3-5—Poverty rates by region and metro status, 2006. Source: USDA ERS 2010b.

Another factor that adds to the vulnerability of rural areas is their dependence on government transfer payments. Based on 2001 data (USDA ERS 2010k), government transfer payments averaged $4,365 per person per year in rural, nonmetro areas compared to $3,798 for metro areas. Federal and state government

transfers accounted for about one-fifth of rural income as compared to just one-eighth of metro income. Unless government transfer payments to rural areas are able to keep up with increased need resulting from climate change impacts, rural areas may experience greater vulnerability to climate change than urban areas.

Most outdoor recreation areas are in rural counties of the United States; for example, 334 of the 368 (91 percent) recreation-dominated counties[6] were rural and only 34 were urban in 2003 (Whitener and Parker 2007) (fig. 3-6). Many of the jobs that are usually associated with recreation, such as those in hotels and restaurants, often are low paying with few fringe benefits (Deller et al. 2001). However, in rural areas, which have lower incomes and higher poverty incidence than their urban counterparts, even these low-paying jobs might be quite important for the livelihoods of communities. If climate change dramatically reduces or shifts job opportunities in recreation, most of the impact will be felt by rural communities, where most of the recreation employees reside (Morello et al. 2009). However, as

[6] Rural counties have been classified using a combination of factors by Economic Research Service, including share of employment or share of earnings in recreation-related industries in 1999, share of seasonal or occasional-use housing units in 2000, and per capita receipts from motels and hotels in 1997. See USDA ERS 2010e for details.

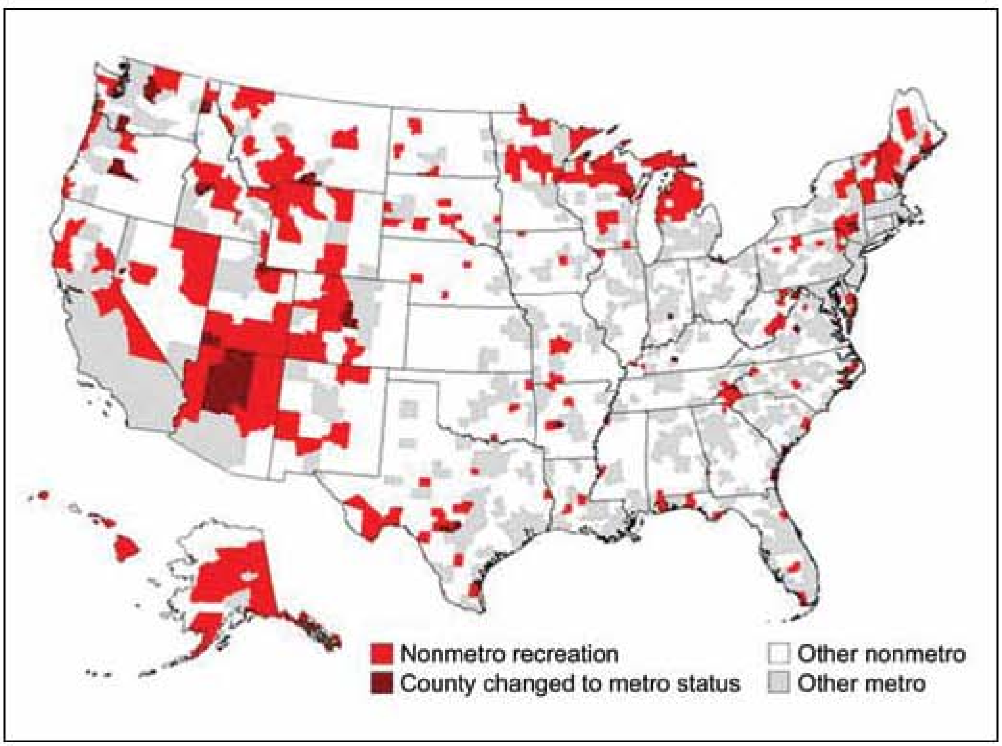

Figure 3-6—Nonmetro recreation counties, 1999. Source: Source: USDA ERS 2010a.

we discuss below, impacts of climate change on recreation will vary considerably geographically.

Rural residents tend to have higher rates of age-adjusted mortality, disability, and chronic disease than their urban counterparts, although mortality and disability rates vary more by region than by metro status (Jones et al. 2009). Furthermore, as young adults move out of small, rural communities, many rural communities tend to reflect an increasingly vulnerable demographic of very old and very young people, placing them more at risk for climate change effects than urban communities. Climate impacts, coupled with demographic shifts in rural communities, may make it more difficult to supply adequate and efficient public health services and educational opportunities to rural areas (USGCRP 2009). Detrimental climate change effects are also likely to be compounded by additional stresses and disturbances such as increased land use change, pollution, wildfires, and invasive species (USGCRP 2009).

The accessibility of health care resources tends to decline as population density declines and geographic isolation increases. As a result, rural residents tend to face higher financial and travel costs to access health care and pay a greater share of household income for health care than their urban counterparts (Jones et al. 2009). Furthermore, emergency response systems are often less effective in rural areas because the population is dispersed and geographically isolated. The combined

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Climate change may have different effects geographically and on different parts of rural and urban communities.

effects of changing demographics and increasing health costs are likely to make it more difficult to supply adequate and efficient public health services to rural areas in the future. Therefore, with lower access to health infrastructure and higher proportion of income spent on health services, rural communities are likely to be more vulnerable to adverse health impacts caused by climate change.

A changing climate will mean reduced opportunities for some activities and locations and expanded opportunities for others, leading to regional differentiation of impacts in term of incidence and intensity. Certain facets of climate change may impact one particular region but not others. For example, increased risk of drought, pests, and extreme weather events may add additional economic stress and tension to rural communities (Motha and Baier 2005, Parton et al. 2007). However, as we explore below, climate-driven shifts in crop types and recreation areas may also benefit some rural communities. Similarly, impacts on water quality and quantity owing to climate change will differ across regions. For example, reduced snowpack and earlier snowmelt because of warmer temperatures will alter the timing and amount of water supplies, impacting the Western United States harder than the Eastern United States (USGCRP 2009). Climate change events may also differentially affect the culture and livelihood patterns of indigenous communities in the United States.

Impacts on Rural Communities

Climate change impacts will differ by region and sector, and so will the capacity to handle the resulting challenges. Climate change will likely produce a range of impacts depending on specific attributes of the affected rural communities or industries. Some communities may benefit from climate-induced changes, whereas others may face large losses. For example, communities dependent on oil and gas extraction and mining-related industries are likely to experience climate change differently than predominantly agricultural communities (USGCRP 2009). Furthermore, agricultural communities in different parts of the United States will likely also differ in how climate change affects them. For example, farming communities in the Great Lakes States may benefit from warming climate owing to improved growing conditions for some crops (like fruit production) that are currently limited by length of growing season and temperature, whereas farming communities in the Midwest may face adverse impacts of climate change owing to lower availability of irrigation water (Hatfield et al. 2008).

Social Impacts

Important characteristics of rural society make it vulnerable to climate change impacts and affect how the risks and costs may be distributed among different regions. Salient social impacts include impacts on human health via direct effects (e.g., thermal stress) and indirect effects (e.g., disease vectors and infectious agents), increase in societal conflicts, and high vulnerability of particular community groups such as Native Americans.

Human health—

Climate change will affect human health through both direct and indirect pathways. Direct impacts will result from increased exposure to temperature (heat waves, winter cold) and other extreme weather events (floods, cyclones, storm surges, droughts) and increased production of air pollutants and aeroallergens such as spores and molds (USGCRP 2009). Figure 3-7 shows temperature changes projected under two GHG emission scenarios. The average U.S. temperature is projected to increase by approximately 7 to 11 °F for the higher emissions scenario and 4 to 6.5 °F for the lower emission scenario (USGCRP 2009). Although most of the country will face greater warming in summer than in winter, Alaska is expected to experience far more warming in winter than summer (Christensen et al. 2007).

The occurrence of extreme heat events like the Chicago heat wave of 1995, which lasted for 5 days and resulted in an 85-percent increase in heat-related mortality and an 11-percent increase in heat-related hospitalizations, are expected to become more frequent as a result of climate change. However, rural counties, which have lower builtup area than cities, should be less vulnerable to extreme heat events. This is due to the fact that concrete and asphalt in cities absorb and hold heat, while tall buildings prevent heat from dissipating and reduce air flow leading to a "heat island effect." The larger amounts of vegetation in rural areas also tend to provide more shade and evaporative cooling than in urban areas.

Human health may also be indirectly affected by an increase in water, food, and vector-borne diseases. Kilpatrick et al. (2008) suggested that increasing temperatures significantly increases dissemination and transmission of viral infection, most likely through increased viral replication. The distribution and abundance of vector organisms and intermediate hosts can also be affected by physical factors such as temperature, precipitation, humidity, surface water, and wind and by biotic factors such as vegetation, host species, predators, competitors, and parasites, all of which may be altered by climate change (PSR 2010).

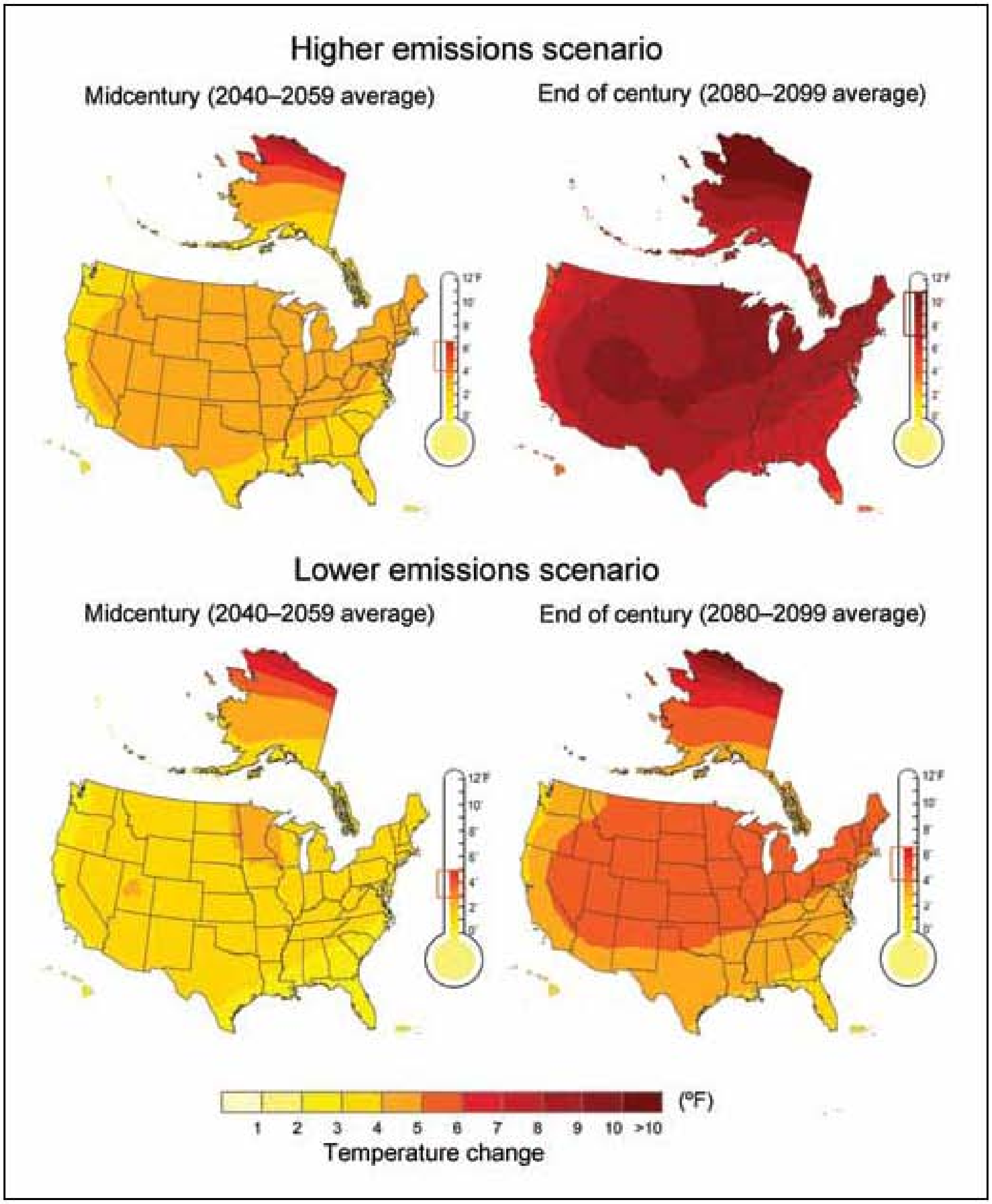

Figure 3-7—Projected temperature change (Fahrenheit) from 1961–1979 baseline for two emission scenarios. Based on projections of future temperature by 16 of the Coupled Model Intercomparison Project Three climate models for IPCC higher and lower scenarios. The brackets on the thermometers represent the likely range of model projections, although lower or higher outcomes are possible. Source: USGCRP 2009.

There are clear trends of increasing incidents of very heavy precipitation in the Nation as a whole, and particularly in the Northeast, Midwest, Alaska, and islands as shown in figure 3-8.

Heavy downpours can lead to increased sediment in runoff and outbreaks of waterborne diseases (Ebi et al. 2008, Field et al. 2007). Degradation of water quality and increases in pollution carried to lakes, estuaries, and the coastal ocean

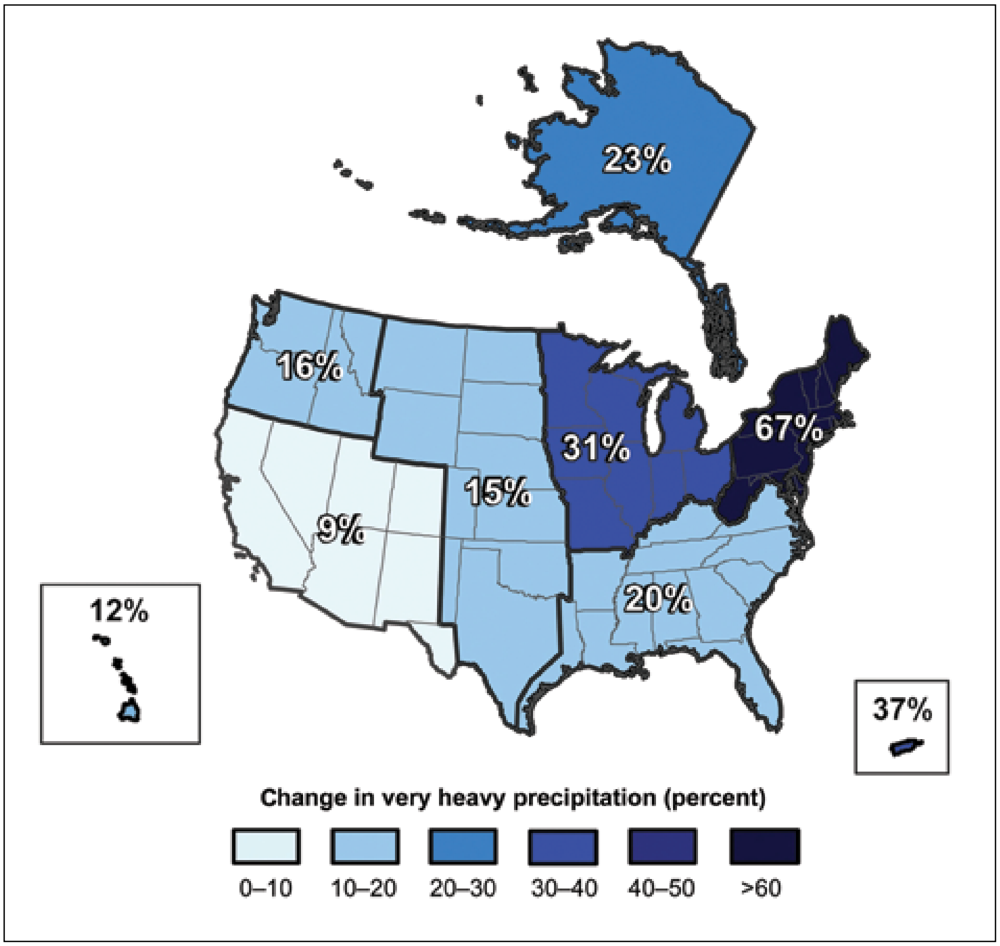

Figure 3-8—Increases in amounts of very heavy precipitation, 1958–2007. Source: USGCRP 2009 based on Groisman et al. 2004.

following heavy downpours, especially when coupled with increased temperature, can also result in blooms of harmful algae and bacteria and increased risk of water-borne parasites such as *Cryptosporidium* and *Giardia*. Incidences of heavy rain and flooding can also contaminate food crops with feces from nearby livestock or wild animals, increasing the likelihood of food-borne disease (Ebi et al. 2008). Projected increases in carbon dioxide (CO_2) can also stimulate the growth of stinging nettle and leafy spurge, two weeds that cause rashes when they come into contact with human skin (Ziska 2003).

Impacts on indigenous communities—

Native American communities, which are predominantly rural, may face disproportionately higher levels of climate change impacts on their livelihoods, rights and access to natural resources, future growth, and in some cases, their culture, which depends on traditional ways of collecting and sharing food

(Hanna 2007, Nilsson 2008, Tsosie 2007, USGCRP 2009). For many indigenous communities, climate change may also reduce the availability and accessibility of such traditional food sources as seals, whose migration patterns depend on their ability to cross frozen rivers and wetlands (USGCRP 2009). It is estimated that climate change may increase flooding and erosion in 184 out of 213, or 86 percent, of Native Alaskan communities (USGAO 2003). Native cultures in the Great Plains and Southwest are also vulnerable to climate change effects. Many of these tribes have limited capacity to respond to climate change and already face severe problems with water quantity and quality—problems likely to be exacerbated by climate change.

Relocation options tend to be limited for many Native Americans who live on established reservations and may be restricted to reservation boundaries (NAST 2001). Having already been relocated to reservations, these communities have historically been disconnected from their traditional life, prohibited from engaging in important social and cultural practices, and allowed limited participation in land management and planning (Tsosie 2007). Furthermore, Native American communities may be more vulnerable to climate change impacts, as their rights and livelihoods tend to be interwoven with specific lands limiting their relocation options in the face of alterations in resource availability (Donoghue et al. 2009).

The melting of permafrost, which has already turned solid ground into mush in some places in Alaska, threatens the economies and cultures of many Alaskan tribes as they may be required to relocate at large economic and cultural cost (NTAA 2009). For example, the way of life of the Inupiaq Tribe in Alaska is threatened owing to climate change. The traditional method of food storage of Inupiaqs is being disrupted by warming, as “permafrost” does not remain permanent, leading their belowground storages (*sigulaqs* in native language) to be thawed and sometimes flooded with meltwater. The resulting spoiled meat increases the risk of food-related illness.

Subsistence cultures such as Native Alaskans adapt to year-to-year fluctuations of game species by shifting practices and target species, which implies some ability to adapt to effects of near-term climate change (USGCRP 2009). Integrating the adaptation insights of indigenous peoples in terms of access, process, and the outcomes of climate policy and planning should be helpful in reducing impacts (Nilsson 2008). However, these adaptation opportunities may be severely constrained, as warming in Alaska is especially likely to reshape patterns of human settlement and intertwined economic activities (Wilbanks et al. 2007).

Economic Impacts

Major parts of the rural economies of the United States are directly sensitive to climate change, including the agriculture, recreation and tourism, forestry, water resources, energy, and fisheries sectors.

Agriculture—

Agriculture will certainly face significant changes from climate change. Longer growing seasons and increased CO_2 have positive effects on some crop yields, although this might be counterbalanced in part by the negative effects of additional disease-causing pathogens, insect pests, and weeds (USGCRP 2009). Hatfield et al. (2008) suggested that even moderate increases in temperature will decrease yields of corn, wheat, sorghum, bean, rice, cotton, and peanut crops. More frequent temperature extremes will also create problems for crops. For example, tomatoes, which are well-adapted to warmth, produce lower yields or quality when daytime maximum temperatures exceed 90 °F for even short periods during critical reproductive stages (Kunkel et al. 2008). Some crops, however, benefit from higher temperatures, and global warming will likely result in a longer growing season for crops like melon, okra, and sweet potato (Hatfield et al. 2008). Significant technological progress might also temper adverse climate change impacts. For example, corn yields have shown an upward trend even in light of variation caused by climate events (fig. 3-9). However, U.S. Global Change Research Program (2009) argued that it is difficult to maintain this historical upward trend without dramatic technological innovations.

Climate change may increase agricultural production costs for a number of reasons. For example, the expansion of weeds may be exacerbated by climate change if weeds benefit more from higher temperatures and CO_2 levels than traditional crops (Hatfield et al. 2008). With continued warming, invasive weed species are expected to expand northward and increase costs and crop losses as evidenced by the fact that loss of crops owing to weeds is higher in the South than in the North. For example, southern farmers lose 64 percent of the soybean crop to weeds, whereas northern farmers lose just 22 percent (Ryan et al. 2008). Controlling weeds currently costs the United States more than $11 billion a year, with the majority spent on herbicides (Kiely et al. 2004). This cost is likely to increase as temperatures rise. The problem is aggravated by the fact that the most widely used herbicide in the country, *glyphosate*, loses its efficacy at CO_2 levels that are projected to occur in the coming decades (Wolfe et al. 2007). Another potential impact of climate change is premature plant development and blooming, resulting in exposure of young plants and plant tissues to late-season frosts. For

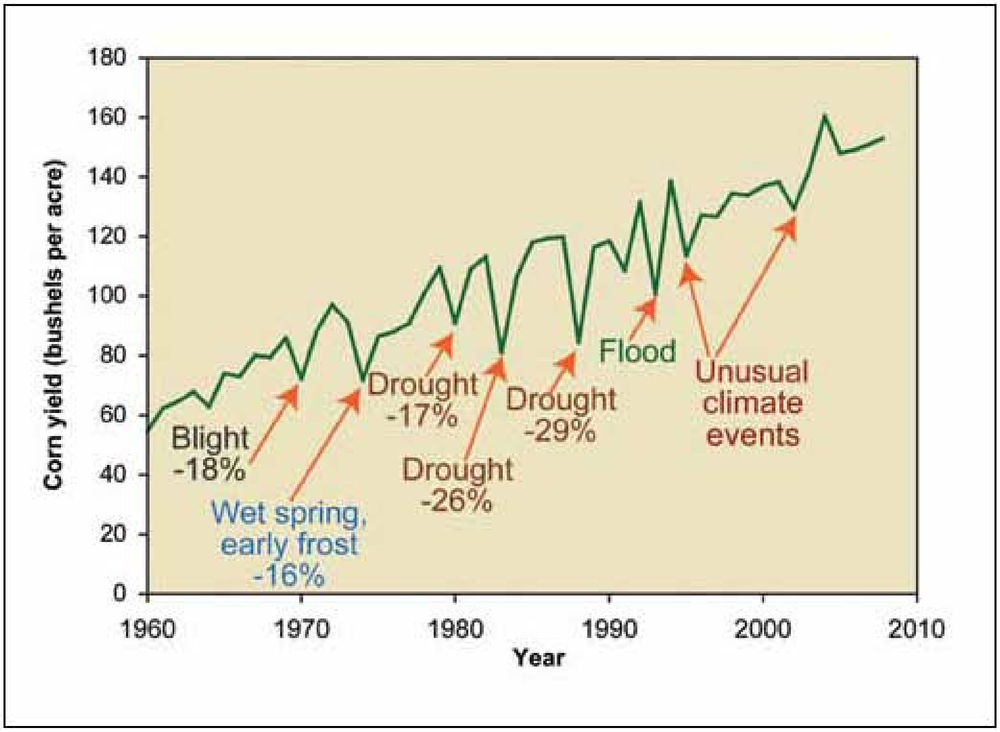

Figure 3-9—United States corn yield trend since 1960. Source: USGCRP 2009 based on NAST 2001.

example, the 2007 spring freeze in the Eastern United States led to widespread devastation of crops and natural vegetation, because the frost occurred during the flowering period of many trees and during early grain development on wheat plants (Gu et al. 2008).

Climate change is projected to increase the intensity of precipitation, resulting in heavy downpours across the country (Kunkel et al. 2008). This excessive rainfall may delay spring planting, in turn lowering profits for farmers who are paid a premium for early-season production of high-value crops such as melons, sweet corn, and tomatoes. Field flooding during the growing season by heavy downpours leads to low oxygen levels in the soil, higher susceptibility to root diseases, and increased soil compaction from the use of heavy farm equipment on wet soils. Increased intensity of precipitation can also result in reduced quality of many crops.

The projected warmer temperatures are expected to increase livestock production costs owing to lower feed intake and increased requirements for energy to maintain healthy livestock at higher temperatures. Forage production may also be affected by climate change. Rising atmospheric CO_2 concentrations can increase the quantity of forage produced, but it might reduce forage quality, as plant nitrogen and protein concentrations often decline with higher concentrations of CO_2 (Hatfield et al. 2008). The dairy industry is also quite sensitive to temperature

changes, as dairy cows' productivity decreases above 77 °F (25 °C). By late in this century, all Northeastern States except the northern parts of Maine, New Hampshire, New York, and Vermont are projected to suffer declines in July milk production under the higher emissions scenario (USGCRP 2009). In California, an annual loss of $287 to $902 million is expected for this $4.1 billion industry. In parts of Connecticut, Massachusetts, New Jersey, New York, and Pennsylvania, climate change is projected to produce a large decline in milk production from 10 to 20 percent or greater (USGCRP 2009).

Climate change impacts on rural communities engaged in agriculture will differ across regions; some will likely benefit while others lose depending on their geographic location and adaptive capacity. Heat and water stress from droughts and heat waves is likely to decrease yields and adversely affect crops like wheat, hay, corn, barley, cattle, and cotton in the Great Plains (Motha and Baier 2005). Much of the Northwest region's agriculture will experience detrimental impacts. Particularly impacted will be specialty crops in California such as apricots, almonds, artichokes, figs, kiwis, olives, and walnuts (Lobbel et al. 2006). By late in this century, winter temperatures in many important fruit-producing regions such as the Northeast may be too warm to support fruit production. For example, Massachusetts and New Jersey supply nearly half the Nation's cranberry crop. By the middle of this century, these areas may not be able to support cranberry production owing to lack of winter chilling (Frumhoff et al. 2007, Wolfe et al. 2007).

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Climate change may affect costs and production levels for forestry and agricultural enterprises.

In contrast, warming is expected to improve the climate for fruit production in regions such as the Great Lakes (Field et al. 2007) or Midwest (USGCRP 2009). However, even farms and regions that temporarily benefit from altered environmental conditions (e.g., carbon fertilization and extended growing season) risk economic losses if temperatures exceed those preferred by the crops they currently produce (Ruth et al. 2007). In the Midwest, the projected increases in winter and spring precipitation and flooding are likely to delay planting and crop establishment.

Recreation and tourism—

Outdoor recreation activities depend on the availability and quality of natural resources, such as beaches, forests, wetlands, snow, and wildlife (USGCRP 2009). Johnson and Beale (2002) identified 329 recreation-dependent counties by geographic location, natural amenities, and form of recreation.[7] Most of the rural recreation counties are concentrated in the West, the Upper Great Lakes, and the Northeast regions (Reeder and Brown 2005). Recreation counties in general tend to have relatively low population densities, and more of their residents live in rural parts of the county (Jones et al. 2009). In the West, rural counties reflect opportunities for hiking, mountain climbing, fishing, and wintertime sports found in the many national parks and ski resorts. On the other hand, recreation-dependent counties in the Upper Great Lakes and Northeast—especially in New England and Upstate New York—are largely due to second homes in areas with lakes. Many of these areas also have significant wintertime recreation activities, including snowmobiling and skiing.

Increased temperatures and precipitation owing to climate change are expected to have a direct effect on the enjoyment of tourism activities, and on the desired number of visitor days and associated levels of visitor spending and employment. Climate change could affect recreation through three pathways: winter activities such as downhill and cross-country skiing, snowshoeing, and snowmobiling; nature

[7] Recreational counties were identified based on a multistep selection procedure combining empirical measures of recreational activity along with a review of recreation-related contextual material existing in the counties. These empirical measures used were (1) wage and salary employment in entertainment and recreation, accommodations, eating and drinking places, and real estate as a percentage of all employment reported in the Census Bureau's County Business Patterns for 1999; (2) percentage of total personal income reported for these same categories by the Bureau of Economic Analysis; (3) percentage of housing units intended for seasonal or occasional use reported in the 2000 Census; and (4) per capita receipts from motels and hotels as reported in the 1997 Census of Business. For details see Johnson and Beale 2002.

tourism and related activities such as biking, walking, hunting, etc.; and water-related sports such as diving, sailing, and fishing. A changing climate will mean reduced opportunities for some activities and locations and expanded opportunities for others (Sussman et al. 2008). The length of the season, and, in many cases, the desirability of popular activities like walking; visiting a beach, lakeshore, or river; sightseeing; swimming; and picnicking might increase because of small near-term increases in temperature. On the other hand, snow- and ice-dependent activities, including skiing, snowmobiling, and ice fishing, could be adversely affected by even small increases in temperature. Hunting and fishing opportunities will change as animals' habitats shift and as relationships among species in natural communities are disrupted by their different responses to rapid climate change (USGCRP 2009). In the longer term, as climate change affects ecosystems and seasonality becomes more pronounced, the net economic effect on recreation and how it will influence different population groups in different regions is not known (Wilbanks et al. 2007).

The impact of climate change on ski, snowmobile, and other winter sport industries is expected to be more pronounced in the Northeast and Southwest regions. The ski resorts in the Northeast have three climate-related criteria to remain viable: the average length of the ski season must be at least 100 days, there must be a good probability of being open during the lucrative winter holiday between Christmas and the New Year, and there must be enough nights that are sufficiently cold to enable snowmaking operations. By these standards, only one area in the region (fig. 3-10) is projected to be able to support viable ski resorts by the end of this century under a higher emissions scenario (USGCRP 2009).

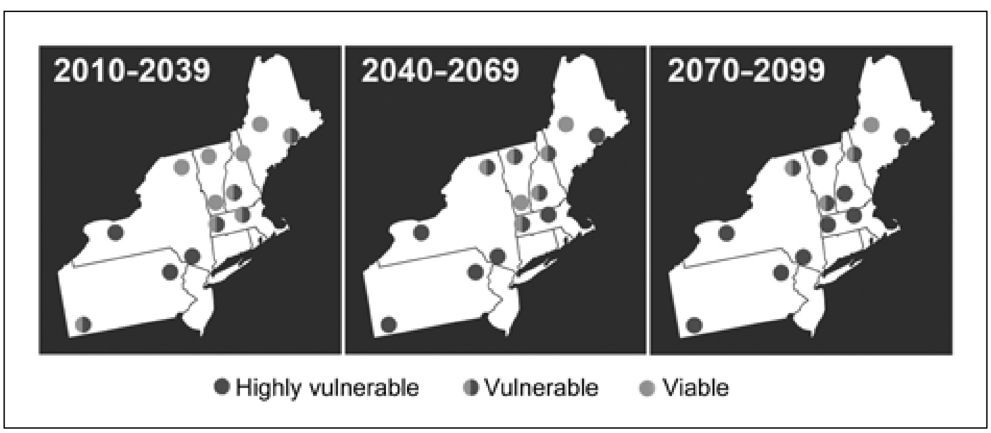

Figure 3-10—Ski areas at risk in the Northeastern United States. Source: USGCRP 2009 based on Frumhoff et al. 2007.

Reduced snowmaking in the Southwest owing to climate change is also expected to shorten the ski season substantially, with projected losses of 3 to 6 weeks (by the 2050s) and 7 to 15 weeks (2080s) in the Sierra Nevada of California (Hayhoe et al. 2004, Scott and Jones 2005). Projections indicate later snow and less snow coverage in ski resort areas, particularly those at lower elevations and in the southern part of the Southwest region. Decreases from 40 to almost 90 percent are likely in end-of-season snowpack under a higher emissions scenario in counties with major ski resorts from New Mexico to California (Zimmerman et al. 2006). The snowmelt dates are also projected to shift earlier at most sites (fig. 3-11).

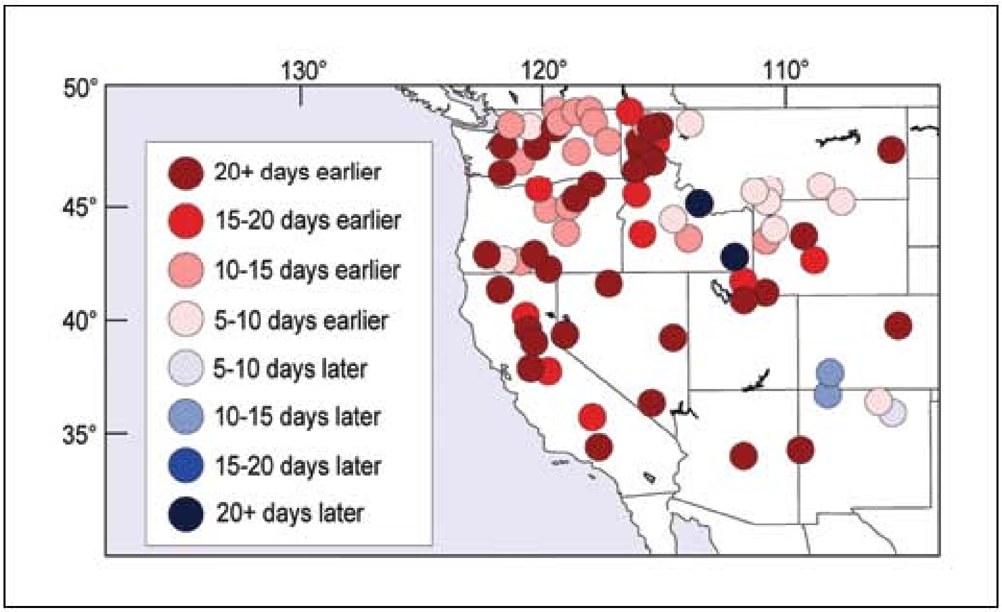

Figure 3-11—Observed spring snowmelt dates in Western United States. Source: USGS 2005.

In addition to shorter seasons, earlier wet snow avalanches could force ski areas to shut down many runs before the season would otherwise end (Lazar and Williams 2008). Resorts require a certain number of days just to break even; cutting the season short by even a few weeks, particularly if those occur during the lucrative holiday season, could easily render a resort unprofitable. The snowmobiling industry is also vulnerable to climate change as it relies on natural snowfall. Some predict that by the 2050s, a reliable snowmobile season will disappear from most regions of the East (Scott and Jones 2006, Scott et al. 2008).

Nature-based tourism—hiking; camping; bird watching; visiting a beach, lake-shore, or river; sightseeing; swimming; and picnicking—is a major market segment in many parts of the country, with over 900 million visitor-days in national, state, and local parks reported in 2001 (USGCRP 2009). The length of the nature tourism season is likely to be enhanced by small near-term increases in temperature. Visits to national parks are projected to increase by 9 to 25 percent (2050s) and 10 to 40 percent (2080s) as a result of a lengthened warm-weather tourism season (Scott and Jones 2006). Nearby communities may benefit economically, but visitor-related ecological pressures could be exacerbated in some parks. Activities like hunting and wildlife-related tourism will change as habitats shift and relationships among species in natural communities are disrupted by their different responses to rapid climate change (USGCRP 2009). Climate-induced environmental changes (e.g., loss of glaciers, altered biodiversity, fire- or insect-impacted forests) may also affect nature tourism, although uncertainty is higher regarding the regional specifics and magnitude of these impacts (Richardson and Loomis 2004, Scott et al. 2007).

The impacts on water-related tourism are likely to be exacerbated by rising sea levels and storm severity especially in areas projected to get drier, such as the Southwest, and in beach communities that are expected to see rising sea levels (Clark et al. 2008, Kleinosky et al. 2005, Williams et al. 2009, Wu et al. 2002). There is evidence that the global sea level is currently rising at an increased rate (Bindoff et al. 2007, Rahmstorf et al. 2007, Vermeer and Rahmstorf 2009). Water sports that depend on the flows of rivers and sufficient water in lakes and reservoirs are already being affected, and much larger changes are expected in the future (Sussman et al. 2008). Higher sea levels may erode beaches, and along with increasing water temperatures, destroy or degrade natural resources such as mangroves and coral reef ecosystems that attract tourists (Mimura et al. 2007). However, the vulnerability of key recreation areas in the coastal United States to climate change events has not been comprehensively assessed (USGCRP 2009).

Recreational fisheries in many rural counties will also be impacted by climate change. For example, approximately half of the wild trout populations are expected to disappear from the Southern Appalachian Mountains owing to rising stream temperatures. Losses of western trout populations may exceed 60 percent in certain regions. About 90 percent of bull trout (*Salvelinus confluentus*), which live in western rivers, are projected to be lost on account of warming. The state of Pennsylvania is predicted to lose 50 percent of its trout habitat in the coming decades, and warmer states such as North Carolina and Virginia, may lose up to 90 percent (Willliams et al. 2007).

The U.S. islands (Hawaii, Puerto Rico, Virgin Islands, Guam, American Samoa) face potentially large impacts from climate change. For island fisheries sustained by healthy coral reefs and marine ecosystems, climate change impacts exacerbate stresses such as overfishing (Mimura et al. 2007), affecting both fisheries and tourism. Any adverse impacts on tourism threaten the livelihood of many island communities. For example, in 1999, the Caribbean Islands had tourism-based gross earnings of $17 billion, providing 900,000 jobs and making the Caribbean one of the most tourism-dependent regions in the world (Heileman et al. 2004).

Forestry—

The impacts of climate change on forestry are expected to arise from shifts in forest distribution and types, increased wildfire risk, increased chance of pest attacks and diseases, and adverse impacts on biodiversity. Projected changes in climate and the consequent impact on forests could affect market incentives for investing in intensive forest management (such as planting, thinning, genetic conservation, and tree improvement) and developing and investing in wood-conserving technologies. The effect on rural communities will differ depending on the geography, demographics, and social and economic conditions each community faces; as with agriculture, some may benefit while others lose.

Potential habitats for trees favored by cool environments are likely to shift north (NAST 2001) (fig. 3-12). As tree species migrate northward or to higher elevations, habitats of alpine and subalpine spruce-fir could possibly be eliminated (IPCC 2007). Aspen and eastern birch communities are also likely to contract dramatically in the United States and largely shift into Canada. Potential habitats that could possibly expand in the United States are oak/hickory and oak/pine in the Eastern United States and ponderosa pine and arid woodland communities in the West. The changing forest distribution is already being observed in many areas. For example, in Colorado, aspen (*Populus* sp. Michx.) has advanced into the more cold-tolerant spruce-fir forests over the past 100 years (Elliott and Baker 2004). The northern limit of the lodgepole pine (*Pinus contorta* Douglas ex Louden) range is advancing into the zone previously dominated by the more cold-tolerant black spruce (*Picea mariana* (Mill.) Britton, Sterns & Poggenb.) in the Yukon (Johnstone and Chapin 2003). In addition, many of the economically valuable timber species in the Midwest—aspen, jack pine (*Pinus banksiana* Lamb.), red pine (*Pinus resinosa* Aiton), and white pine (*Pinus strobus* L.)—may be lost owing to global warming (Easterling and Karl 2001). If the forests in the South and Northeast shift to oak and hickory species in lieu of softwoods, the pulp/wood fiber industry could experience large losses (USGCRP 2009), in turn impacting the rural communities who depend on these industries for their livelihoods.

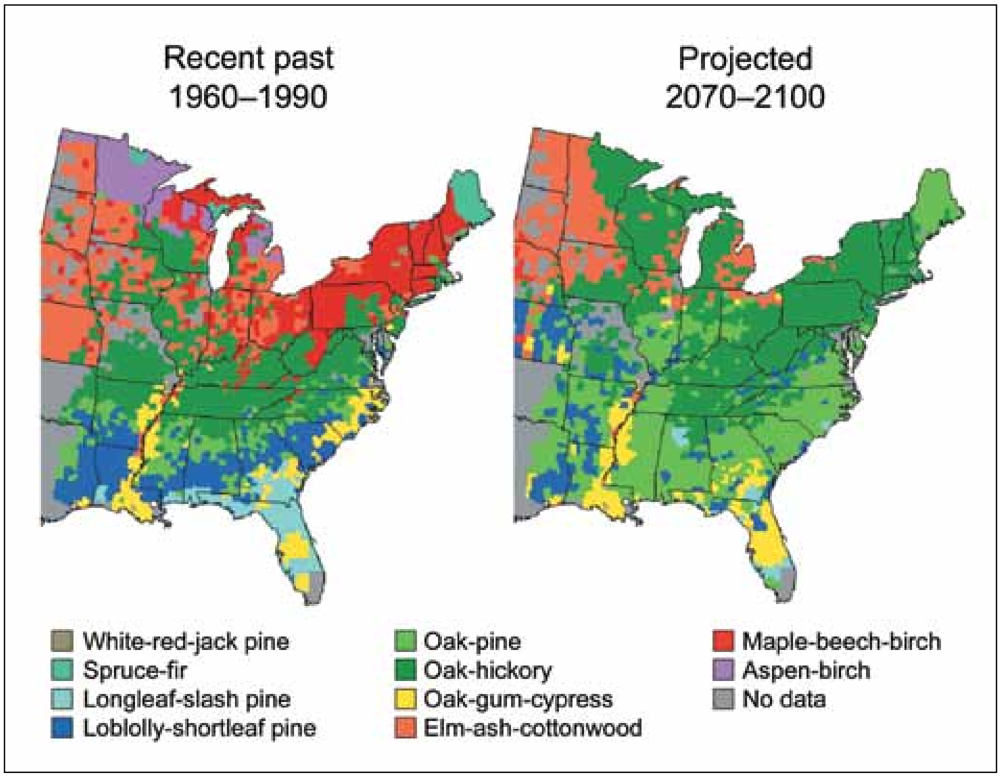

Figure 3-12—Projected shift in forest types in Eastern United States under a midrange warming scenario. Source: USGCRP 2009 based on NAST 2001.

Warmer summer temperatures and reduced rainfall in the West are projected to extend the annual window of wildfire risk by 10 to 30 percent (Brown et al. 2004). These factors are contributing to an overall increase in the area of forest burned each year in the Pacific Northwest and in the United States as a whole (USDA FS 2000). Westerling et al. (2006) analyzed wildfire trends in the Western United States and found a sixfold increase in the area of forest burned since 1986 compared with the 1970–86 period. The average duration of fires increased from 7.5 to 37.1 days—mostly because of an increase in spring and summer temperatures and earlier thawing of snowpacks. The increased incidences of wildfires could affect communities in a number of ways including loss of forest recreation opportunities and increased costs for fire suppression and recovery. For example, Ruth et al. (2007) predicted that the climate-change-induced warming will mean that the state of Washington will face fire suppression cost increases of over 50 percent by 2020 and over 100 percent by 2040, raising the expenses to $93 million and $124 million, respectively. Because many rural communities reside adjacent to forest or are dependent on forest industries for their livelihood, they tend to be directly affected by these wildfires. These wildfires are adversely impacting indigenous communities as well (NTAA 2009).

Climate change is also likely to result in more disturbances from insects, invasive species, and diseases (Alig et al. 2004, Gan 2004, Logan et al. 2003). For example, Ryan et al. (2008) predicted an increase in the frequency and intensity of mountain pine beetle (*Dendroctonus ponderosae*) and other insect attacks, further increasing fire risk and reducing timber production. Insects, historically controlled by cold winters, more easily survive milder winters and produce larger populations in warmer climates. In a changing climate, populations of some pests such as red fire ants (*Solenopsis invicta* Buren), better adapted to a warmer climate, are projected to increase (Cameron and Scheel 2001, Levia and Frost 2004). Invasive weed species that disperse rapidly are likely to find increased opportunities under climate change. Pests can also impact rural communities and especially Native American communities by reducing the availability of nontimber forest products (NTAA 2009).

Damages to forest resources from pests can be significant. For example, spruce bark beetle (*Dendroctonus rufipennis*) outbreaks in the Kenai Peninsula of Alaska (red areas in fig. 3-13) have led to the loss of over 5 million acres of spruce forests. The recent spread of southern pine beetle (*Dendroctonus frontalis* Zimmermann), attributable, in part, to climate change, has affected sawtimber and pulpwood production in Alabama, Louisiana, Mississippi, Tennessee, Kentucky, and the Carolinas. On average, annual losses have reached over 1 percent of gross state product (Ruth et al. 2007).

Changes in temperature and precipitation affect the composition and diversity of native animals and plants through altering their breeding patterns, water and food supply, and habitat availability (Feng and Hu 2007). Therefore, we expect increased extinction of local populations and loss of biological diversity if climate change outpaces species' ability to shift their ranges and form successful new ecosystems. Residents of Alaska are likely to experience the most disruptive impacts of climate change in the near term, including shifts in the range or abundance of wild species crucial to the livelihoods and well-being of indigenous populations (Houser et al. 2001, Parson et al. 2001).

Higher temperatures, decreased soil moisture, and more frequent fires may stress forest ecosystems and ultimately may lead to a conversion of some forests to savannah and grassland (Burkett et al. 2001). Grassland and plains birds, already besieged by habitat fragmentation, could experience significant shifts and reductions in their ranges (Peterson 2003). Biodiversity impacts of climate change may also alter distribution of prominent game and other bird species (e.g., waterfowl, warblers, perching bird species) in many recreational rural counties. The conversion of forest land, habitat fragmentation, and reduced hunting and birdwatching

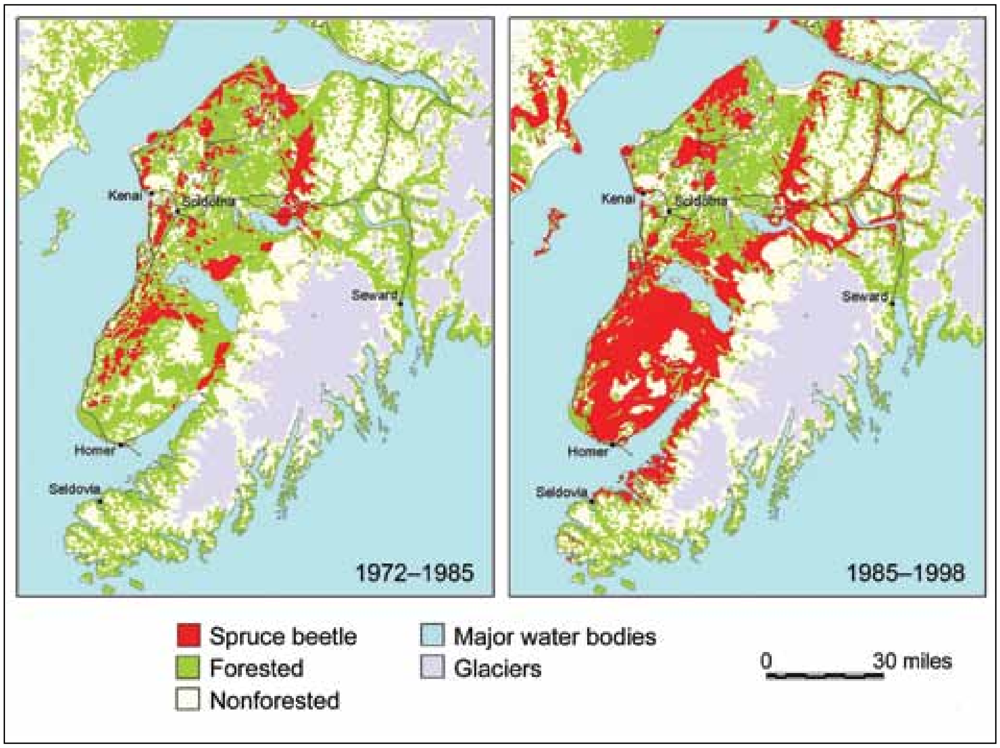

Figure 3-13—Spruce forest loss in Kenai Peninsula, Alaska. Source: USGCRP 2009 based on Berman et al. 1999.

could have adverse impacts on forest-sensitive rural communities in terms of lower employment and income.

Although current research suggests that timber supply will expand nationally, regional impacts are much more uncertain. A higher level of atmospheric CO_2 in the atmosphere results in trees capturing more carbon from the atmosphere and higher growth rates in some regions, especially in relatively young forests on fertile soils (Ryan et al. 2008). This increased growth could be tempered, however, by local conditions such as moisture stress, nutrient availability, or increased tropospheric ozone (Karnosky et al. 2005, Triggs et al. 2004). In the absence of dramatic increases in disturbance, effects of climate change could result in larger timber inventories (Perez-Garcia et al. 2002). Climate change scenarios predicting increased harvests, however, tend to lead to lower prices and, as a consequence, reduced harvests in regions with higher production costs (Perez-Garcia et al. 2002, Sohngen and Sedjo 2005). Warmer winters with more sporadic freezing and thawing are likely to increase erosion and landslides on forest roads, and reduce access for winter harvesting (USGCRP 2009), in turn, increasing cost and reducing supply of forest products. Under these conditions, a shrinking forest industry would lead to loss of employment for many rural communities.

The effect of climate change on forest-dependent communities will vary regionally. Wildfire risk is expected to be most severe in the Southwest and Northwest, largely because of higher summer temperatures and earlier spring snowmelt. Higher temperatures could lead to increased incidences of pest attacks and tree diseases all across the United States. Altered harvesting frequency and associated impacts on forest product prices could be felt nationwide. The impact, however, is expected to be higher in the timber-producing regions of the Southeast and old-growth forests of the West.

Water resources—

Impacts of climate change on water resources could result in increasing incidences of droughts, changing precipitation intensity and runoff, lower availability of water for irrigation, changing water demands, and lower water availability for energy production. Incidences of drought have dramatically changed during the last 50 years (fig. 3-14). Much of the Southeast and West have faced increases in drought severity and duration, while decreases have been observed in much of Midwest, Great Plains, and Northeast.

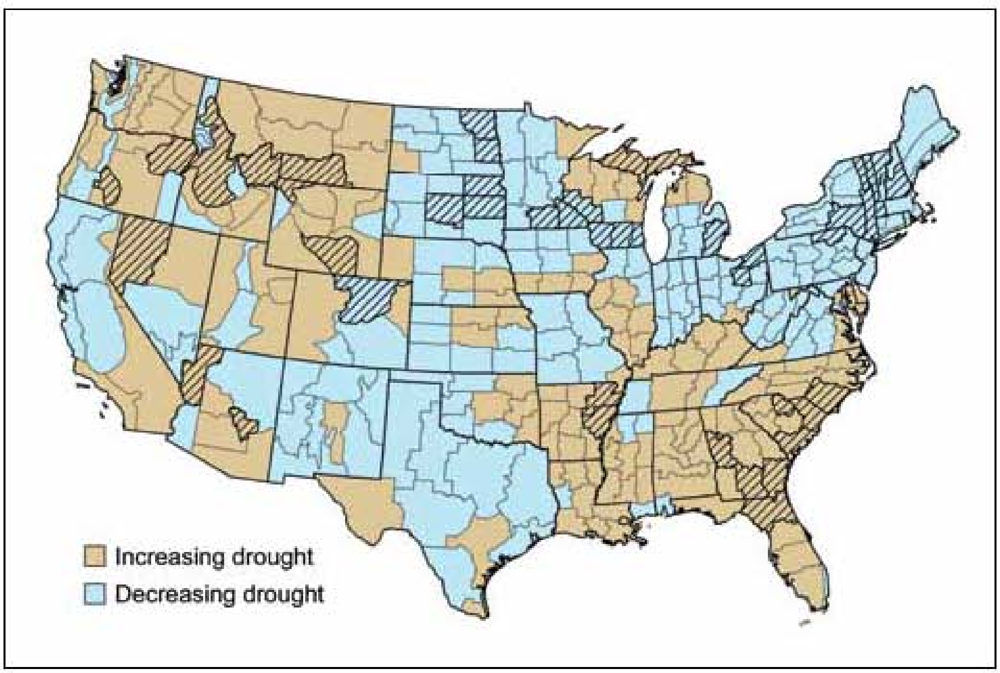

Figure 3-14— United States drought trends, 1958–2007. Crosshatched areas have statistically significant trends. Source: USGCRP 2009 based on Guttman and Quale 1996.

Limitations imposed on water supply by projected temperature increases are likely to be made worse by substantial reductions in rain and snowfall in the spring months, when precipitation is most needed to fill reservoirs to meet summer demand (Milly et al. 2008). The number of dry days between precipitation events is also projected to increase in the Southwest and the Mountain West, two of the most rapidly growing areas of the country. Continued population growth in these arid and semiarid regions would also stress water supplies, although the impact will be more severe for urban centers than rural counties.

Floods are also projected to be more frequent and intense as regional and seasonal precipitation patterns change and rainfall becomes more concentrated in heavy events. For the past century, total precipitation has increased by about 7 percent, while the heaviest 1 percent of rain events increased by approximately 20 percent (Gutowski et al. 2008). In general, International Panel for Climate Change climate models agree that northern areas are likely to get wetter and southern areas drier. Figure 3-15 outlines projected average precipitation changes by the 2090s in terms of light, moderate, and heavy storm events. The lightest precipitation is projected to decrease, and the heaviest will increase, continuing the observed trends.

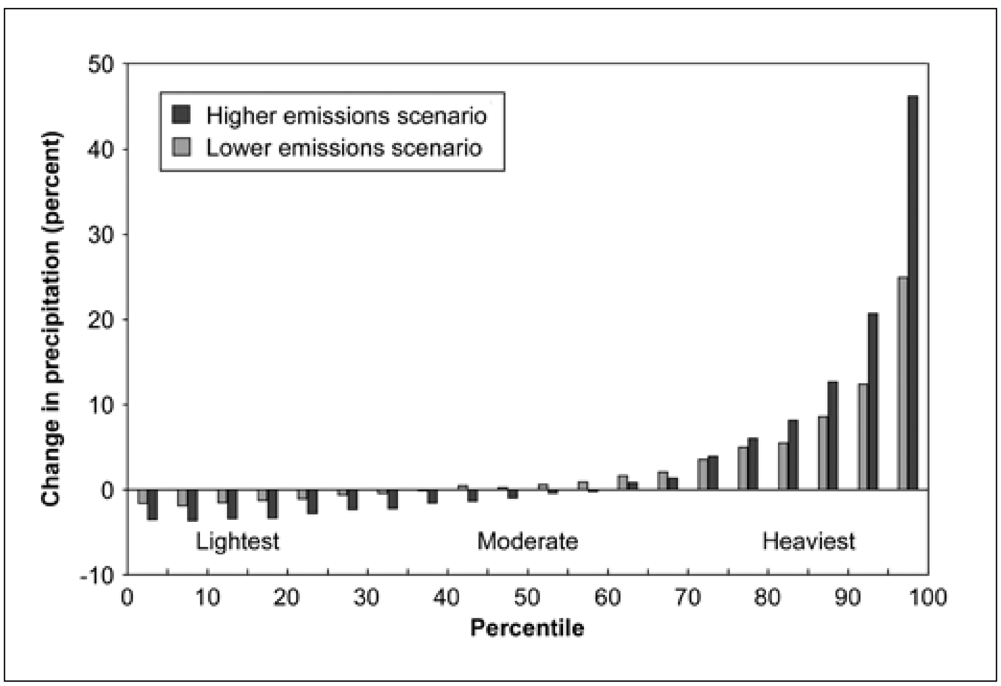

Figure 3-15—Projected changes in light, moderate, and heavy precipitation in North America (based on Intergovernmental Panel for Climate Change higher and lower emission scenarios). Source: USGCRP 2009 based on Gutowski et al. 2008.

Climate change is also projected to cause changes in runoff, the amount of precipitation that is not evaporated, stored as snowpack or soil moisture, or filtered down to groundwater. Figure 3-16 shows that the eastern part of the country will experience increased runoff, accompanied by declines in the West, especially the Southwest. This means that wet areas are projected to get wetter and dry areas drier, thus adding to the woes of agricultural and forest-dependent communities whose livelihoods (or incomes) in many cases are sensitive to water availability. The farming-dominated counties in the Great Plains and Midwest, however, are not expected to experience as large an impact as their Northeastern, Western, or Southwestern counterparts.

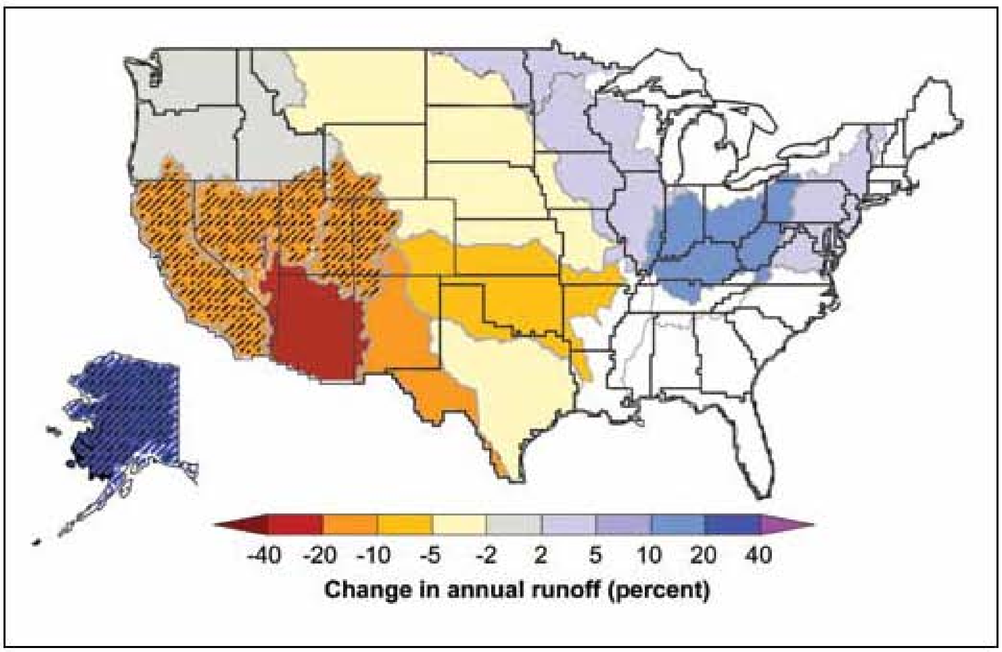

Figure 3-16—Projected changes in annual runoff for 2041–2060 relative to 1901–1970 for emissions in between the lower and higher emissions scenarios. Crosshatched areas indicate greater confidence in projection because of strong agreement among model projections. White areas indicate divergence among model projections. Source: USGCRP 2009:45 based on Milly et al. 2008.

Meeting the challenge of climate change has important implications for the United States in terms of intervention and resolution of intra- and intergroup conflicts. For example, decreased water availability in different regions of the country owing to increased temperature and lower or infrequent precipitation, along with an increase in water demand from increased population or agricultural activities, could produce more frequent and intense conflicts over water rights. The U.S. Bureau of Reclamation (2005) has identified many areas in the country that are already at risk for serious conflicts over water, even in the absence of climate change. Figure 3-17

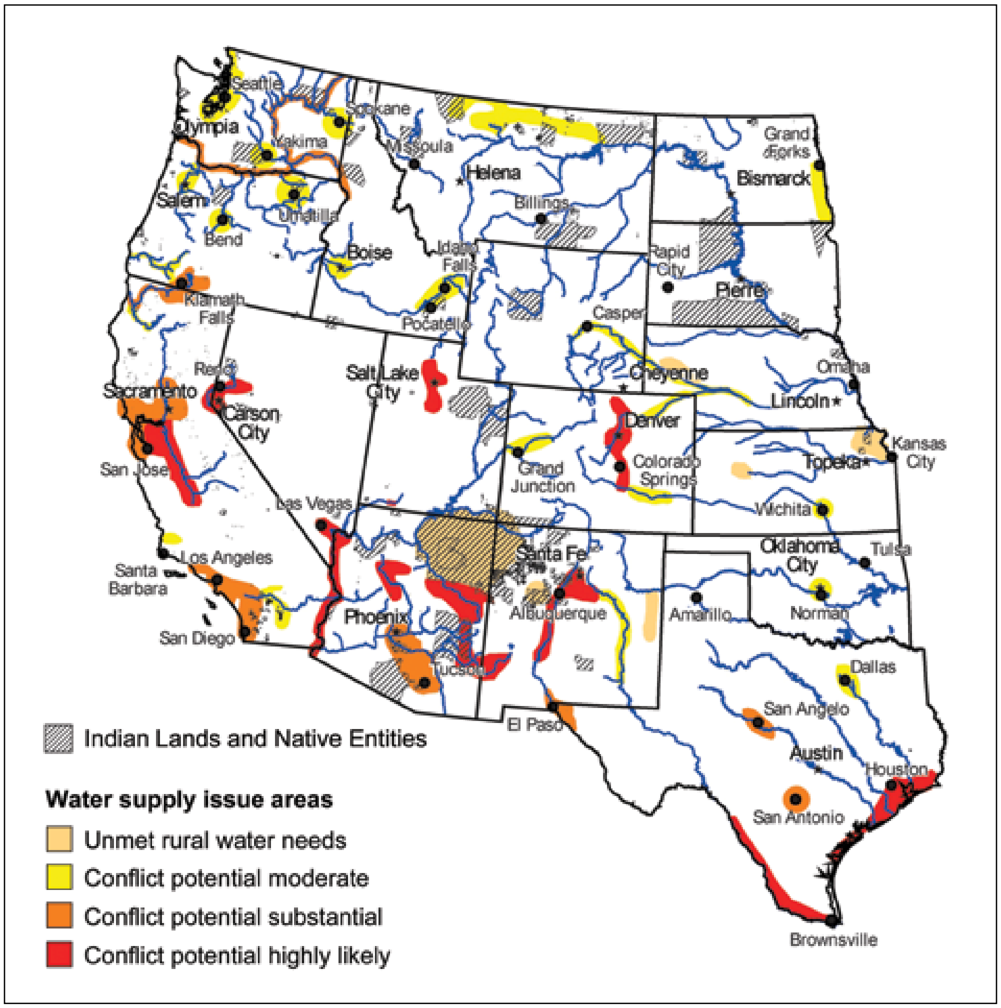

Figure 3-17—Likely water supply conflict regions in Western United States by 2025 without climate change effects. Source: USGCRP 2009 based on U.S. Bureau of Reclamation 2005.

shows regions in the West where water supply conflicts are likely to occur by 2025, based on a combination of factors such as population trends and endangered species need for water without factoring in climate change effects, which might exacerbate many of these conflicts.

Rural communities engaged in activities like farming are expected to be under additional water stress from climate change. For example, climate change increases the chance of water-related conflicts in already water-scarce regions like the Great Plains and Southwest. Current water use in the Great Plains is unsustainable, as the High Plains aquifer continues to be tapped faster than the rate of recharge. Similarly, groundwater pumping is lowering water tables, and rising temperatures reduce riverflows in vital rivers (Barnett et al. 2008)

Energy—

With increasing pressure on existing energy sources, rural communities' access to traditional energy sources could be threatened by climate change. Increased demand for energy as well as lower or uncertain supplies in many areas will accentuate such threats. Scott and Huang (2007) projected that temperature increases are likely to increase peak demand for electricity in most regions of the country. The energy demand for cooling is also expected to increase along with peak demands and higher temperatures. The increase in demand will be higher in the South, a region with especially high per capita electricity use (Scott and Huang 2007). The Southern region accounts for most of the persistently poor rural counties in the United States. Rural communities in the South might not be able to cope with the higher costs associated with increased demand, in turn increasing their vulnerability to climate change.

Renewable sources of energy, such as biomass-based energy, are already being promoted to increase energy supply, create jobs, reduce reliance on fossil fuels, and improve access to rural communities. The federal and state government incentives and mandates such as renewable fuel standards, blending incentives, research and development support, among others, are accelerating the process of making such energy sources commercially viable. The biomass-based energy markets could benefit rural landowners in terms of higher product prices as well as increased avenues for employment.

Fisheries—

America's coastlines and fisheries are especially at risk from climate change. Fisheries feed local people and provide livelihood to rural communities and indigenous peoples in many parts of the country. The habitats of some mountain species and coldwater fish, such as salmon and trout, are very likely to contract in response to warming, whereas some warm-water fishes such as smallmouth bass (*Micropterus dolomieu*) and bluegill (*Lepomis macrochirus*) might expand their ranges (Janetos et al. 2008). Apart from changes in species composition and availability of native fish species, aquatic ecosystem disruptions are likely to be compounded by invasion of nonnative invasive species, which tend to thrive under a wide range of environmental conditions.

In Alaska, climate change is already causing significant alterations in marine ecosystems (fig. 3-18), restricting fisheries and adding to the hardships of the rural people who depend on them (USGCRP 2009). Historically, warm periods in coastal waters have coincided with relatively low abundances of salmon, and cooler ocean temperatures have coincided with relatively high salmon numbers (Crozier et al. 2008). It has been estimated that as much as 40 percent of Northwest salmon populations may be lost by 2050 owing to climate change (Battin et al. 2007).


Bob Czaro

Climate change has caused alterations in marine ecosystems in Alaska.

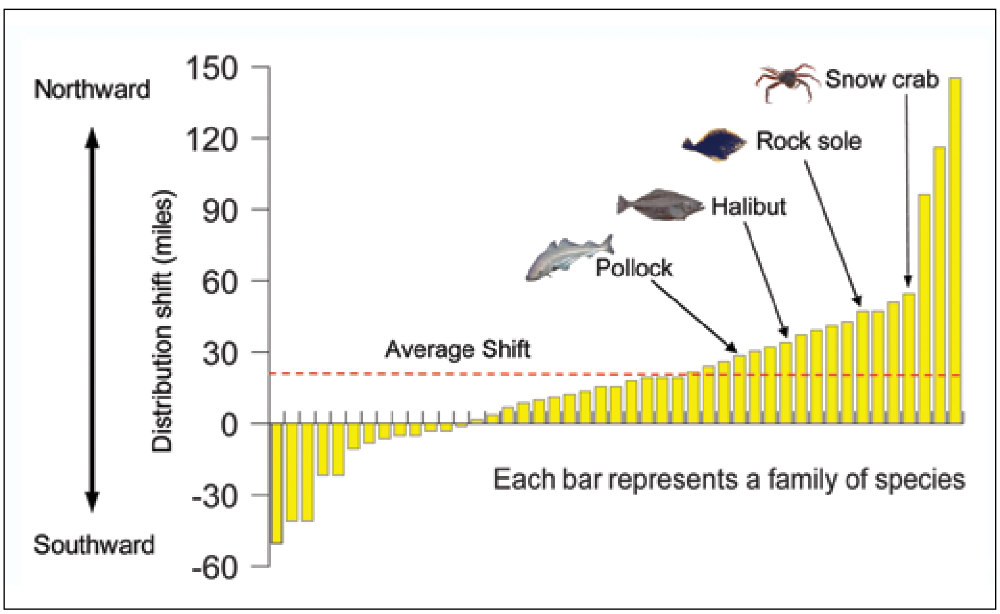

Figure 3-18—Marine species shift in Alaska from 1982 to 2006. Source: USGCRP 2009 based on Mueter and Litzow 2007.

Alaska leads the country in terms of its commercial and subsistence fishing catch. Most of the Nation’s salmon, crab, halibut, and herring come from Alaska. In addition, many native communities depend on local harvests of fish, walruses, seals, whales, seabirds, and other marine species for their food supply. Subsistence

fishing accounts for a large share of the food consumed in rural Alaska. The state's rural residents harvest an average of 225 pounds of fish per person (U.S. Fish and Wildlife Service 2010). The warmer water is already leading to a lower catch of salmon in Alaska creating hardships on the rural people and indigenous tribes who are dependent on these fishes for subsistence or employment (NTAA 2009).

In the Northeast, lobster fisheries are projected to continue a northward shift, and the cod fisheries in the Northeast are likely to be diminished with increasing ocean temperatures associated with climate change (USGCRP 2009). The possibility of ocean acidification owing to climate change may also endanger fisheries in the Northeast. For example, increased acidification in Passamaquoddy and Cobscook Bays and Bay of Fundy threaten shellfish including clams, scallops, and lobsters.

Climate change is also expected to reduce coral reefs and reef fish species (Graham et al. 2006). Changes in the species composition of coral reef ecosystems will likely have significant repercussions for both subsistence and commercial fishing in Hawaii, Puerto Rico, U.S. Virgin Islands, Guam, and American Samoa (Janetos et al. 2008). Change in fish availability owing to climate change may hit Guam and American Samoa particularly hard as almost all communities within the Pacific Islands derive between 25 and 69 percent of their animal protein from fish (Hotta 2000). The Southeast United States will most likely also observe a decline of wetland-dependent coastal fish and shellfish populations owing to the rapid loss of coastal marsh from rising sea levels associated with climate change (Zimmermann et al. 2002).

Conclusions

The potential impacts of climate change on rural communities include increased risks to human health, changes to the agricultural and forestry sectors, stress on water resources and fisheries, increased conflicts over scarce resources, impacts on recreation and tourism, adverse effects on indigenous communities, and additional impacts related to an increase in adverse weather events. Directly or indirectly, positively or negatively, climate change will affect all sectors and regions of the country, although the impacts will not be homogenous across regions, sectors, population groups, or time.

The impact of climate change on rural communities depends on complex interactions among different sectors, regions, and population groups and the environment. However, there is a dearth of information and literature on how the myriad socioeconomic and demographic factors will react to the biophysical changes accompanying climate change and virtually none on how

the interconnected socioeconomic/ecological systems will respond. Most of the current literature is based on such coarse temporal and spatial resolution as to offer only very general guidance for investment and policymaking. For example, understanding the economic effects of climate change on timber production is constrained by limited scientific understanding of several key factors that control the response of natural and managed forests to climate change. Timber production will depend not only on climatic factors but also on stresses from pollution (e.g., acid rain), future trends in forest management practices, economic demand for forest products, and land-use change. Clarification of the uncertainties concerning how all of these factors will interact in the face of climate change will permit more informed policy and programmatic responses to reducing the vulnerability of rural communities to the impacts of climate change.

Climate change will affect rural communities through changes in availability or access to climate-sensitive resources that occur at local, regional, or national levels. The vitality of local communities (Hutton 2001, Jensen 2009, Wall et al. 2005), changes in monetary conditions (Ikeme 2003), status of emergency facilities and preparedness and planning (Murphy et al. 2005), condition of the public health system (Kinney et al. 2001), and exposure to conflict (Barnett 2003) all have the potential to either exacerbate or ameliorate the vulnerability of rural communities to climate change. Vulnerability to climate change tends to be greater for rural communities who typically have fewer resources and fewer alternatives than urban areas. Therefore, the climate risk mitigation and adaptive capacity of rural communities remains an important area for public policy interventions and future research. A suite of adaptation and mitigation policy options needs to be developed to reduce vulnerability of rural communities under a variety of climate change scenarios.

In light of the potential impacts of climate change on rural communities, enhancing their coping and adaptive capabilities is crucial. However, public discussion about adaptation is at an early stage in the United States (Moser 2005). An active dialogue among stakeholders and political institutions could help clarify the opportunities for adapting to and coping with climate change. A significant difference in infrastructure needs between rural and urban areas suggests that research focusing on assessing rural communities' adaptive capacity, costs and effectiveness of adaptation options, implementation impediments, and expected consequences is warranted.

Although much data on the biophysical impacts of climate change are already freely and readily available to a broad range of users, sociocultural and economic data and information related to how climate change will affect rural communities,

their resilience, and adaptive capacity are scarce. Developing effective data collection systems and analyses of these issues first requires agreed-upon baseline indicators and measures of environmental, demographic, and economic conditions that can be used to track the effects of changes in climate on rural communities (Karl et al. 2009). A set of regional studies is needed to improve our understanding of climate change impacts and the distribution of costs and benefits of the impacts across rural and urban communities in the United States, and to develop appropriate policies to mitigate the impacts.

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Metric Equivalents

When you know:	Multiply by:	To get:
Acres (ac)	0.405	Hectares
Pounds (lb)	454	Grams
Tons	.907	Tonnes (metric tons)
Degrees Farenheit (°F)	.55(°F – 32)	Degrees Celsius

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