Chapter 5
Climate Change and Forest Values

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5.1 Introduction

Human concerns about the effects of climate change on forests are related to the values that forests provide to human populations, that is, to the effects on ecosystem services derived from forests. Forests are valued for the services they provide such as timber products, water resources, aesthetics, and spiritual qualities. Effects of climate change on forest ecosystems will change service flows, people's perception of value, and their decisions regarding land and resource uses. Thus, social systems will need to adapt to climate changes, producing secondary and tertiary effects on the condition of forests in the United States.

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Forests and derivative ecosystem services are produced and consumed in (1) rural settings, where human population densities are low and forest cover dominates, (2) urban communities, where forests and trees may be scarce but their relative value, measured as direct ecosystem services, may be high, and (3) transition zones between rural and urban settings (the wildland-urban interface [WUI]), where forest settings comingle with human populations. These three settings pose different challenges for resource management and policy as related to climate change, and each defines a different set of opportunities to affect changes in forest conditions and service flows.

Here we explore how climate change interacts with forest condition, human values, policy, management, and other institutions, and the potential effects of these interactions on human well-being. We examine (1) socioeconomic context (ownership structure, how value is derived, institutional context), (2) interactions between land-use changes and climate change that affect forest ecosystems, and (3) social interactions with forests under climate change (climate factors, community structure, social vulnerability).

5.2 Socioeconomic Context: Ownership, Values, and Institutions

In the United States, forest conditions and the flow of ecosystem services from forest land reflect a long history of intensive, extensive, and passive management, as well as the influence of policy affecting public and private lands (Williams 1989). Future forest management and policy require an understanding of socioeconomic interactions with forests and how they might determine future conditions in a warmer climate. The socioeconomic context of forests in the United States includes (1) ownership patterns that define the institutional context of management, (2) forest contributions to human well-being through provision of various ecosystem services, and (3) institutional settings that affect decision making.

5.2.1 Forest Ownership Patterns

Forest owners comprise the individuals and groups most directly affected by, and most capable of mitigating, the potential impacts of climate change on forests. Working within social and biophysical constraints, owners ultimately decide the fate of the forest: whether it will remain forested and how (or if) it will be managed. Of the 304 million ha of forest land in the United States, 56 % is non-governmental owned by individuals, families, corporations, Native American tribes, and other groups (Butler 2008) (Fig. 5.1). The remaining forest land is publicly owned and controlled by federal, state, and local government agencies. Ownership patterns

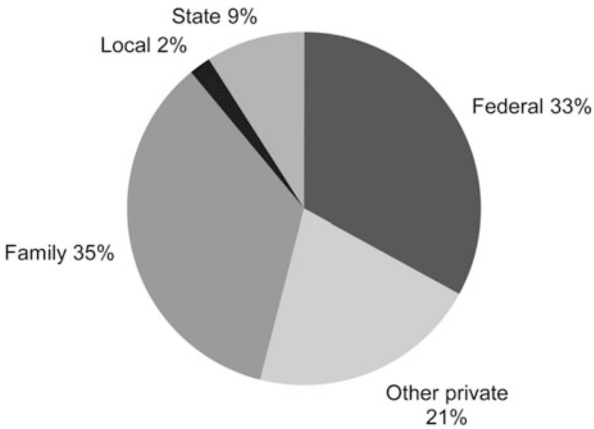

Fig. 5.1 Forest ownership in the United States, 2006 (From Butler 2008)

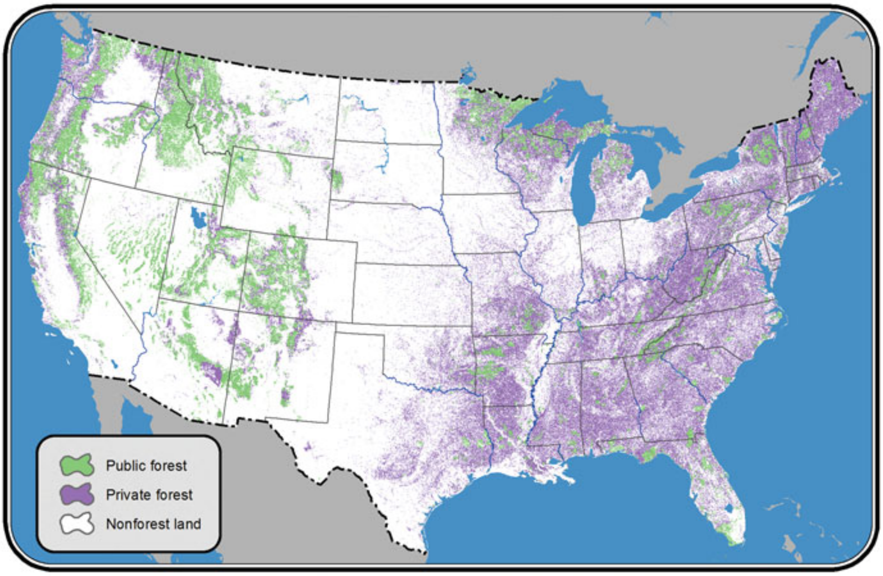

Fig. 5.2 Distribution of public and private forest ownership in the United States

differ across the country (Fig. 5.2). In the East, where 51 % of U.S. forests are located, private ownership is 81 %, and as high as 94 % in some states. Western forests are dominated by public, primarily federal, ownership (70 %), with public ownership in some states as high as 98 % (Butler 2008).

Public forests are often managed for multiple uses, although a single use may dominate at local scales (e.g., water protection, timber production, wildlife habitat, preservation of unique places). The federal government owns 33 % of all forest land, with the greatest percentage being managed by the U.S. Forest Service (59 million ha) and Bureau of Land Management (19 million ha). State agencies own 9 %

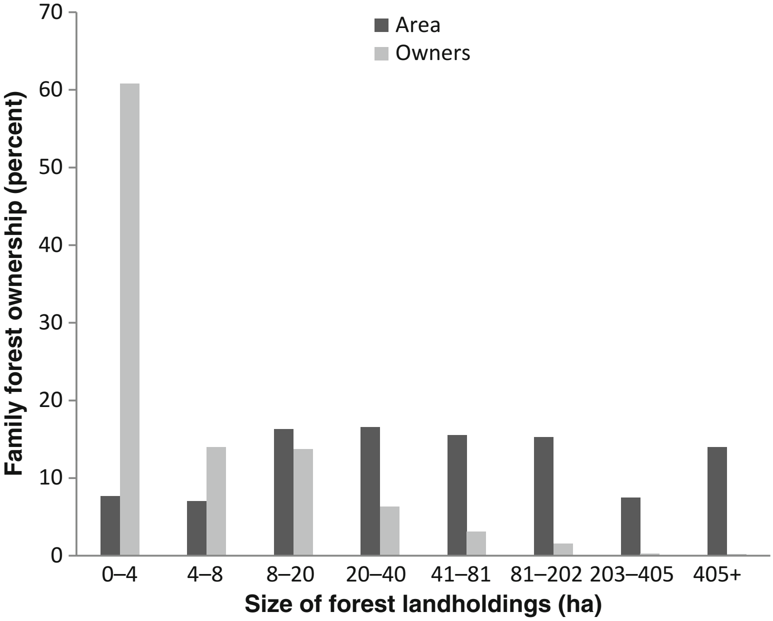

Fig. 5.3 Family forest ownerships in the United States by size of forest holdings, 2006 (From Butler 2008)

of U.S. forest land, and county and municipal governments own 2 %. Most state management objectives are similar to federal uses. Common objectives of many local land management agencies are water protection, recreation, and open space preservation.

Of the major forest ownership categories, families and individuals own a plurality (35 %, 106 million ha) of the forest land in the United States—there are over 10 million of these family ownerships. Although most (61 %) family forest ownerships are small (0.4–3.6 ha), 53 % of the land is owned by those with at least 41 ha (Fig. 5.3). Most family forest ownerships focus on amenity values, although for a significant number of ownerships, especially with larger forest holdings, timber production and land investment are important. Approximately 27 % of family forest ownerships have harvested trees. Although few family forest owners have a written management plan, participated in a cost-share program, green-certified their land, or obtained a conservation easement (Butler 2008), most family forest owners have a strong land and conservation ethic (Butler et al. 2007). In recent years, family forests have been undergoing "parcelization," the dividing of larger parcels of land into smaller ones. When parcelization is accompanied by new houses, roads, or other changes, then forest fragmentation increases, which can harm some ecosystem functions. Twenty percent of current family forest landowners are at least 75 years old, suggesting that a large proportion of forest land will soon change hands, with the potential for increased parcelization and altered ownership objectives.

Most other private forest land is controlled by corporations (56 million ha, 18 % of all forest land), including traditional forest industry and forest management companies, timber investment management organizations (TIMOs), and timberland real estate investment trusts (REITs). Other corporations also own forest land but do not have forest management as their primary business. Native American tribes, nongovernmental organizations, clubs, and unincorporated partnerships control 8.5 million ha (3 %) of the forest land. Some ownerships are explicitly for forest conservation (e.g., land trusts), and others are largely for recreation (e.g., hunting clubs) and other proposes.

From 1977 to 2007, the total area of U.S. forest land increased by 8.9 million ha (4 %) (Smith et al. 2009), with most of the increase occurring in public (especially state) ownership. However, from 1997 to 2007, private forest land decreased a net 0.4 million ha. Over the next 50 years, U.S. forest land is projected to have a net loss of 9.3 million ha (Alig et al. 2003), mostly on private lands subject to urbanization. Since the 1980s, the types of corporations that own forest land underwent a major change. Traditionally, most corporate forest land was owned by forest industry companies, which owned both forest land and facilities to process wood. Beginning in the 1980s most of these companies separated their forest holdings from other assets, and many began to divest themselves of land. This decrease was accompanied by an increase in TIMOs and REITs which often have shorter investment time horizons and no need to supply mills.

Private forest owners will need to play a critical role for successful mitigation of climate change effects, because they own over half of U.S. forest land. Therefore, an ongoing dialogue is needed about the level and types of management necessary to sustain desired ecosystem services in forests and to enhance resilience of existing forest ecosystems in the face of a warmer climate and increased disturbances. Policies that aim to mitigate the effects of climate change on forests must consider the needs, desires, and resources of all forest owners.

5.2.2 Economic Contributions of Forests

Forests deliver many values to private landowners, but also to the public at large. In rural areas, forest cover can generally be equated with forest land use, because forests are a consequence of a decision either to dedicate land to growing trees or to allow land to return to a fallow state. Rural forest ownership can provide direct returns, consumptive values, and monetary returns. Direct returns accrue through extractive activities (mainly commercial timber harvesting) or *in situ* values (e.g., hunting leases, conservation easements). Consumptive values can accrue through direct use of forests for recreation, existence value, and aesthetics. Most monetary returns are from timber production, with some additional returns from recreation leases, conservation easements, and payments for other ecosystem services.

The United States produces more timber by volume than any other nation, and timber represents a significant source of value for forest landowners. Although the volume of roundwood used for industry and fuelwood nearly doubled between 1945 and the late 1980s, production since then has declined. In 2006, the year before the latest recession, total timber production stood at about 90 % of its peak value in 1988. The economic contribution of harvested timber has also declined. Between 1997 and 2006, the value of shipments (the sum of net selling values of freight on board of all products shipped by the sector) fell from a peak of $334 billion to $309 billion (Howard et al. 2010b), a result of declines in the paper products industry.

Although per capita consumption of wood products has been trending downward since the late 1980s, population growth has continued to push total consumption upward, from 0.37 billion m^3 in 1988 to 0.57 billion m^3 in the 1990s and 2000s (Howard et al. 2010a). Between 1957 and 2006, U.S. per capita consumption of wood products averaged 2 m^3 per person, peaking in the late 1980s (2.32 m^3 per person) and falling in the 2000s (1.95 m^3 per person). This reduction was caused mostly by reduced consumption of fuelwood, indicating that consumption of wood and paper products has risen in direct proportion to population growth (Howard et al. 2010b).

The value of U.S. timber production returned to forest landowners was $22 billion in 1997, with 89 % returned to private landowners (USDA FS 2011), roughly 7 % of the value of shipments for wood products. In 2006, the value of all wild-harvested non-timber resources was $0.5 billion, and direct payments to landowners for forest-based ecosystem services (conservation easements, hunting leases, wetland mitigation banks) was $2 billion (USDA FS 2011). In rural forests, ecosystem services such as aesthetics, dispersed recreation, spiritual values, and protection of water quality rarely provide monetary compensation. Current policy initiatives (e.g., the 2008 Farm Bill [Food, Conservation, and Energy Act of 2008]) focus on providing payments, often through constructed markets, to compensate landowners for ecosystem services. It has also been proposed that municipalities compensate landowners in municipal watersheds for protecting water quality (Brauman et al. 2007; Greenwalt and McGrath 2009). In urban settings, trees remove pollution, store C, cool microclimates, and provide recreation. Trees in the WUI typically have little extractive value other than as fuel wood, and these environments are greatly influenced by human activities that occur there.

5.2.3 Policy Context of Forest Management in Response to Climate Change

Forest land ownership, nongovernmental involvement in forest values, and policy instruments (laws and taxes) that influence land management decisions all affect forest management and landowner behavior. Because land-use decisions are the dominant cause of landscape change, human institutions strongly affect future forest conditions and thus responses to climate change. Forest management in the United States derives from the interaction of private and public ownership. Private ownership affords extensive property rights but is constrained by tax and regulatory policy. Although production of nonmarket goods is a primary rationale for public ownership of forest land (e.g., Krutilla and Haigh 1978), nonmarket ecosystem services, which deliver considerable value to society, are not likely to be fully valued in private transactions. Government can direct the actions of individual landowners toward producing other nonmarket benefits by altering incentives (e.g., reforestation subsidies) and selectively restricting property rights (e.g., through forestry practice regulations). Nongovernmental organizations can directly affect changes in land use and resource allocation through outright purchases of land or purchase of development or other rights using conservation easements.

Private forest owners might be expected to alter their management plans more rapidly in response to climate change effects, altered market prices, and policy instruments that affect the provision of non-market ecosystem services. However, management objectives differ greatly between corporate and family forest owners and among subgroups of family forest owners (Butler et al. 2007). The private forest sector has shown high responsiveness to market signals in harvesting timber and investing in future timber production, especially in the southeastern United States where intensively managed pine plantations doubled between 1990 and 2010 (Wear and Prestemon 2004; Wear and Greis 2011). Private forests in the United States have less inventory (reflecting "younger" forest ages), are more accessible, and are more likely to be harvested or actively managed than public forests. On the other hand, public management can seek to maximize public welfare derived from forests and produce benefits not provided by markets, although public (especially federal) management adjusts slowly to changing conditions (Wilkensen and Anderson 1987; Yaffee 1994).

Future responses to climate change, and especially to programs designed to mitigate greenhouse gas (GHG) emissions, will probably be larger on private lands, where market signals and direct policy instruments (incentives and disincentives) are readily translated into management actions. Responses may include more harvesting (a result of new product markets such as biofuels) and altered forest management (responding to demands for forest-based C storage). Responses could also occur as increased or decreased forest area, depending on comparative returns to land from forest and agricultural uses. Therefore, larger policy impacts on GHG mitigation management activities are expected in the eastern United States, where private ownership dominates and transportation and processing infrastructure for wood products are more extensive.

In the forest sector, policy responses to climate change have focused largely on mitigation that reduces the use of fossil fuel (through bioenergy products) or amount of carbon dioxide (CO_2) in the atmosphere (through sequestration). Use of woody biomass for energy can offset fossil fuel consumption, and C storage can be increased through forest growth and conversion of trees to durable wood products. Policies outside the forest sector may have secondary effects on forests, largely through land-use changes; for example, crop price support programs may motivate conversion of some forests to agricultural land.

5.3 Rural Forests, Land-Use Change, and Climate Change

Land-use changes are influenced by choices of landowners, market forces, and economic and environmental policies. In rural environments, market forces influence shifts between agricultural uses and forest uses. Urban expansion converts forest land, with loss of some trees, and intensification of urban areas often leads to the loss of most trees. In the WUI, conversion of large forest tracts to residential areas is driven by home buyers who value the amenities of living in or near forests and are willing to pay more to do so. These changes in land cover can affect local temperature and precipitation (Fall et al. 2009) and interact with climate change to influence forest dynamics.

History demonstrates a tradeoff between agricultural and forest uses in the United States, based on shifting advantages and returns. Climate is a key driver of agricultural productivity, and along with population growth, may influence returns to agriculture and land use switching among cropland, forest, and other uses. Crop productivity is negatively related to non-autumn temperature increases, positively related to non-autumn precipitation (Mendelsohn et al. 1994), and affected by climatic variability (Mendehsohn et al. 2007). Large declines in productivity are projected for important crops in the United States, especially in the latter part of the twenty-first century (Schlenker and Roberts 2009). Assessments of climate change on forest productivity have been less definitive (see Chap. 3), because forest ecosystems are more complex and forest dynamics are not as well understood in relation to climate. Furthermore, disturbances such as wildfire and insect outbreaks can result in immediate changes, including extensive mortality and erosion (see Chap. 4).

Future rural land uses will be affected by a combination of population-driven urbanization, comparative returns to agriculture and forestry, and policies that influence the expression the first two factors. The recent Renewable Resources Planning Assessment Act (RPA) (Wear 2011; USDA FS 2012) forecasts an increase in developed uses from about 30 million ha in 1997 to 54–65 million ha in 2060, based on alternative projections of population and income. Comparative returns to agriculture and forestry could be altered directly and indirectly by climate change, and at the margin, shifts in agricultural productivity could lead to a switch between forests and crops. Shifts in comparative returns to forestry and agriculture would probably result from policy designed to encourage bioenergy production. The degree to which a bioenergy sector favors agricultural feedstocks (e.g., corn) or cellulosic feedstocks from forests will determine the comparative position of forest and agricultural land use. Federal policy to date has subsidized corn ethanol production, but the 2008 Farm Bill and some State-level policies encourage use of wood in electricity generation. In some areas of the United States, policies that mitigate climate change through bioenergy and C sequestration may influence land use and forest area more than climate change itself.

5.4 Trees and Climate in Urban Environments

Trees in developed areas may provide a disproportionately higher value of ecosystem services because of their proximity to human habitation. As the area of urban use expands, the extent and importance of urban trees will increase. Climate change will likewise have important effects on these trees, and urban trees have the potential to moderate climate in urban environments.

In 2000, urban areas occupied 24 million ha (3.1 %) of the conterminous United States and contained over 80 % of the country's population (Nowak et al. 2005), and urban/community lands occupied 41 million ha (5.3 %) (Nowak and Greenfield 2012b). Urban areas are projected to increase to 8.1 % by 2050 (Nowak et al. 2005; Nowak and Walton 2005), resulting in an increase in urban land of 39.2 million ha and a concomitant conversion of 11.8 million ha of forest to urban land (Nowak and Walton 2005).

Percentage of tree cover nationally is projected to decrease by 1.1–1.6 % between 2000 and 2060 (USDA FS 2012). Within urban areas of the conterminous United States, tree cover is declining at a rate of 0.03 % per year, equivalent to 7,900 ha or four million trees per year, or 0.27 % percent of city area per year for densely populated areas (Nowak and Greenfield 2012a). Cities developed in naturally forested regions typically have a higher percentage of tree cover than cities developed in grassland or desert areas (Nowak et al. 1996, 2001; Nowak and Greenfield 2012b).

The structural value of urban trees (cost of replacement or compensation for loss) in the United States is estimated at $2.4 trillion (Nowak et al. 2002b). Urban trees provide additional benefits, such as air pollution removal and C sequestration (Nowak et al. 2006). Thus, as climate changes, urban forests and their associated benefits will be affected even as they help to reduce CO_2 emissions. Urban trees in the United States are estimated to store 643 million Mg C ($50.5 billion value; based on a price of $20.30 per Mg C), with a gross C sequestration rate of $25.6 million Mg C year^{-1} (2.0 billion year^{-1}) (Nowak et al. 2013).

The biggest effects of climate change on urban trees and forests will likely be caused by warmer air temperature, strengthening wind patterns, extreme weather events, and higher concentrations of atmospheric CO_2. In addition, urban surfaces and activities (e.g., buildings, vegetation, emissions) influence local air temperature, precipitation, and windspeed. Urban areas often create an "urban heat island," where air temperatures are higher (1–6 °C) than in surrounding areas (US EPA 2008). In some areas in the southeastern United States, monthly rainfall rates are 28 % higher within 30–60 km downwind of cities, with a 5.6 % increase over the city (Shepherd et al. 2002; Shepherd 2005).

Potential effects of climate change on urban tree populations include changes in tree vigor and physiological condition, species composition (e.g., Iverson and Prasad 2001), insect and disease occurrence, and management and maintenance activities that mitigate tree health and species composition changes (Nowak 2000, 2010). Management activities to sustain healthy tree cover will alter C emissions (because of fossil fuel use), species composition, and urban forest attributes such as biodiversity, wildlife habitat, and human preferences and attitudes toward urban vegetation. Climate change effects on the urban forest may be accelerated or reduced depending on whether urban forests are managed for better adapted species or managed more intensively (e.g., through watering and fertilization) to reduce climate impacts.

Nowak (2000) proposed four ways in which urban forests affect climate change:

- *Removing and storing CO_2*—Trees remove CO_2 from the atmosphere and sequester C in their biomass (McKinley et al. 2011). The net C storage in a given area with a given tree composition cycles through time as the population grows and declines. When forest growth (C accumulation) is larger than decomposition, net C storage increases. Some C from previous generations can also be sequestered in soils. Management activities can enhance long-term C storage by growing large, long-lived species; minimizing use of fossil fuels to manage vegetation; strategically planting vegetation to reduce air temperature and energy use, and using urban tree biomass for energy production (Nowak et al. 2002a).
- *Emitting atmospheric chemicals through vegetation maintenance*—Urban tree management often uses large amounts of energy to maintain vegetation structure (transportation, vehicles, other equipment), and emissions from these activities need to be considered in evaluating the net effect of management.
- *Altering urban microclimates*—Trees are part of the urban structure, and they affect the urban microclimate by cooling the air through transpiration, blocking winds, shading surfaces, and helping to mitigate heat-island effects.
- *Altering energy use in buildings*—Urban trees can reduce energy use in summer through shade and reduced air temperatures, and they can either increase or decrease winter energy use (Heisler 1986), depending on tree location around buildings (e.g., providing shade, blocking winter winds).

5.5 Climate Change and the Wildland-Urban Interface

The WUI encompasses where people live in direct contact with forests and other wildlands, and where development of forested lands for residential and commercial uses has direct, ongoing effects on the forest (Radeloff et al. 2005). Key changes driven by climate change, population growth, and markets for land uses are especially concentrated in this zone. Growth in the WUI has outpaced growth outside the WUI, a trend expected to continue in coming decades, particularly in Western states (Theobald and Romme 2007; Hammer et al. 2009). Area in the WUI is expected to increase 17 % within 50 km of federal lands by 2030 (Radeloff et al. 2010). Proximity to protected areas is an attraction to home buyers because it guarantees that changes to the viewshed will be minimal (Radeloff et al. 2010; Wade and Theobald 2010). These lands have protected status in part to ensure that plant and animal species will be sustained, which makes their attractiveness for adjacent housing troubling from an ecological perspective (Gimmi et al. 2011).

People who live in the WUI are more likely to be aware of forest disturbances that might be exacerbated by climate change, such as drought, wildfire, insect outbreaks, and spread of invasive plants. Awareness and acceptance of the need to prepare for wildland fire has grown in the WUI over the past decade. Since 2002, the Firewise program (http://firewise.org) has assisted communities across the country in developing and maintaining residential areas to minimize fire risk through modification of vegetation and use of fire-resistant building materials (Cohen 2000; NFPA 2011).

Ideally, entire communities would be "fire adapted," where fire passes through and around a community without causing extensive damage. Recent studies of risk perception and response related to wildfire (Cova et al. 2009; McCaffrey 2009) conform to established psychological concepts of risk and actions to reduce risk (Slovik 1987). Climate change, like wildfire, presents many challenges for the ability of people to understand, judge, and act on new information. Specific, observable changes in forest resources, particularly in familiar and local forests, are best able to engage the attention and concern of the general public. Because people attach such great value to forests, it may be more feasible to engage landowners in adapting to climate change than for other resource sectors, especially in the case of fire, insect outbreaks, and other disturbances that have highly visible effects.

Like climate change itself, activity in the WUI affects forest structure and dynamics. Regulations such as zoning ordinances that limit housing density and neighborhood covenants governing property management are intended (in part) to protect the environment. However, multiple small disturbances can overwhelm the ability of forests to adapt by requiring a rapid transition to new conditions, a situation not typically addressed through land use and other residential policies.

Communities in or near forests could be well designed and governed under effective regulations, yet still lack the capacity needed to adapt to climate change. For example, a zoning code that specifies the number of trees retained in a subdivision without accounting for their configuration may result in a fragmented forest and degraded wildlife habitat. However, once known and understood, resource management concerns that are communicated effectively can change human behavior. For example, in Fremont County, Colorado, WUI residents actively learned from each other and engaged in managing several complex WUI resource issues (Larsen et al. 2011). Given expectations for continued WUI growth, together with the effects of climate change, such activities will be essential for maintaining the capacity of forests to adapt to climate-caused changes in the biophysical environment.

5.6 Social Interactions with Forests Under Climate Change

People and the actions they take directly alter the capacity of forests to sequester C and adapt to a changing climate. By modifying the landscape, people alter forest extent, sustainability, and capacity to meet the needs of other species. People and

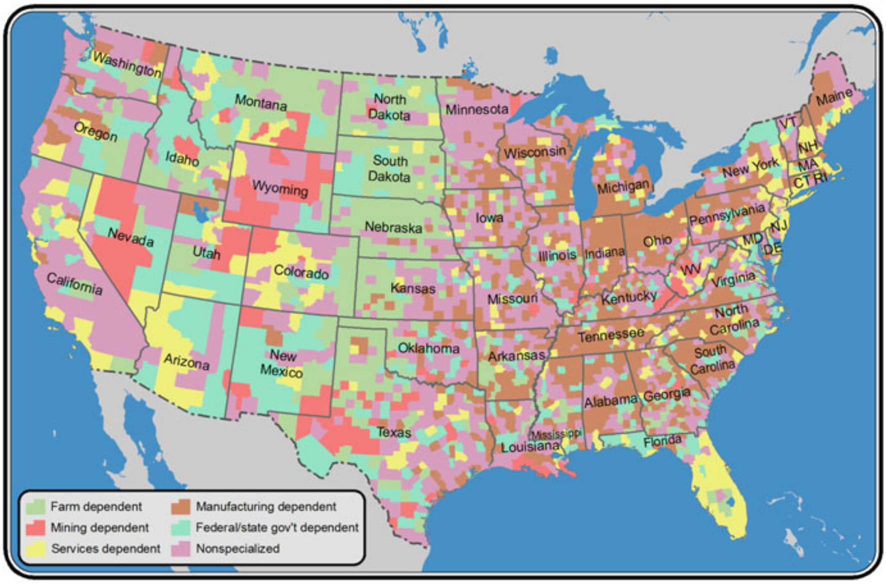

Fig. 5.4 Economic dependence in the United States (From USDA ERS 2012)

societies mediate the relationship between forests and climate change directly (by altering forests) and indirectly (by changing other biophysical conditions that in turn alter forests). Interactions between social relationships with forests and climate change will potentially alter ecosystem services on which people depend.

In natural resource-based communities, socioeconomic relationships based on commodities (e.g., timber) or amenities (e.g., recreation) may be disproportionately affected by climate-forest interactions. On tribal lands, which may be vulnerable to effects of climate change because of strong links among economies, cultures, and natural resources, the ability to adapt by moving to another location is limited because of strong ties to a specific place (often a reservation). Assessing the resilience of natural resource-based and tribal communities to climate change requires understanding ecological, social, and economic vulnerabilities.

5.6.1 Natural Resource-Based Communities

Natural resource-based communities are closely linked with their geographic setting and environmental context. People in these communities derive economic benefits from the surrounding natural resources and withstand their associated natural disturbances, such as wildfires and hurricanes. Natural resource-based communities depend to varying degrees on different resource sectors (USDA ERS 2011). Farm dependency has declined greatly; in 2000, only 20 % of nonmetropolitan counties were considered farming dependent (Dimitri et al. 2005) (Fig. 5.4). Other counties, particularly in the West, depend on federal or state government and mining. Of 368 recreation-dominated counties, 91 % are in rural areas (Lal et al. 2010).

Natural resource-based communities in or near forests often experience the consequences of natural disasters or environmental stresses sooner than do farther-removed populations (Lynn and Gerlitz 2006; Haque and Etkin 2007; Lynn et al. 2011). Although developing regions of the globe present the most glaring examples of forest-dependent communities vulnerable to climate change, these relationships also occur in developed regions of North America. Individual and community vulnerability can be affected by characteristics such as income level, race, ethnicity, health, language, literacy, and land-use patterns. Thus, the social vulnerability of natural resource-based communities can exacerbate biophysical vulnerabilities.

Specific social characteristics associated with forest-based communities can increase climate change risks (Davidson et al. 2003). For example, human capital development is typically lower with respect to educational attainment in these areas, reducing the potential for laborers to transfer skills to other occupations. Politicization of the role of deforestation in climate change can create a larger populace that is unsympathetic to labor dilemmas facing communities dependent on forestry. Uncertainty about climate change effects, coupled with the long-term planning horizon of forest management, elevates risks associated with investments in forest-based industries, leading to under-investment in communities that depend on a single sector economy. As noted in the Fourth Intergovernmental Panel on Climate Change Assessment, social vulnerability may be geographically dispersed: "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" (Pachauri and Resinger 2007; Solomon et al. 2007). In addition, climate change may not be perceived as a real threat by local residents or key decision makers, resulting in reluctance to devise adaptive strategies to reduce stresses.

5.6.2 Tribal Forests

American Indians and Alaska Natives rely on reservation lands and access to traditional territories outside of reservations for economic, cultural, and spiritual values. Tribes have unique rights, including treaties with the federal government that protect access to water, hunting, fishing, gathering, and cultural practices (Pevar 1992; Lynn et al. 2011). Indian reservations contain 7.2 million ha of forestland, of which 3.1 million ha are classified as timberland and 2.3 million ha as commercial timberland (Gordon et al. 2003), including conifer forest in the Pacific Northwest, dry pine forest and juniper woodland in the Southwest, mixed hardwood-conifer forest in the Lake States, and spruce forest in the southern Appalachian Mountains (Gordon et al. 2003) (Fig. 5.5).

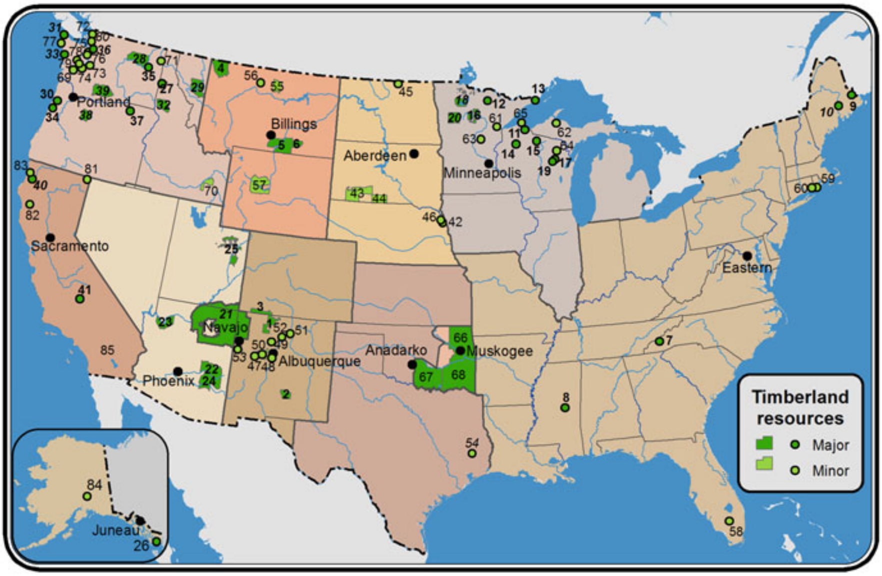

Fig. 5.5 Reservations with significant timberland resources. Numbers 1 through 41 have over 4,000 ha of commercial timberland per reservation. Numbers 41 through 83 have less area in timberland, but what they have is economically viable (Adapted from IFMAT (2003), Intertribal Timber Council, with permission). See Vose et al. (2012, p. 115) for list of reservation names

Tribal forests and woodlands provide jobs and revenue from timber production, non-timber forest products, grazing, fishing, and hunting. They also provide recreation opportunities, energy resources, places for religious ceremonies and solitude, and material for shelter, clothing, medicines, and food. Climate change effects on tribal forests will have implications for treaty rights if the ranges of culturally significant plant and animal species move outside reservation boundaries; water resources and tribal water rights may be especially affected by climate change (Karl et al. 2009; Curry et al. 2011). Current adaptation approaches on tribal lands include watershed management surrounding sacred waters, natural hazard management, and efforts to create green jobs (Lynn et al. 2011), and some tribes have begun to explore options to manage forest lands for C sequestration. The fixed location of tribal lands constrains the adaptive capacity of tribal communities with regard to climate change, especially on reservations that are small or fragmented.

5.6.3 Social Vulnerability and Climate Change

Socially vulnerable populations are often considered as marginal groups in terms of material well-being, which reduces their ability to anticipate, cope with, or recover from environmental stresses (Kelly and Adger 2000). Vulnerability is not just susceptibility or sensitivity to loss arising from hazard exposure, but also a function of sensitivity and adaptive capacity (Brooks 2003; Smit and Wandel 2006; Polsky et al. 2007). *Exposure* is the proximity to a physical hazard or stressor. *Sensitivity* is the susceptibility of humans in sociodemographic terms to physical hazard, which can also include sensitivities of the built environment. *Adaptive capacity* is any mitigation and adaptation to hazard via sociodemographic factors or other means.

Vulnerability can occur after individuals or communities have experienced an environmental stressor, such as incremental changes in climate (Watson 2001), which is why so much emphasis is placed on projecting a "future," an endpoint of vulnerability—sometimes called *outcome vulnerability*—as a consequence of increased GHGs and resultant climate change. Biophysical effects on humans and physical systems are then projected, and adaptation options can then be formulated.

Contextual vulnerability differs from outcome vulnerability in that it analyzes current vulnerabilities within the current social structure of a given place. An analysis of contextual vulnerability (e.g., economic reliance on river-based tourism) focuses on relationships among political actors (elected officials), institutions (rules for concessionaires), socioeconomic well-being (workforce education level), and culture to identify how goods and information are distributed across society. From this evidence, the analysis projects response to a future threat (e.g., whether guides will be able to maintain their concession for river rafting as in-stream flows decline). The ability of human communities to cope with environmental and societal stressors determines how well they will respond to future stressors. This approach first identifies vulnerable communities, then develops management actions that will improve adaptive capacity.

Socioeconomic vulnerability assessment (SEVA) is a promising approach for linking social and biophysical vulnerabilities to climate change. A SEVA first summarizes secondary data from the U.S. Census Bureau (U.S. Census Bureau 2007) and similar sources. Then, a SEVA (1) briefly discusses the social history of the forest and its human geography, including communities of place and communities of interest, (2) links current and expected biophysical changes to community-relevant outcomes, (3) determines stakeholder perceptions of values at risk, and (4) prioritizes threats to vulnerable communities and identifies those for which adaptation is feasible. This basic approach is flexible enough to accommodate a range of different conditions and levels of detail, depending on the goals of the assessment team.

5.7 Conclusions

Interactions between changes in biophysical environments (climate, disturbance, and ecological function) and human responses to those changes (management and policy) will determine the effects of climate change on human communities. The ultimate effects on people are measured in terms of changes in ecosystem services provided by forested landscapes, including traditional timber products and new extractive uses, rural and urban recreation, cultural resources, contributions of urban forests to human health, and protection of water quality. Climate change has been linked to bioenergy and C sequestration policy options, emphasizing the effect of climate-human interactions on forests as well as the role of forests in mitigating climate change. Any effect of climate change on forests will result in a ripple effect of policy and economic response affecting economic sectors and human communities.

The key mechanism of change in human-dominated landscapes is choice. Where private ownership dominates, choices regarding land use and resource production directly and indirectly affect changes in forest conditions and the flow of ecosystem services. The choices are directly influenced by shifts in land productivity, prices of various products, and ultimately economic returns for different land uses. Land-use shifts in rural areas under climate change could include conversion between forests and agricultural uses, depending on market conditions. Climate changes are expected to alter productivity (local scale) and prices (market scale). Land-use patterns dictate the availability of ecosystem services from forests and from trees within other land types. Both WUI and urban areas are projected to increase, often at the expense of rural forests. Anticipated climate changes, coupled with population growth, strongly increase the extent and value of urban trees in providing ecosystem services and for mitigating climate change impacts at fine scales. However, climate change also increases the challenge of keeping trees healthy in urban environments.

Collective choice, in the form of various policies, also affects land use and forest conditions relative to climate change. Policies targeting climate mitigation, especially for bioenergy production and C sequestration, directly influence forest extent and use. Implemented through markets, these policies yield secondary and tertiary effects on forest composition and structure through direct action and through resource input and product substitutions in related sectors. These and other policies (forest management regulations, land-use restrictions, property taxes) provide a context for and potentially constrain adaptive choices by private landowners.

Human communities in urban, WUI, and rural environments will experience changes to forests as a result of climate change. Those communities dependent on forests for economic or cultural values are likely to see the effects of climate change first. The potential for human communities to adapt to potential climate changes is linked to their exposure to climate change, which differs along the rural-to-urban gradient, and also to the nature of the social and institutional structures in each environment. We can prepare for or mitigate future climate stresses in these environments by ensuring that present-day human communities are resilient and therefore better able to respond to future stresses.

References

Alig, R. J., Plantinga, A. J., Ahn, S., & Kline, J. D. (2003). *Land use changes involving forestry in the United States: 1952 to 1997, with projections to 2050* (Gen. Tech. Rep. PNW-GTR-587, 92pp). Portland: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Brauman, K. A., Dailey, G. C., Duartel, T. K., & Mooney, H. A. (2007). The nature and value of ecosystem services: An overview highlighting hydrologic services. *Annual Review of Environmental Resources, 32*, 67–98.

Brooks, N. (2003). *Vulnerability, risk and adaptation: A conceptual framework* (Working Paper 38, 16pp). Norwich: University of East Anglia, School of Environmental Sciences, Tyndall Centre for Climate Change Research.

Butler, B. J. (2008). *Family forest owners of the United States, 2006* (Gen. Tech. Rep. NRS-27, 73pp). Newtown Square: U.S. Department of Agriculture, Forest Service, Northern Research Station.

Butler, B. J., Tyrrell, M., Feinberg, G., et al. (2007). Understanding and reaching family forest owners: Lessons from social marketing research. *Journal of Forestry, 105*, 348–357.

Cohen, J. D. (2000). Preventing disaster: Home ignitability in the wildland-urban interface. *Journal of Forestry, 98*, 15–21.

Cova, T. J., Drews, F. A., Siebeneck, L. K., & Musters, A. (2009). Protective actions in wildfires: Evacuate or shelter-in-place? *Natural Hazards Review, 10*, 151–162.

Curry, R., Eichman, C., Staudt, A., et al. (2011). *Facing the storm: Indian tribes, climate-induced weather extremes, and the future for Indian country* (28pp). Boulder: National Wildlife Federation, Rocky Mountain Regional Center.

Davidson, D. J., Williamson, T., & Parkins, J. (2003). Understanding climate change risk and vulnerability in Northern forest-based communities. *Canadian Journal of Forest Research, 33*, 2252–2261.

Dimitri, C., Effland, A., & Conklin, N. (2005). *The 20th-century transformation of U.S. agriculture and farm policy* (Economic Information Bulletin Number EIB3, 17pp). Washington, DC: U.S. Department of Agriculture, Economic Research Service.

Fall, S., Niyogi, D., Gluhovsky, A., et al. (2009). Impacts of land use land cover on temperature trends over the continental United States: Assessment using the North American regional reanalysis. *International Journal of Climatology, 30*, 1980–1993.

Food, Conservation, and Energy Act. (2008). *Public Law 110–234*. Washington, DC: V.S. Government.

Gimmi, U., Schmidt, S. M., Hawbaker, T. J., et al. (2011). Decreasing effectiveness of protected areas due to increasing development in the surroundings of U.S. National Park Service holdings after park establishment. *Journal of Environmental Management, 92*, 229–239.

Gordon, J., Berry, J., Ferrucci, M., et al. (2003). *An assessment of Indian forests and forest management in the United States: By the Second Indian Forest Management Assessment Team for the Intertribal Timber Council* (134pp). Portland: Clear Water Printing.

Greenwalt, T., & McGrath, D. (2009). Protecting the city's water: Designing a payment for ecosystem services program. *Natural Resources and Environment, 24*, 9–13.

Hammer, R. B., Stewart, S. I., & Radeloff, V. C. (2009). Demographic trends, the wildland-urban interface, and wildfire management. *Society and Natural Resources, 22*, 777–782.

Haque, C. E., & Etkin, D. (2007). People and community as constituent parts of hazards: The significance of societal dimensions in hazards analysis. *Natural Hazards, 41*, 271–282.

Heisler, G. M. (1986). Energy savings with trees. *Journal of Arboriculture, 12*, 113–125.

Howard, J. L., Westby, R., & Skog, K. E. (2010a). *Criterion 6 indicator 25: Value and volume of wood and wood products production, including primary and secondary processing* (Res. Note FPL-RN-0316, 14pp). Madison: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory.

Howard, J. L., Westby, R., & Skog, K. E. (2010b). *Criterion 6 indicator 28: Total and per capita consumption of wood and wood products in roundwood equivalents* (Res. Note FPL-RN-0317, 20pp). Madison: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory.

Indian Forest Management Assessment Team [IFMAT]. (2003). *An assessment of Indian forests and forest management in the United States* (134pp). Portland: Intertribal Timber Council.

Iverson, L. R., & Prasad, A. M. (2001). Potential changes in tree species richness and forest community types following climate change. *Ecosystems, 4*, 186–199.

Karl, T. R., Melillo, J. M., Peterson, T. C. (Eds.). (2009). *Global climate change impacts in the United States* (196pp). Cambridge: Cambridge University Press.

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

Krutilla, J., & Haigh, J. A. (1978). An integrated approach to National Forest management. *Environmental Law, 8*, 373–415.

Lal, P., Alavalapati, J., & Mercer, D. E. (2010). Socioeconomic impacts of climate change on rural communities in the United States. In R. J. Alig (Tech. Coord.), *Effects of climate change on natural resources and communities: A compendium of briefing papers* (Gen. Tech. Rep. PNW-GTR-837, pp. 73–118). Portland: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. Chapter 3.

Larsen, S. C., Foulkes, M., Sorenson, C. J., & Thomas, A. (2011). Environmental learning and the social construction of an exurban landscape in Fremont County, Colorado. *Geoforum, 42*, 83–93.

Lynn, K., & Gerlitz W. (2006). Mapping the relationship between wildfire and poverty. In P. L. Andrews & B.W. Butler (Comps.), *Fuels management—How to measure success* (Proceedings RMRS-P-41, pp. 401–415). Fort Collins: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Lynn, K., MacKendrick, K., & Donoghue, E. M. (2011). *Social vulnerability and climate change: Synthesis of literature* (Gen. Tech. Rep. PNW-GTR-838, 70pp). Portland: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

McCaffrey, S. (2009). Crucial factors influencing public acceptance of fuels treatments. *Fire Management Today, 69*, 9–12.

McKinley, D. C., Ryan, M. G., Birdsey, R. A., et al. (2011). A synthesis of current knowledge on forests and carbon storage in the United States. *Ecological Applications, 21*, 1902–1924.

Mendehsohn, R., Basist, A., Dinar, A., et al. (2007). What explains agricultural performance: Climate normals or climate variance? *Climatic Change, 81*, 85–99.

Mendelsohn, R., Nordhaus, W. D., & Shaw, D. (1994). The impact of global warming on agriculture: A Ricardian analysis. *American Economic Review, 84*, 753–771.

National Fire Protection Association [NFPA]. (2011). *Firewise at NFPA: A brief history*. http://www.firewise.org/About/History.aspx. Accessed 10 Jan 2012.

Nowak, D. J. (2000). The interactions between urban forests and global climate change. In K. K. Abdollahi, Z. H. Ning, & A. Appeaning (Eds.), *Global climate change and the urban forest* (pp. 31–44). Baton Rouge: GCRCC and Franklin Press.

Nowak, D. J. (2010). Urban biodiversity and climate change. In N. Muller, P. Werner, & J. G. Kelcey (Eds.), *Urban biodiversity and design* (pp. 101–117). Hoboken: Wiley-Blackwell Publishing.

Nowak, D. J., & Greenfield, E. J. (2012a). Tree and impervious cover change in U.S. cities. *Urban Forestry and Urban Greening, 11*, 21–30.

Nowak, D. J., & Greenfield, E. J. (2012b). Tree and impervious cover in the United States. *Landscape and Urban Planning, 107*, 21–30.

Nowak, D. J., Greenfield, E. J., Hoehn, R., & La Point, E. (2013). Carbon storage and sequestration by trees in urban and community areas of the United States. *Environmental Pollution, 178*, 229–236.

Nowak, D. J., & Walton, T. (2005). Projected urban growth and its estimated impact on the U.S. forest resource (2000–2050). *Journal of Forestry, 103*, 383–389.

Nowak, D. J., Rowntree, R. A., McPherson, E. G., et al. (1996). Measuring and analyzing urban tree cover. *Landscape and Urban Planning, 36*, 49–57.

Nowak, D. J., Noble, M. H., Sisinni, S. M., & Dwyer, J. F. (2001). Assessing the US urban forest resource. *Journal of Forestry, 99*, 37–42.

Nowak, D. J., Crane, D. E., & Dwyer, J. F. (2002a). Compensatory value of urban trees in the United States. *Journal of Arboriculture, 28*, 194–199.

Nowak, D. J., Stevens, J. C., Sisinni, S. M., & Luley, C. J. (2002b). Effects of urban tree management and species selection on atmospheric carbon dioxide. *Journal of Arboriculture, 28*, 113–122.

Nowak, D. J., Walton, J. T., Dwyer, J. F., et al. (2005). The increasing influence of urban environments on U.S. forest management. *Journal of Forestry, 103*, 377–382.

Nowak, D. J., Crane, D. E., & Stevens, J. C. (2006). Air pollution removal by urban trees and shrubs in the United States. *Urban Forestry and Urban Greening, 4*, 115–123.

Pachauri, R. K., & Reisinger, A. (Eds.). 2007. *Climate change 2007: Synthesis report* (104pp). Cambridge: Cambridge University Press.

Pevar, S. L. (1992). *The rights of Indians and tribes: The basic ACLU guide to Indian and tribal rights* (2nd ed., 315pp). Carbondale: Southern Illinois University Press.

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

Radeloff, V. C., Hammer, R. B., & Stewart, S. I. (2005). The wildland urban interface in the United States. *Ecological Applications, 15*, 799–805.

Radeloff, V. C., Stewart, S. I., Hawbaker, T. J., et al. (2010). Housing growth in and near United States' protected areas limits their conservation value. *Proceedings of the National Academy of Sciences, USA, 107*, 940–945.

Schlenker, W., & Roberts, M. J. (2009). Nonlinear temperature effects indicate sever damages to US crop yields under climate change. *Proceedings of the National Academy of Sciences, USA, 106*, 15594–15598.

Shepherd, J. M. (2005). A review of current investigations of urban-induced rainfall and recommendations for the future. *Earth Interactions, 9*, 1–6.

Shepherd, J. M., Pierce, H., & Negri, A. J. (2002). Rainfall modification by major urban areas: Observations from spaceborne rain radar on the TRMM satellite. *Journal of Applied Meteorology, 41*, 689–701.

Slovik, P. (1987). Perception of risk. *Science, 236*, 280–285.

Smit, B., & Wandel, J. (2006). Adaptation, adaptive capacity and vulnerability. *Global Environmental Change, 16*, 282–292.

Smith, W. B., Miles, P. D., Perry, C. H., & Pugh, S. A. (2009). *Forest resources of the United States, 2007* (Gen. Tech. Rep. WO-78, 336pp). Washington, DC: U.S. Department of Agriculture, Forest Service.

Solomon, S., Qin, D., Manning, M., et al. (2007). *Climate change 2007: The physical science basis—Contribution of Working Group I to the fourth assessment report of the Intergovernmental Panel on Climate Change* (996pp). Cambridge: Cambridge University Press.

Theobald, D. M., & Romme, W. H. (2007). Expansion of the US wildland–urban interface. *Landscape and Urban Planning., 83*, 340–354.

U.S. Census Bureau. (2007). *U.S. census data*. www.census.gov. Accessed Jan 2007.

U.S. Department of Agriculture, Economic Research Service [USDA ERS]. (2011). *Atlas of rural and small-town America*. http://www.ers.usda.gov/data/ruralatlas

U.S. Department of Agriculture, Forest Service [USDA FS]. (2011). *National report on sustainable forests—2010* (FS-979). Washington, DC.

U.S. Department of Agriculture, Forest Service [USDA FS]. (2012). *Future of Americas forest and rangelands: Forest Service 2010 Resources Planning Act assessment* (Gen. Tech. Rep. WO-87, 198pp). Washington, DC.

U.S. Environmental Protection Agency. (2008). *Heat island effect*. http://www.epa.gov/hiri/. Accessed July 2008.

Vose, J. M., Peterson, D. L., & Patel-Weynand, T. (2012). Effects of climatic variability and change on forest ecosystems: a comprehensive science synthesis for the U.S. forest sector. (Gen. Tech. Rep. PNW-GTR-870, 265 pp). Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Wade, A. A., & Theobald, D. M. (2010). Residential development encroachment on U.S. protected areas. *Conservation Biology, 24*, 151–161.

Watson, R. T. (Ed.). (2001). *Climate change 2001: Synthesis report* (398pp). Cambridge/New York: Cambridge University Press.

Wear, D. N. (2011). *Forecasts of county-level land uses under three future scenarios: A technical document supporting the Forest Service 2010 RPA assessment* (Gen. Tech. Rep. SRS-141, 41pp). Asheville: U.S. Department of Agriculture, Forest Service, Southern Research Station.

Wear, D. N., & Greis, J. G. (Eds.). (2011). *The Southern forest futures project: Technical report*. http://www.srs.fs.usda.gov/futures/reports/draft/pdf/technicalreport.pdf. Accessed 27 June 2012.

Wear, D. N., & Prestemon, J. (2004). Timber market research, private forests, and policy rhetoric. In M. Rauschner, & K. Johnsen (Eds.), *Southern forest science: Past, present and future* (Gen. Tech. Rep. SRS-75, pp. 289–300). Asheville: U.S. Department of Agriculture, Forest Service, Southern Research Station.

Williams, M. (1989). *Americans and their forests: A historical geography* (599pp). New York: Cambridge University Press.

Willkinson, C. F., & Anderson, H. M. (1987). *Land and resource planning in the national forests* (396pp). Washington, DC: The Island Press.

Yaffee, S. L. (1994). *The wisdom of the spotted owl: policy lessons for a new century* (430pp). Washington, DC: Island Press.