Future of America's Forests and Rangelands

Forest Service
2010 Resources Planning Act Assessment

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Abstract

The 2010 Resources Planning Act (RPA) Assessment summarizes findings about the status, trends, and projected future of forests, rangelands, wildlife and fish, biodiversity, water, outdoor recreation, wilderness, and urban forests, as well as the effects of climate change upon these resources. The outlook for U.S. resources is largely influenced by a set of scenarios that have varying assumptions about global population and economic growth, global wood energy consumption, U.S. population and economic growth, land use change, and global climate change from 2010 to 2060. Four key themes from the findings are (1) land development will continue to threaten the integrity of natural ecosystems, (2) climate change will alter natural ecosystems and affect their ability to provide goods and services, (3) competition for goods and services from natural ecosystems will increase, and (4) geographic variation in resource responses to drivers of change will require regional and local strategies to address resource management issues. The results from this report will be useful to resource managers and policymakers as they develop strategies to sustain natural resources.

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Acknowledgments

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Executive Summary

The 2010 Resources Planning Act (RPA) Assessment is the fifth report prepared in response to the mandate in the 1974 Forest and Rangeland Renewable Resources Planning Act (Public Law 93–378, 88 Stat 475, as amended). This report summarizes findings about the status, trends, and projected future of forests, rangelands, wildlife and fish, biodiversity, water, outdoor recreation, wilderness, and urban forests, and the effects of climate change upon these resources. The results will be useful to resource managers and policymakers as they develop strategies to sustain natural resources. The Forest Service, an agency of the U.S. Department of Agriculture, will continue to use the results to inform strategic planning and forest planning.

The 2010 RPA Assessment outlook for U.S. resources is largely influenced by a set of RPA scenarios with varying assumptions about global population and economic growth, global wood energy consumption, U.S. population and economic growth, U.S. land use change, and global climate change from 2010 to 2060.

Key Themes

Land development will continue to threaten the integrity of natural ecosystems.

Urban and developed land area is projected to increase across RPA scenarios between 41 and 77 percent by 2060. Although urban and developed land area remains a relatively small percentage of the U.S. land base, this expansion occurs at the expense of forest and rangelands. Forest land area is affected the most: forest losses are projected to range from 16 to 34 million acres in the conterminous United States. The South Region is expected to have the greatest loss of forest, ranging from 9 to 21 million acres, roughly 4 to 8 percent of the South's 2007 forest land base.

The loss of forest land contributes to reduced growth in total forest inventory, reduced forest carbon stocks, and reduced tree canopy cover. Forest inventory volumes are expected to peak between 2020 and 2030, followed by a decline in volume to 2060. Only in one RPA scenario is inventory volume in 2060 less than in 2010, however. Carbon stocks are also projected to decrease across all RPA scenarios as a result of declining forest land area and changes in carbon stored per acre. The result is that forest land becomes an emissions source in future decades, the tipping point varying by the particular dynamics of land use change and timber harvest levels in each RPA scenario.

Although the loss of acres is important, low-density development may pose a greater threat to the integrity of remaining forest and rangelands through the effects of fragmentation. The expansion of housing in the wildland-urban interface and housing development around public lands fragment natural land covers and often lead to additional development. Habitat loss and degradation are major causes of species endangerment. At-risk species tend to be prominent in areas with high human-population densities, where land use intensification has occurred, or where species with restricted ranges are concentrated. Given the projected land use changes, biodiversity in the United States is expected to continue to erode.

Climate change will alter natural ecosystems and affect their ability to provide goods and services.

Changes in temperature and precipitation generally had limited effects on the distribution of forest types and forest inventory during the RPA projection period, but those effects were more noticeable in the Western United States. At least in the immediate future, climate change is not posing a risk to having sufficient inventory to sustain forest products production. The risk to providing other forest ecosystem services is not known, however, nor is the potential effect of increasing occurrences of extreme events.

Rangeland ecosystems typically occur in areas of environmental limitations. The diversity of rangeland ecosystems, the multitude of current stressors, and the potential changes in climate will result in highly diverse responses to climate change across rangeland systems. Effects on forage availability, with consequences to ranch enterprises of livestock, game, or tourism will require flexible, and possibly novel, management to maintain rangeland health and economic viability.

Climate change is projected to have substantial effects on water demand and supply. The primary effects of climate change on water demand are increases in agricultural irrigation and landscape watering in response to rising plant water needs. Across a range of RPA scenario-climate combinations, water withdrawal would increase from 2 to 42 percent from 2005 to 2060. The result of the combination of increasing water demand and declining water yields is an increase in vulnerability of the U.S. water supply to shortage, especially in the larger Southwest and Great Plains.

Change in terrestrial wildlife habitats will affect both the current habitat of wildlife species and their ability to migrate if habitats change. The grassland-forest land transition throughout the Central United States and the steep elevation gradients in the Intermountain West will be most exposed to habitat stress caused by a shifting climate regime. A comparison of areas of future stress to areas of current stress associated with the distribution of at-risk species and intense land uses indicated that the location of high current stressors tends not to overlap well with the location of high future stress associated with climate change. This lack of overlap potentially complicates the efforts of managers to prioritize wildlife conservation actions.

Climate variables only slightly affected outdoor recreation participation, with results indicating slight increases or decreases in participation rates and days of participation that varied across outdoor recreation activities. The exceptions were snowmobiling and undeveloped skiing (cross-country skiing and snowshoeing), for which climate effects resulted in substantial declines. The effects of climate change on the recreation environment are also expected to affect future outdoor recreation opportunities.

Competition for goods and services from natural ecosystems will increase.

Increasing water demands are likely to increase competition between water uses. The water projections indicate that the United States is on a pathway to unsustainable levels of water use in several regions across a range of RPA scenarios. Increased water use efficiencies, water demand reductions, increased trading or sale of water rights, and higher pricing for water consumed are possible mechanisms that could help to bring water supplies into balance with future water demands. Future water use levels depend most importantly on uses in the agriculture sector because irrigation requirements are highly sensitive to changing precipitation and temperature patterns. The current outlook indicates that demand pressures will increase, continuing or increasing current groundwater mining and further depleting streamflows, especially in drier areas of the United States. These pressures, in combination with development effects on water quality, raise concerns about the health and relative abundance of aquatic species in the future.

Species associated with aquatic habitats have higher proportions of at-risk species than other species groups. The condition of aquatic systems varies across the United States. Nationwide, more than one-half of monitored lakes were ranked in good condition, but only 28 percent of wadeable streams were ranked in good condition. Imperiled aquatic species tend to occur in areas with high population density, and many of those areas are projected to have increased population and development in the future. Maintaining or improving water quality and streamflows is likely to be challenging, especially in the face of increasing development pressure and water demands.

The availability of suitable land may constrain growing recreation demand. A stable public land base, a declining private natural land base, and increasing numbers of outdoor recreation participants are expected to result in increased conflicts among recreationists and declines in the quality and number of per-person recreation opportunities. The ability of recreation resources to absorb additional demand varies widely across the United States. The limited amount of public land in the East, where most forest land is privately owned, will likely be under greater stress from additional demand than public lands in the West. Pressures are likely to be greatest on public lands near large and growing population centers.

In contrast to the water and outdoor recreation situations, future demands for livestock forage and forest products can be met out to 2060 for most RPA scenarios, despite the projected losses in land area devoted to these uses. Currently, forage availability exceeds forage demand on 98 percent of all rangeland, and little increased grazing pressure on rangeland is expected in the near future. Given the current general abundance of forage, effects of climate change on ranch enterprises are likely to be localized.

Timber resources are projected to be abundant enough to meet demands, especially if we continue to see efficiency gains in harvesting and conversion technology. Only the RPA scenario with the highest increase in wood biomass use for energy is expected to lead to potential competition for land resources with other uses, particularly with agriculture. The high harvest levels to meet these demands may create conflict with other forest uses. For example, the projected expansion of planted pine in the South Region to meet those biomass energy demands would displace natural pine, which may be undesirable from a biodiversity perspective.

Geographic variation in resource responses to drivers of change will require regional and local strategies to address resource management issues.

Projected population growth rates—and associated urban and suburban development patterns—vary across the United States. Areas with high population growth rates will see large expansions of urban areas, unless local and regional master plans are in place to manage the growth effects. Trees in urban areas—the urban forest—deliver a variety of ecosystem services. Retaining and managing trees in newly developed urban areas will be increasingly important in the future to continue receiving ecosystem services that are critical to urban quality of life. Low-density development patterns are more difficult to predict but are more likely to occur in rural areas where population continues to grow than in areas where population declines are projected.

Development will also affect rangelands, even though the proportional loss of rangelands is smaller than for forest land area. Rangeland areas with the highest levels of fragmentation occur where agricultural land uses are prevalent. Many of these areas have projected declines in population, which should stem development pressure. Expansion of farming could result in the conversion of some rangelands to crops in places suitable for increased agricultural production, particularly if crop prices remain high. Conversely, several areas—particularly in the Southwest—that currently have relatively little fragmentation will likely be exposed to development pressure from population growth.

The projected changes in vulnerability of the U.S. water supply vary geographically. Decreases in water yield (that in turn affects water supply) have a greater effect on future vulnerability than the effect of increases in water demand in about half of the assessment subregions (ASRs) where vulnerability is projected to increase. In some ASRs, the combined effect of changes in water yield and demand lead to untenable levels of vulnerability, suggesting that adaptation to water shortage there will be essential. Currently, the West has more areas of higher vulnerability. Future increases in vulnerability may also affect some parts of the East, along with becoming more prevalent in the West.

Imperiled aquatic species are concentrated in the Eastern and Southwestern United States. Where increased risks of water shortages are projected, threats to aquatic species are likely to increase. Conflicts about water uses, maintenance of instream flows, eroding water quality, and prices for water and water rights are all likely to increase in the future, exacerbating the threats to these species. Water policymakers and water rights owners are likely to face more tensions among water uses and pressures to change or adapt existing policies to better reflect shifting water use values.

Looking Forward

The United States has abundant natural resources. A growing population is projected to lead both to increased demands for a wide array of goods and ecosystem services from forests and rangelands and to shifts in land uses as public values for certain goods and services change. Woody biomass production to promote domestic energy security is a prime example.

The outlook shown in this report is based on a continuation of current natural resource management policies in the face of projected changes in demographic and economic conditions and social values. The results highlight a number of areas in which pressures may emerge on policymakers to change current policies or develop new policy approaches. The negative effects on the environment, economy, and society portrayed by the scenarios in this RPA Assessment are not foregone conclusions. They can be avoided by timely actions from policymakers and land managers. This RPA Assessment lays the scientific foundation for taking action and dealing with the issues before their full effect is felt.

Chapter 1. Introduction

The 2010 Resources Planning Act (RPA) Assessment is the fifth report prepared in response to the mandate in the 1974 Forest and Rangeland Renewable Resources Planning Act (Public Law 93-378, 88 Stat 475, as amended). The RPA Assessment is intended to provide reliable information on the status, trends, and projected future of the Nation's renewable natural resources on forests and rangelands on a 10-year cycle. The RPA Assessment includes analyses of forests, rangelands, wildlife and fish, biodiversity, water, outdoor recreation, wilderness, and urban forests and the effects of climate change upon these resources.

The Forest and Rangeland Renewable Resources Planning Act recognized the importance of natural resources to people's well-being and quality of life. The American public continues to depend on our forests and rangelands to provide a variety of ecosystem services. The intent of the RPA Assessment is to provide information for policymakers and resource managers to help address the challenges of satisfying diverse natural resource demands in the future.

The RPA Assessment reports on a body of targeted research funded by the Forest Service, an agency of the U.S. Department of Agriculture, to address the RPA legislative mandate, both providing historical trends and projecting likely futures. The RPA Assessment is not a comprehensive synthesis of status, trends, and projections of all renewable natural resources. Our research focuses on analyzing the influences of multiple drivers of change on renewable natural resources during the next 50 years. This focus is a particularly important point with regard to the potential effects of climate change, as we have included climate variables to assess the potential effects on future resource trends into our modeling structure, just as we incorporate demographic, economic, and other variables in our models.

Document Organization

Following this introduction, the key results of the 2010 RPA Assessment are presented in two chapters. The first focuses on linkages across resource analyses (chapter 2), and the second presents highlights by individual resource topic (chapter 3). Following these summary chapters, we describe global and U.S. trends that affect the renewable resource situation (chapter 4) and the future scenarios used as the basis for the 2010 RPA Assessment projections (chapter 5).

Chapters 6 through 14 present findings by resource area or resource sector. The information presented in these chapters begins with historical information that is tracked across RPA Assessment reporting cycles. Changes in historical trends are of particular interest because future projections are tied to historical trends. Future resource conditions, demand, and supply are projected for 50 years (2010 to 2060 in this RPA Assessment cycle) for those resources for which sufficient data were available. The projections assume no changes in policies. The 5-year RPA Assessment update cycle will evaluate potential effects of policy change on resource futures.

This document summarizes the results of analyses that are documented in more detail in a series of technical supporting documents referenced throughout the following chapters. These supporting documents provide more details on data, methods, and results.[1]

Scope of the Analysis

The renewable natural resources included in the RPA Assessment reflect the mandated national focus and the natural resources and related economic sectors for which the Forest Service also has related management responsibilities, including forests, rangelands, wildlife and fish, outdoor recreation, and water. The national focus limited us to analyzing those resources for which nationally consistent data are available or for which data can be consistently compiled to the national level. In many cases, our analyses only cover the conterminous United States because of data limitations.

We capitalize on those areas in which the Forest Service has research capacity. We also use the expertise of other Federal agencies that have responsibilities for national analyses by using their data and incorporating their reports by reference. For example, we rely on information from the U.S. Environmental Protection Agency about water quality. Similarly, we do not

[1] RPA Assessment supporting technical documents are available on the Forest Service's RPA Assessment Web page as they become available: http://www.fs.fed.us/research/rpa/.

analyze renewable energy, with the exception of wood-based bioenergy, because the U.S. Department of Energy conducts comprehensive analyses of the energy sector.

The 2010 RPA Assessment is the fifth report since the RPA legislation was passed in 1974. Rather than attempt to synthesize all existing research on the status and trends of natural renewable resources, we continue to target our research to improve our understanding of the multiple and interacting factors that we expect to affect natural resources in the future. This focus is a unique contribution that provides important information to policymakers and resource managers as they develop strategies for sustaining the Nation's renewable natural resources.

Chapter 2. Synthesis of 2010 RPA Assessment Results

The 2010 Resources Planning Act (RPA) Assessment summarizes the present condition and future outlook for the Nation's renewable natural resources. We used a set of scenarios (hereafter referred to as RPA scenarios) to analyze the future effects of human and environmental influences on our forests and rangelands. The RPA scenarios differ in their assumptions about the rate of population growth, economic growth, land use change, biomass energy use, and climate change during the next 50 years. The RPA scenarios, described in chapter 5, enabled us to test the sensitivity of natural resources to these influences to provide better information to policymakers and resource managers about potential resource futures. In this chapter, we focus on integrative resource management themes that synthesize findings across the resource analyses described in chapters 6 through 14, and we identify how underlying drivers of change influence future resource conditions. In the next chapter, we focus on individual resource key findings.

Resource Highlights

Integrative Resource Management Themes

- Land development will continue to threaten the integrity of natural ecosystems.
- Climate change will alter natural ecosystems and affect their ability to provide goods and services.
- Competition for goods and services from natural ecosystems will increase.
- Geographic variation in resource responses to drivers of change will require regional and local strategies to address resource management issues.

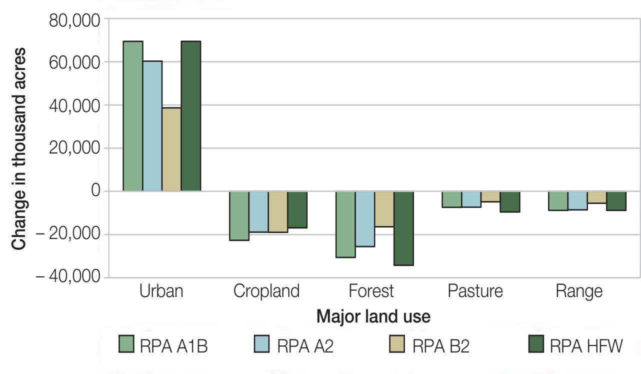
Land development will continue to threaten the integrity of natural ecosystems.

Land development—including the expansion of housing, commercial enterprises, industrial capacity, and related facilities such as roads, mines, and electricity generating plants—already strongly influences natural ecosystems, particularly in the Eastern United States, with its higher population density and limited amount of Federal land. Whereas urbanization tends to convert ecosystems, low-density development in more rural landscapes tends to fragment natural ecosystems.

Population and economic growth will fuel the expansion of developed and urban land uses, with increases across RPA scenarios ranging from 41 to 77 percent. Although urban and developed land area remains a relatively small percentage of the U.S. land base, this expansion occurs at the expense of forest and rangelands. We project a loss of forest and rangeland across all RPA scenarios; the only difference across scenarios is in the relative scale of the loss (figure 1). These losses have a variety of effects on natural resources, both through the absolute loss of acres and via changes in the character of the remaining resource base.

Forest land is the land use most affected by urbanization and developed uses, with the greatest losses in the South Region, where we project losses of up to 21 million acres by 2060, or up to 8 percent of the region's forest land base. Rangeland losses are projected to be greatest in the Rocky Mountain Region, where up to 4.4 million acres (about 2 percent of total rangeland in the region) could be lost.

Figure 1. Projected cumulative change in the area of major non-Federal land uses in the conterminous United States, by RPA scenario, 2010–2060.



The loss of forest land contributes to reduced growth in total forest inventory, reduced forest carbon stocks, and reduced tree canopy cover. Forest inventory volumes demonstrate the same general pattern of change in all RPA scenarios: a peaking of volume between 2020 and 2030, followed by a decline in volume to 2060. This projected future reverses the historical trend of increasing volumes, but only one RPA scenario results in a lower inventory volume in 2060 than exists in 2010. This lower volume is the combined result of forest land loss and high harvest rates. Hardwood inventories are more severely affected because forest losses are more often coincident with hardwood forest types.

Although forests continue to sequester substantial amounts of carbon, carbon stocks are projected to decrease across all RPA scenarios, a result of declining forest land area and changes in carbon stored per acre. The result is that forests become an emissions source in future decades, the tipping point varying by the particular dynamics of land use change and timber harvest levels in each RPA scenario.

Decreases in tree canopy cover occur because urbanization is projected to affect forests more than other land covers. As urban growth reduces the area of natural ecosystems, urban forests are likely to increase in significance as local residents increasingly rely on the crucial ecosystem services these forests can provide.

Rangelands are projected to decline at a slower rate than in recent decades. Rangeland ecosystems may be more threatened by low-density development and fragmenting agents such as oil and gas development.

Land area is crucial to the support of wildlife species. Most forest bird communities were projected to support a lower variety of species across all RPA scenarios, especially species that prefer intact interior habitats. Only species associated with human settlements are expected to increase. Habitat loss is a major cause of species endangerment. At-risk species show some degree of association with high human population densities, human population growth, and areas known to support high numbers of species with restricted ranges. Given the projected land use changes, we concluded that biodiversity in the United States will continue to erode.

Loss of forest and rangelands will reduce outdoor recreation opportunities on private lands. In addition to the loss of area, land conversion may further fragment surrounding private lands. Development around public lands can also reduce access to public lands, thereby limiting recreation opportunities on public lands.

Land development, in its effects on total area of natural ecosystems and on their pattern and condition, is clearly a crucial factor affecting the future of all natural resources considered in this assessment. Development is inevitable to meet the needs of a growing population, but that same population also demands goods and services from natural ecosystems. Balancing those needs will remain a challenge into the future.

Climate change will alter natural ecosystems and affect their ability to provide goods and services.

Native insects and disease, wildfire, and other natural disturbances such as extreme weather events are part of the natural landscape. Periods of less-than-normal precipitation and above-normal temperatures interact with other stresses to increase the risk of wildfire and to reduce the resistance of ecosystems to insects and pathogens. Climate change will alter these natural disturbances and interact with human disturbances. For example, climate change may further enhance the spread of invasive species.

Climate change is already influencing forest health. High levels of tree mortality in the first decade of the 2000s were largely the result of bark beetle activity in the West after severe regional droughts in combination with susceptible forest stand conditions. Climate change is also expected to increase the number and size of wildfires, particularly in western forests and rangelands. Climate change will affect the ability of natural ecosystems and developed areas to sustain trees. Increasing aridity is projected for much of the United States, which will reduce the ability of some areas to maintain tree cover or change species type.

Forest inventory was projected under a range of RPA scenario-climate combinations. Projected changes in temperature and precipitation across a range of RPA scenario-climate combinations generally had limited effects on the distribution of forest types and inventory across the United States, but those effects were more pronounced in the Western United States. For example, in the Rocky Mountain Region, both Douglas-fir and lodgepole pine decline across all RPA scenarios. For

Douglas-fir, declines range from 20 to 38 percent of its 2010 area; for lodgepole pine, declines range from 6 to 28 percent. At least in the immediate future, changes in temperature and precipitation are not posing a risk to sufficient inventory to support forest products demand, particularly in the South Region. The risk to providing other forest ecosystem services is not known, nor is the potential effect of increasing occurrences of extreme events.

Rangeland ecosystems typically occur in areas of environmental limitations and, as a consequence, have developed a diverse suite of adaptations to the moisture limitations typical of these ecosystems. These adaptations, the future changes in precipitation and temperature, and the future increases in atmospheric carbon dioxide complicate our ability to determine the potential effects of climate change on rangelands. If, as projected, northern latitudes warm while maintaining or increasing precipitation, productivity on northern and high-altitude rangelands could be enhanced. In the Southwestern United States, where projections indicate sharp increases in temperature coupled with decreased precipitation, rangeland productivity will likely decrease, with only the most drought-tolerant species prevailing. Importantly, several studies indicate that climate change, in combination with increased fire frequency and intensity, may exacerbate current management challenges, such as woody encroachment and invasive species. The diversity of rangeland ecosystems, the multitude of current stressors, and the potential changes in climate will result in highly diverse responses to climate change across rangeland systems. Effects on forage availability, with consequences to ranch enterprises of livestock, game, or tourism, will require flexible, and possibly novel, management to maintain rangeland health and economic viability.

Climate change is projected to have substantial effects on water demand and supply. Water demands are increasing, but the growth in population and economic activity alone are comparatively minor sources of the increase. The primary effects of climate change on water demand are increases in agricultural irrigation and landscape watering in response to rising plant water needs. In the absence of climate change, total U.S. water withdrawal was projected to decrease slightly or increase up to 8 percent by 2060, depending on the RPA scenario. Across a range of RPA scenario-climate combinations, however, water withdrawal would increase from 2 to 42 percent from 2005 to 2060 (figure 2). Similarly, water yields, affected only by changes in precipitation and temperature, decline under all RPA scenario-climate combinations (figure 3). The combination of increasing water demand and declining water yields leads to an increase in vulnerability of the water supply to shortage in large portions of the United States, especially in the larger Southwest and Great Plains.

Terrestrial wildlife habitats, already affected by fragmentation and encroachment of urban and developed areas, will be

Figure 2. Past and projected water withdrawal for the conterminous United States for nine RPA scenario-climate combinations and RPA A1B with no climate effects, 1985–2060. Future years are multiyear averages.

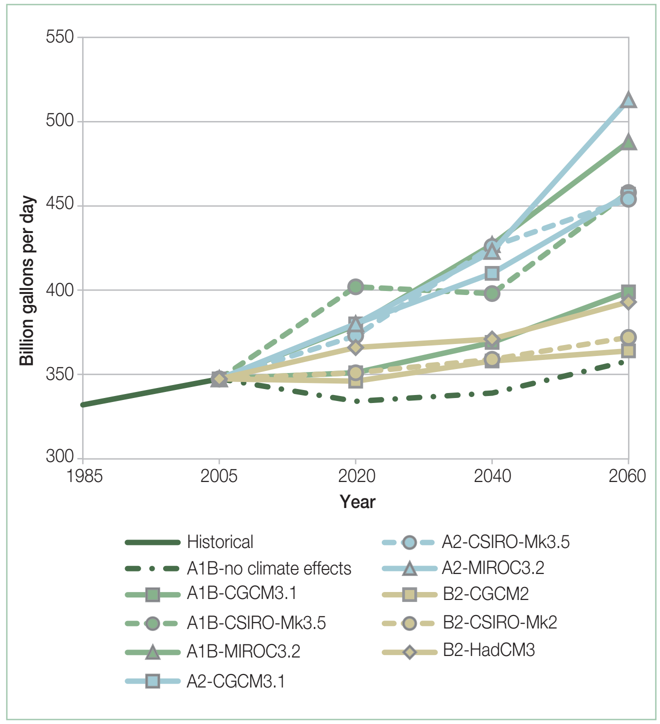
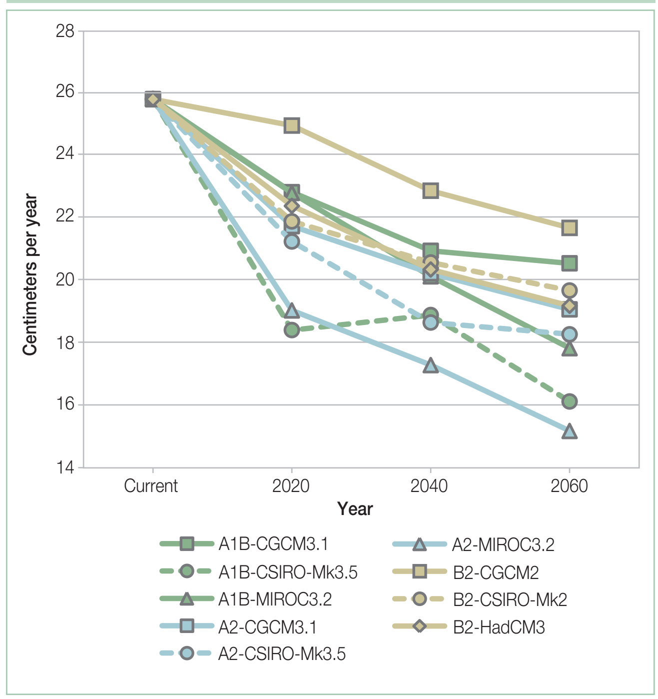


Figure 3. Mean annual water yield in the conterminous United States by RPA scenario-climate combination for four 20-year periods. "Current" yield is evaluated over the 20-year period, 1986–2005. Future yield is estimated for three 20-year periods centered at 2020, 2040, and 2060.

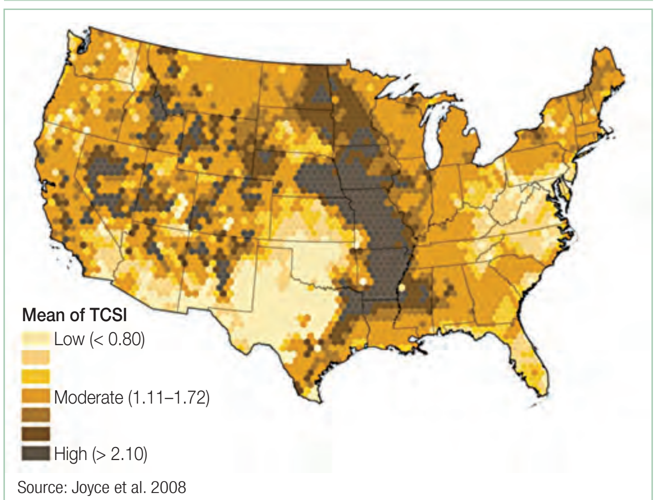


stressed further by changes to terrestrial habitat attributed to climate change. We defined an index of habitat stress based on the degree of change in an area's climate regime (temperature and precipitation), habitat quality (vegetation productivity), and habitat area (distribution of broad vegetation types) between the recent history and projected future. Based on this index, we found that the grassland-forest land transition throughout the Central United States and the steep elevation gradients in the Intermountain West will be most exposed to habitat stress caused by a shifting climate regime (figure 4). We also compared areas of future stress to areas of current stress associated with the distribution of at-risk species and intense land uses, and results indicated that the location of high current stressors tend not to overlap well with the location of high future stress associated with climate change. This lack of overlap potentially complicates the efforts of managers to prioritize wildlife conservation actions.

Climate change is expected to affect both individual willingness to participate in outdoor recreation activities and the level of participation. Climate variables used in the outdoor recreation participation models mostly resulted in a slight increase or decrease in the participation rates or average days of participation compared with the "no climate change" projection. Climate effects resulted in substantial declines in snowmobiling and undeveloped skiing, however. We were not able to incorporate the effects of climate change on the recreation environment, which is also likely to affect future outdoor recreation opportunities.

This analysis of climate change effects on renewable natural resources suggests that climate change will alter natural ecosystems in ways that we understand and in ways that will surprise. The ability of the forest and rangelands to continue to produce ecosystem services will be affected particularly as climate

Figure 4. Mean Terrestrial Climate Stress Index (TCSI) based on the average across multiple alternative futures.



change affects human population distribution patterns, which in turn will affect patterns of land use change. Consideration of these interactive effects will be important for designing flexible resource management strategies, particularly at local and regional scales, where the effects will be evident.

Competition for goods and services from natural ecosystems will increase.

The United States has abundant natural resources, but an increasing population and economic growth combined with climate change effects will put continuing pressure on these resources. The effects of land use change and climate change were summarized in the previous two topics. In this topic, we examine areas in which competition for resources is likely to require resource managers and planners to address important resource tradeoffs.

Increasing water demands are likely to increase competition between water uses. The water projections indicate that the United States is on a pathway to unsustainable levels of water use in several regions across a range of RPA scenarios. Increased water use efficiencies, water demand reductions, increased trading or sale of water rights, and higher pricing for water consumed are possible mechanisms that could help to bring water supplies into balance with future water demands. Future water use levels depend most importantly on uses in the agriculture sector, because irrigation consumes the bulk of the U.S. water supply and because irrigation requirements are highly sensitive to changing precipitation and temperature patterns. The current outlook indicates that demand pressures will increase, continuing or increasing current groundwater mining and further depleting streamflows, especially in drier areas of the United States. These pressures, in combination with development effects on water quality, raise concerns about the health and relative abundance of aquatic species in the future.

Species associated with aquatic habitats have higher proportions of at-risk species than other species groups. The condition of aquatic systems varies across the United States. Nationwide, more than one-half of monitored lakes were ranked in good condition, but only 28 percent of wadable streams were ranked in good condition. Imperiled aquatic species tend to occur in areas with high population density, and many of those areas are projected to have increased population and development in the future. Maintaining or improving water quality and streamflows will be challenging, especially in the face of increasing development pressure and water demands. In addition to effects on imperiled aquatic species, commercial and recreational fisheries could be negatively affected.

The availability of suitable land may constrain growing recreation demand. A stable public land base, a declining private natural land base, and increasing numbers of outdoor recreation participants are expected to result in increased conflicts among recreationists and declines in the quality and number of per-person recreation opportunities. The ability of recreation resources to absorb additional demand varies widely across the United States. The limited amount of public land in the East, where most forest land is privately owned, will likely put greater stress on outdoor recreation opportunities than will be experienced in the West. Pressures are likely to be greatest on public lands near large and growing population centers.

Despite the loss of land area, we expect the resource base to be able to meet future demands for livestock forage and forest products under most RPA scenarios. Currently, forage availability exceeds forage demand on 98 percent of all rangeland. Projections of slight increases in cattle numbers through 2020 indicate little increased grazing pressure on rangeland in the near future. The ability of rangeland to meet future increases in cattle numbers will depend on market developments and on future rangeland productivity. Given the current general abundance of forage, the effects of climate change on ranch enterprises are likely to be localized.

Timber resources are projected to be abundant enough to meet demands, especially if we continue to see efficiency gains in harvesting and conversion technology. Only the RPA scenario with the highest increase in wood biomass use for energy (figure 5) is expected to lead to potential competition for land resources with other uses, particularly with agriculture. The high harvest levels required to meet these demands may create conflict with other forest uses. For example, the projected expansion of planted pine in the South Region to meet those biomass energy demands would displace natural pine, which may be undesirable from a biodiversity perspective.

Forest and rangelands are projected to be able to meet commodity demands into the future across most RPA scenarios, with the exception of water resources. Water shortages, which are already affecting many areas of the country, are expected to increase in the future in the absence of policy change. The outlook for wildlife, particularly aquatic species, is less assured, as is the outlook for recreation resources. Demands on one resource often influence conditions of other resources (such as the effect of water demands on instream flow for aquatic species). These interactions need to be considered in designing resource policy and management strategies.

Geographic variation in resource responses to drivers of change will require regional and local strategies to address resource management issues.

The effects of human and natural forces on natural resources vary across geographic regions. Examples from various resource analyses are presented here to illustrate that management strategies must be flexible enough to address local and regional needs.

Urbanization and development have been identified as future causes of both loss of natural environments and degradation through fragmentation and other effects. Projected population growth rates—and associated urban and suburban development patterns—vary across the United States. Figure 6 shows the projected change in population density by county between 2010 and 2060 for the RPA scenario with medium population growth, demonstrating the highly variable pattern of population growth expected in the future. Those areas with the highest increase in population density will drive urbanization, as

Figure 5. Annual U.S. wood fuel feedstock consumption, 1970–2010, and projections by RPA scenario, 2020–2060.

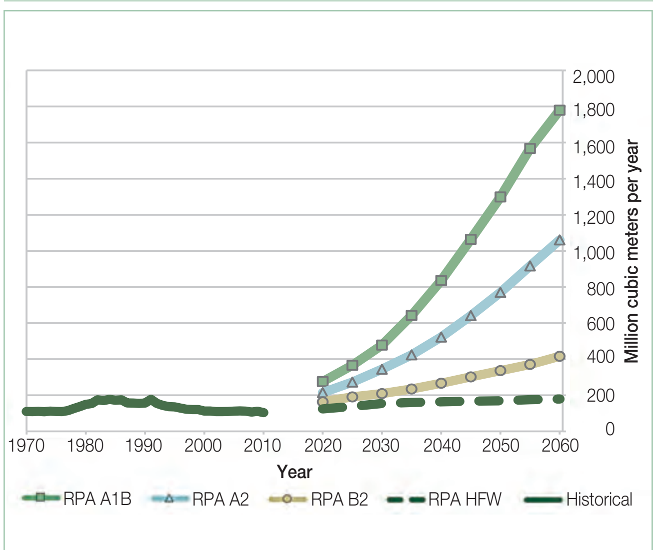
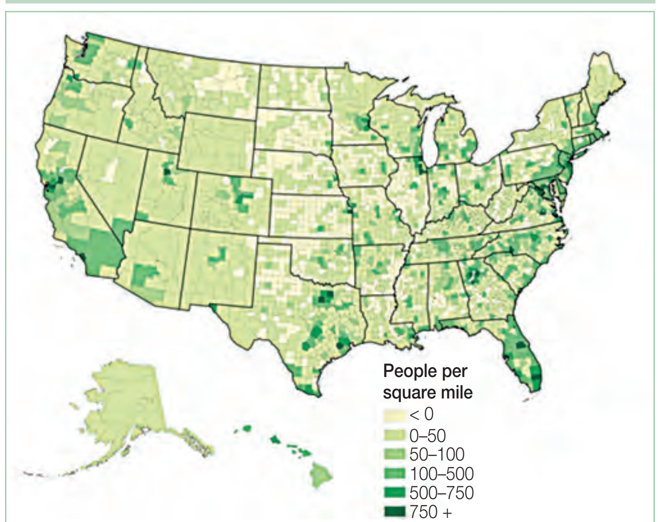


Figure 6. Projected change in U.S. population density (people per square mile), 2010–2060, for the medium population growth scenario (RPA A1B).



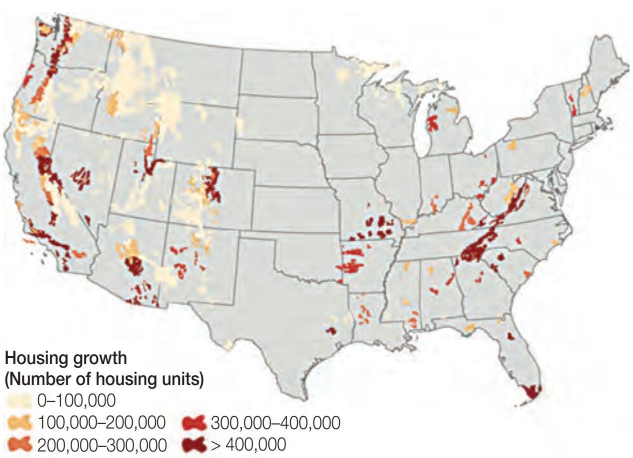
urbanization tends to spread from existing urban areas. In urbanizing areas, the importance of urban forests to delivering a variety of ecosystem services will increase in the future.

Low-density development patterns are more difficult to predict but are likely to occur in rural areas where population continues to grow in contrast with areas where population declines are projected. Low-density development is often concentrated around high-amenity locations, such as public lands. Historical patterns of housing development show a clustering around public lands, particularly Federal lands. Although the number of homes built increased more rapidly in the Eastern United States (figure 7), the rate of growth was higher in the Western United States. Historical patterns show a significant relationship between rural population growth and the presence of natural amenities that are often found on public lands. This development pattern creates unique challenges for Federal land managers.

Rangelands will also be affected by development, even though less area is projected to be lost than for forest land. Rangeland areas with the highest levels of fragmentation occur where agricultural land uses are prevalent (figure 8). Many of these areas have projected declines in population, which should stem development pressure. If crop prices remain high, there could be pressure to convert some rangelands to crop production in places suitable for increased agricultural production. Conversely, several areas—particularly in the Southwest—that currently have relatively little fragmentation will likely be exposed to development pressure from population growth.

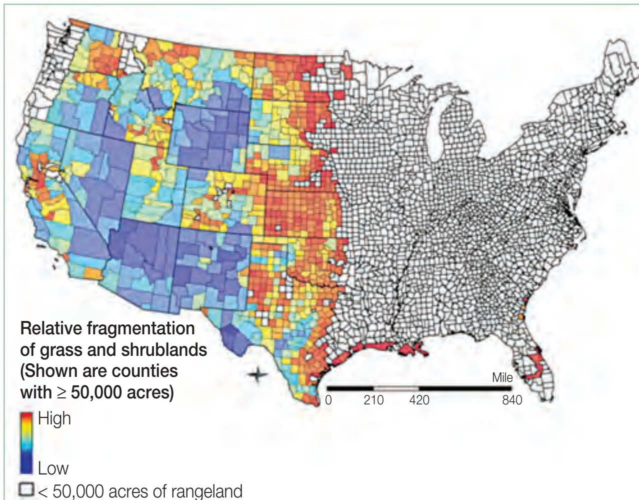
The vulnerability of the U.S. water supply, defined as the probability of shortage in the absence of adaptation and further groundwater mining, increases under all RPA scenarios because of decreasing water yields and increasing water demands. The projected changes have considerable geographic variation, however. Figure 9 shows the variation across the conterminous

Figure 7. Growth in number of housing units within a 30-mile buffer around the outer boundary of each national park, national forest, and wilderness area, 1940–2000.



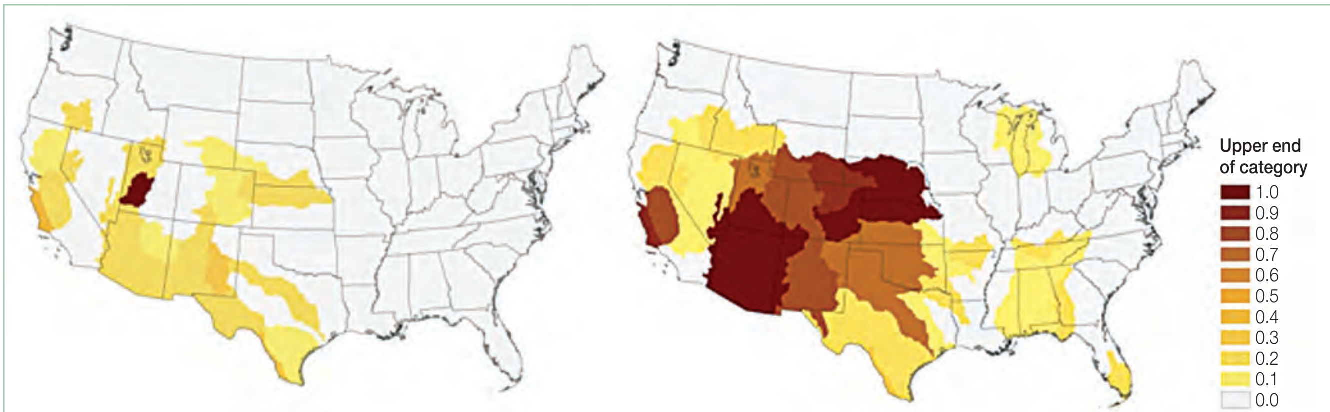
Source: Radeloff et al. 2010

Figure 8. Patterns of relative fragmentation of rangeland using the Morphological Spatial Pattern Analysis (MSPA) index, 2001.



Source: Data adapted from Riitters 2011

Figure 9. Current probability of annual water shortage (left) and future vulnerability (probability of shortage) in 2060 (right) for RPA A2-MIROC3.2.



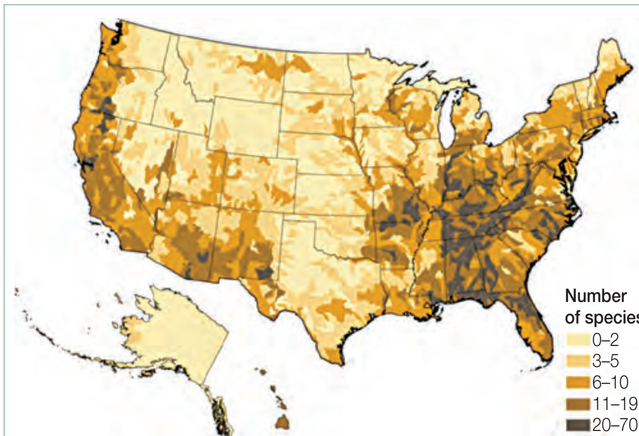
United States for both the current vulnerability of the water supply and the most extreme projected vulnerability, assessed for 98 large basins covering the conterminous United States.

Current vulnerability is concentrated in the Western United States. Projections indicate that increases in vulnerability will continue to be concentrated in the West, although they are quite variable. Increases also occur in parts of the Eastern United States. Vulnerability tends to increase over time as the effects of climate change become larger and as these effects have implications for other resource areas.

Imperiled aquatic species (figure 10) are concentrated in the Eastern United States, but also occur in parts of the Southwest that are expected to experience increasing risks of water shortages. Furthermore, the riparian environments in the arid southwest maintain important habitats used by much of the terrestrial fauna in this region. Conflicts about water uses, maintenance of instream flows, and eroding water quality are likely to increase in the future, exacerbating the threats to these species. Areas supporting concentrations of at-risk aquatic species occur predominantly in forested ecosystems, and the implementation of forestry best management practices can help minimize water quality effects.

Many of the resource concerns discussed in this chapter are common to all regions of the United States. The underlying drivers may vary by region or locale, however, so that a "one size fits all" management approach will not work in all local and regional situations. Because different assumptions about driving forces can result in very different economic and ecological outcomes, it is important to develop policies and management strategies that are flexible enough to be effective under a wide range of future conditions.

Figure 10. The geographic distribution of species associated with aquatic habitats assessed to be at risk of extinction at the eight-digit hydrologic unit level.



Source: NatureServe 2010

Chapter 3. Resource Highlights of the 2010 RPA Assessment

This chapter summarizes resource highlights following the organization of the resource-specific chapters (chapters 6 through 14). The previous chapter focused on identifying common themes and interactions across resources, whereas in this chapter, we focus on key findings from the individual resource analyses. These findings include key historical and current trends and the range of outcomes from the Resources Planning Act (RPA) scenarios that were used to analyze the effects of human and environmental influences on future resource trends.

Land Resources

Urban and other developed land area will increase in the future.

We expect continued alteration to natural landscapes in the future, as urban and other developed land is projected to expand under all RPA scenarios in response to population and economic growth. Total urban and developed land area is projected to increase between 39 and 69 million acres between 2010 and 2060, an increase of 41 to 77 percent. Urbanization patterns tend to follow population growth patterns, so the greatest amount of development during the projection period is expected in the South Region, although the rate of growth is projected to be highest in the Rocky Mountain Region.

Natural landscape patterns are affected by development patterns.

Ecological risks increase as urban and developed land becomes more interspersed within natural landscapes. The risk of further conversion of natural land covers (forest land, grassland, and shrubland) is highest in landscapes dominated by agriculture, urban, and other developed land uses. Currently, less than 10 percent of the area of these natural land covers occurs in human-dominated landscapes, so their exposure to such ecological risk is relatively low. The risk varies substantially across the Nation, however, and is generally highest in the North Region, which has the highest population density.

A higher proportion of natural land cover area is at risk from interspersed development containing 10 to 60 percent agriculture and developed land cover, with forest land having the greatest area at risk. Excluding Alaska, 23 percent of forest land, 19 percent of grassland, and 7 percent of shrubland occur in such landscapes.

Natural land covers are also at risk from ecological edge effects, such as changes in microclimate and introduction of edge-adapted species, as a result of direct adjacency with other land cover types. Forest, grassland, and shrubland tend to be the dominant types of land cover where they occur, but fragmentation from all causes is so pervasive that the risk of short-range (about 100 feet) edge effects threatens 28 percent of all forest, 30 percent of all shrubland, and 40 percent of all grassland area. Forest, grassland, and shrubland all exhibit substantial fragmentation and measured fragmentation increases across a range of spatial scales. Grassland is the most fragmented and shrubland is the least fragmented natural land cover type; forest land is fragmented more like shrubland at smaller spatial scales and more like grassland at broader spatial scales.

Development pressures around public lands threaten ecological integrity.

Development pressures are particularly strong on lands with high natural amenity values—lands that often occur in proximity to public lands in general and to national forests in particular. Housing development pressures on private lands surrounding public lands affect the ability of those public lands to sustain important ecosystem services and biodiversity. Areas of the country where development pressures near public lands have been particularly high include peninsular Florida, the southern Appalachians, the foothill and front ranges near major metropolitan areas in the Interior West, montane forest habitats in the arid Southwest, and southern California—the very same areas that also support high concentrations of imperiled species.

Although wilderness areas receive the highest level of protection against development and resource extractions within their boundaries, they are not immune to resource effects related to development in the surrounding landscape. Some wilderness areas are increasingly isolated fragments or remnants of historic ecosystems. These threats are more pronounced in wilderness areas of the East, but effects also occur in the West. About 16 million new homes were built within 30 miles of wilderness area boundaries between 1940 and 2000. Development near wilderness areas has been associated with increasing recreation pressure, which, in turn, has been shown to alter vegetation and population demography of recreationally harvested game species.

Forest Resources

Forest area will decline in the future.

The U.S. forest land base has remained relatively stable for almost 100 years, despite population growth. The continuing need to accommodate a growing population is expected to reduce forest area in the future, however, largely as a result of urbanization and other land development. Forest land losses are projected to range from 16 to 34 million acres in the conterminous United States. The South Region is expected to have the greatest loss of forest, ranging from 9 to 21 million acres between 2010 and 2060, roughly 4 to 8 percent of the region's 2007 forest land base.

Forests face threats to their long-term health and sustainability.

Native and exotic pests and pathogens, fire, and other natural disturbances, combined with climate change, pose ongoing risks to forests. Almost 8 percent, or more than 58 million acres, of forest land are at risk to increased activity by forest insect pests and pathogens.

Declining forest area, coupled with climate change and harvesting, will alter forest-type composition in all RPA regions.

The South Region, which is projected to have the largest decline in forest area across all RPA scenarios, is also projected to lose area in most forest types. The main exception is the area of planted pine, which is projected to increase primarily at the expense of natural pine. Upland hardwoods decline as a result of urbanization pressures in the region. Urbanization is also the primary force behind losses of oak-hickory in the North Region. The maple-beech-birch forest type in the region increases under all RPA scenarios.

Projections of forest types in the West were more sensitive to differences in climate projections, often shifting species towards different forest-type groups. In the Rocky Mountain Region, Douglas-fir and lodgepole pine are projected to decline across all RPA scenarios, whereas fir-spruce-hemlock and ponderosa pine area increases. In wet west-side forests of the Pacific Coast Region, hemlock-Sitka spruce area is projected to decline and the area of Douglas-fir to increase. On the east side, only ponderosa pine expands.

Forest inventory is projected to peak between 2020 and 2040, then decline to 2060.

The projected peaking of forest growing stock inventory followed by declines would conclude a long period of inventory accumulation on the Nation's forest lands. Across all RPA scenarios, the greatest projected reduction in forest inventory occurs in the North Region, a result of expansion of timber removals and forest losses from urbanization. Investments in plantations partially offset similar declines in the South Region. In the highest timber demand RPA scenario, planted pine area in the South Region is projected to expand by more than 70 percent, to 67 million acres by 2060, whereas just more than 20 million acres of agricultural land are planted in highly productive agricultural short-rotation woody crops nationwide by 2060. Relative to 2010 levels, total forest inventory in 2060 would range from a loss of 7 percent in the highest timber demand RPA scenario to a gain of 2 percent in the lowest timber demand RPA scenario. The gains in plantation area and timber productivity in the high timber demand RPA scenario offset what would otherwise be a more substantial depletion in U.S. timber inventory.

Softwood inventories are projected to remain relatively stable, whereas hardwood inventories show large declines after 2030.

Hardwood forests are more strongly affected by urbanization than softwood forests and are also affected by expansion in wood energy demands. Therefore, hardwood forest inventories are projected to decline across all RPA scenarios. Losses in softwood types are offset partially by increasing area of intensively managed planted pine in the South Region. This offset is particularly important in the RPA scenario that has the highest rate of both urbanization and wood energy consumption, because it also has the strongest timber markets providing incentives to maintain forest land for production.

Tree canopy cover across all natural landscapes will be affected by development and climate change.

The conversion of forest to more developed uses generally reduces tree canopy cover, whereas development in grassland and other nonforest systems tends to increase tree canopy cover relative to surrounding ecosystems, if water is not limiting. The future land use changes are projected to slightly decrease tree canopy cover across the Nation, reflecting the greater effect of urbanization on forests compared with other land covers.

Climate change will affect the ability of natural landscapes and developed areas to sustain trees. Combining the effects of land use change and climate change, the United States is projected to lose tree canopy cover nationally, with the greatest losses in the Eastern United States and the Pacific Northwest. The results in the Intermountain West vary greatly by RPA scenario, reflecting the variations in the mountain and basin landscapes.

Forest Products

The forest products sector was hard hit by the recession.

Historically, the volume of roundwood needed to make wood and paper products consumed in the United States (including product imports) grew at roughly the rate of population growth. Per capita consumption has declined with the downturn in housing construction since 2005. The lower import share of U.S. wood and paper product consumption and an increase in the export share of production were positive trade balance effects of excess productive capacity and weakening of the U.S. dollar. The weaker U.S. dollar and productivity gains by U.S. producers improved the competitiveness of U.S. forest products, and the United States recently became a net exporter of wood pulp, paper, and paperboard for the first time in many decades.

Timber resources will continue to be adequate to meet demands unless there are very large increases in wood energy demand.

Real price trends indicate that pulpwood has become relatively more abundant in the United States since the late 1990s, a result of increasing supplies (continued timber growth and maturation of pulpwood plantations, and other recent investments in plantation intensity), a general declining trend in consumption, and efficiency gains in timber harvesting and conversion technology. In RPA scenarios that do not have large increases in demand for wood energy, the projected supplies of timber are adequate to meet demands despite a declining forest land base.

Forest product futures are tied to domestic and global wood energy demands.

Assumptions about future expansion in U.S. and global wood energy demands directly influence projected U.S. consumption, production, and net trade in forest products. U.S. producers of forest products can gain competitive advantage in trade in RPA scenarios with significant expansion of global wood energy consumption if the projected average industrial roundwood prices in foreign countries increase more than projected average U.S. industrial roundwood prices. The relatively flat-to-declining timber price projections of other RPA scenarios indicate that, barring really significant and unforeseen structural changes in U.S. forest product demands, timber supplies are increasing and that U.S. timber prices are not projected to increase significantly.

Urban and Community Forests

Urban forest area will increase.

Urban development will be accompanied by increasing urban forest area. Current tree cover on urban lands was estimated at 35 percent. Tree cover tends to decrease as population density increases, so tree cover may decline in some urban areas where density and total population increase. Tree canopy cover can serve as an indicator of the extent to which trees and forests are providing crucial services to local residents. Urban forests are likely to become more important in providing these services in the future as urban growth reduces natural landscapes.

Urban forests will become increasingly important for providing a range of ecosystem services to urban populations.

In 2000, almost 80 percent of the U.S. population lived in urban areas that covered only 3.1 percent of the U.S. land area. As urbanization increases, so will the value of urban forests and surrounding rural forests in providing ecosystem services required by urban residents. Trees in urban areas provide many benefits and values to society, including improving air and water quality and providing aesthetic benefits. Urban trees also store about 700 million tons of carbon. Urban forests in the Northeast, Southeast, and South Central RPA subregions store and sequester the most carbon.

Carbon in Forest Resources and Products

Carbon stored in forests is projected to peak between 2020 and 2040, then decline.

The projected declines in forest area and forest biomass result in an overall decline in the amount of carbon stored in forests by 2060. Forest carbon stocks in 2060 would be reduced by between 0.8 and 2.5 billion metric tons from 2010 levels. Roughly one-half of the carbon losses are projected to occur in the North Region.

Carbon storage projections are highly sensitive to forest land area projections.

Forest land is projected to decline in all of the RPA scenarios. The large decrease in forest land area by the later decades, particularly in the final decade between 2050 and 2060, results in large amounts of carbon being transferred out of the forest and into other land uses, usually developed uses. A complete accounting of carbon across the entire land base would tell a more complete story and more appropriately emphasize the effect of land use change.

Carbon stored in harvested wood products depends on future timber markets.

The projected annual additions to carbon stored in harvested wood products (HWP) dropped dramatically with the recession. Annual additions to carbon stored in HWPs would be higher than historical levels under RPA scenarios in which U.S. forest product production increases to greater-than-historical levels. RPA scenarios with a lower level of U.S. production and higher levels of product imports, however, result in declines in annual additions to carbon storage that never recover to historical levels during the projection period.

Rangeland Resources

Rangelands are projected to continue their slow decline in area.

The historically slow decline in rangeland area is expected to continue under all RPA scenarios, with losses ranging from about 6 to 9 million acres between 2010 and 2060. This loss that is projected to occur during 50 years is roughly the same as the loss of about 9 million acres that occurred in the 25 years between 1982 and 2007. Therefore, the rate of projected decline is less than the recent historical rate of loss. Rangelands will continue to face pressure from expansion of urban and developed land, creating additional fragmentation on rangelands. Currently, Nevada and Arizona have the least fragmented rangelands, and the most fragmented rangelands occur in proximity to areas with high agricultural usage, including Nebraska, Oklahoma, and Texas.

Rangeland productivity is stable.

Rangeland productivity between 2000 and 2009 was unchanged to slightly increasing. Variability in net primary productivity was highest in very dry regions, most likely in response to interannual variation in precipitation.

Rangeland health is difficult to consistently evaluate.

Roughly 80 percent of non-Federal rangeland in the conterminous United States was judged to be in relatively healthy condition in the latest National Resources Inventory and exhibited no significant soil, hydrologic, or biotic integrity problems. Several estimates indicate that woody encroachment and invasive species are becoming increasing problems that may be exacerbated by climate change, however. Nonnative species were present on roughly 50 percent of non-Federal rangeland and represented more than 50 percent of the total plant cover on 5 percent of non-Federal rangeland in 2007. As a whole, approximately 10 percent of U.S. rangeland is currently occupied by invasive juniper species, and mesquite species are a dominant woody plant on more than 94 million acres of what has been considered semiarid southwestern grasslands.

Rangeland forage supply is sufficient to meet demand.

Domestic livestock numbers have generally declined during the last decade, although the U.S. Department of Agriculture projected that cattle numbers are expected to increase slightly through 2020. For most rangeland, forage availability exceeded demand for domestic livestock. Only 2 percent of total rangeland was estimated to have forage demand in excess of forage availability. Texas and California had the largest number of acres where demand exceeded availability.

Water Resources

Climate change will increase future water demands.

In the absence of future climate change, total water withdrawals were projected to remain close to current levels despite large increases in population, because of improving efficiencies in water use. Climate change, however, is projected to increase water demand substantially. For example, one RPA scenario projects water withdrawals will increase between 12 and 41 percent by 2060, as opposed to 3 percent without accounting for future climate change. About three-fourths of the increase is attributable to agricultural irrigation increases.

Projected percentage changes in consumptive water use are larger than those for withdrawal because of improving efficiency in how water withdrawals are being used. In comparison with the increases in withdrawal listed above, consumptive use is projected to increase between 26 and 86 percent with climate change, as opposed to 10 percent without accounting for climate change.

Projected water withdrawal varies considerably across regions.

Assuming medium population growth without future climate effects, water withdrawals were projected to drop in 42 of the 98 assessment subregions (ASRs), increase by less than 25 percent in 38 ASRs, and increase by more than 25 percent in the remaining 18 ASRs. The ASRs where withdrawals are projected to drop are rather evenly divided between the East and West, as are the ASRs expecting increases greater than 25 percent.

Including climate effects in the same RPA scenario results in wide variation in future water withdrawal across ASRs. Projected withdrawals drop in 12 ASRs but increase by less than 25 percent in 34 ASRs, by 25 to 50 percent in 37 ASRs, and by more than 50 percent in 15 ASRs.

Future water use depends most importantly on the agricultural sector.

Irrigation accounts for the bulk of consumptive water use, and irrigation requirements are highly sensitive to climate change. Further, future irrigated area depends on changes in water markets, agricultural markets, and policies that are very difficult to project.

U.S. water yield is projected to decrease.

For the conterminous United States, water yield is projected to decrease throughout the 21st century. For example, average annual yields are projected to decline between 16 and 22 percent by 2060 under the medium population growth RPA scenario across three future climates. Decreases are projected for most, but not all ASRs. In general, the magnitude of the decrease is larger in humid areas. In those areas with increases in average annual yield, the increase is very small in absolute terms.

The vulnerability of the U.S. water supply will increase.

Vulnerability is defined as the probability that supply is less than demand at the ASR scale. The water supply system of much of the United States west of the Mississippi River is vulnerable under current hydroclimatic and socioeconomic conditions. Only a few ASRs show vulnerability values exceeding a 0.05 probability, however. Increases in vulnerability are projected to occur mainly in arid and semiarid areas of the United States, where the current conditions are already precarious (e.g., California, the Southwest, and the central and southern Great Plains). At the ASR scale, most of the Eastern United States is currently characterized by water abundance. Some RPA scenario-climate combinations project moderate shortages in the East. Localized areas within an ASR (such as the Atlanta area), however, may experience substantial vulnerability that is not captured at the ASR scale of analysis. Vulnerability tends to increase over time as the population expands and the effects of climate change become larger. The rate of increase in vulnerability is greatest in the last decade of the projection period, when climate effects become most pronounced.

Increases in vulnerability depend both on changes in water yield and on growth in water demand.

Although climate change will increase water demand, continued improvements in water use efficiency will mitigate that effect. As a result, in about one-half of the ASRs where vulnerability is projected to increase, decreases in water yield (that in turn affect water supply) have a greater effect on future vulnerability than the effect of increases in water demand. In some ASRs, the combined effect of changes in water yield and demand lead to untenable levels of vulnerability, suggesting that adaptation to water shortage there will be essential.

Wildlife, Fish, and Aquatic Resources

Wildlife populations and harvests have mixed trends.

The recent historical trends in wildlife resources vary. Big game and waterfowl have shown a general pattern of increasing population or harvest trends. Although such gains have generally been regarded as a favorable resource situation, evidence suggests that populations of some species may be exceeding the ability of habitat capacity to sustainably support them.

Many small upland and webless migratory game species have shown notable declines in population or harvest. Many of these species are associated with grassland, farmland, and early successional forest habitats and point to the need for active management to increase these habitat types on the landscape. These species have shown little sign of recovery from declines noted in past RPA Assessments.

Fur harvests can change for a number of reasons that are independent of population levels, including changes in pelt prices, the number of trappers and their effort in pursuing furbearers, and changes in the accessibility of land for trapping. The notable declines in fur harvest since the last assessment appear to be driven by substantial declines in pelt prices. Wildlife damage complaints associated with furbearers are likely to become a more prominent management issue in the absence of any economic incentives to increase harvests.

Birds have long been thought to be good indicators of landscape change. For the 426 species with sufficient data to estimate nationwide trends, 45 percent had stable abundance since the mid-1960s. A higher percentage of species had declining trends (31 percent) than increasing trends (24 percent) during this period. Species groups that nest on or near the ground or in grassland habitats had relatively high proportions of species with declining trends. RPA regions already characterized by prominent human effects (the North and South Regions) tended to have higher proportions of species with declining abundance.

Projected land use changes are expected to reduce the variety of forest bird species.

As human populations grow, native habitats are lost to agriculture, road construction, or urbanization. The RPA land use projections indicate that intensive land uses and housing development are expected to increase in forested landscapes. In response to these land use changes, most forest bird communities are expected to support a lower variety of species, particularly among those forest species that prefer intact interior habitats (that is, low fragmentation) or nest on or near the ground. The only group of birds expected to show an increase in species richness are those associated with human settlements. These patterns of bird richness response were similar across all RPA scenarios.

Climate change will differentially stress terrestrial wildlife habitats across the country.

Those areas most exposed to habitat stress attributable to climate change occur along the grassland-forest land transition throughout the central portion of the United States and the steep elevation gradients in the Intermountain West. Areas less sensitive to climate-induced habitat stress include the southern portions of the Great Plains and the Middle Atlantic States. A comparison of areas of likely future stress to areas of current stress associated with the distribution of imperiled species indicate that the locations of high current stressors tend not to overlap with the locations of high future stress associated with climate change, potentially complicating the efforts of managers to prioritize wildlife conservation actions.

Freshwater habitat conditions vary widely across the United States.

Nationwide, the U.S. Environmental Protection Agency ranked more than one-half of monitored lakes in 2007 to be in good condition, but the percentage varied from a high of 91 percent in the Upper Midwest to a low of 1 percent in the northern plains ecoregion. An assessment of small streams in 2004–2005 indicated that 42 percent of stream lengths sampled nationally were determined to be in poor condition. The southern Appalachians, southern plains, and northern plains ecoregions have 50 percent or more of their sampled stream lengths in poor condition. The biological condition of small streams was best in the western mountains ecoregion, where only 25 percent of sampled stream lengths were determined to be in poor condition.

Some commercially and recreationally important fish populations are in decline.

Data availability continues to limit comprehensive evaluations of freshwater fish population trends. Of the 253 marine fish stocks assessed in 2009, 23 percent were deemed to be overfished (fish populations are less than the level needed to replenish themselves) and 15 percent subject to overfishing (fishing mortality is too high to sustain the current fishing levels). Pacific salmon have declined throughout much of their range, although stocks native to Alaska have fared better than those in the Pacific Northwest. Of the 52 distinct populations of salmon and steelhead in the Pacific Northwest, 28 are currently listed as threatened or endangered under the Endangered Species Act of 1973 (ESA). Excessive siltation from land use changes, water removals, and obstructions that prevent fish from reaching spawning habitats have all contributed to Pacific salmon declines.

Biodiversity in the United States continues to erode.

Since the 2000 RPA Assessment, there has been a net gain of 278 species formally listed as threatened or endangered under the ESA. The greatest gains were among plants (152 species) and fish (31 species). Just more than one-fourth of all vertebrates and one-third of vascular plants are of conservation concern—defined as species determined to be possibly extinct or at risk of extinction. Vertebrates with a relatively high percentage of species-of-conservation concern include amphibians (41 percent), freshwater fishes (37 percent), and reptiles (21 percent). Among invertebrates, mollusks (58 percent) and crustaceans (53 percent) have the greatest percentages of species that are of conservation concern. Species associated with aquatic habitats have higher proportions of at-risk species than other species groups.

Concentrations of at-risk species vary geographically.

At-risk species tend to be prominent in areas with high human populations or where land use intensification has occurred (for example, peninsular Florida, the Florida panhandle, coastal California) or in areas known to support high numbers of species with restricted ranges (the arid Southwest). At-risk species that are associated with aquatic habitats are concentrated in watersheds in the southern Appalachians and the southeastern coastal plain.

The number of species that have been extirpated from each State show areas of concentration among the heavily populated Middle Atlantic States. This pattern gives an indication of how much historical biodiversity has been altered by human settlement.

Outdoor Recreation

Outdoor recreation resources are expected to decline on a per-person basis.

The outlook for recreation resources is generally of declining opportunities per person. The public land base is not expected to expand significantly. Therefore, an increasing population will result in decreasing per-person opportunities for recreation across most of the United States. Although many other factors are involved in recreation supply, recreation resources are likely to become less available as more people compete to use them. A major challenge for natural resource managers and planners will be to ensure that recreation opportunities remain viable and grow along with the population. This goal would more than likely be accomplished through management and site attribute inputs and plans, rather than through any major expansions or additions to the land and water base for recreation.

Outdoor recreation participation continues to grow, but activity choices are changing.

The number of outdoor recreation participants increased about 7 percent between 2000 and 2009 for 50 nature-based outdoor recreation activities, and the number of activity days increased 30 percent. Activities oriented toward viewing and photographing nature were among the fastest growing activities. Off-highway vehicle driving increased 34 percent and physically challenging activities, such as kayaking and snowboarding, also had relatively large increases, although a small percentage of the population engages in these activities. Several activities have declining participation rates, including traditional activities such as hunting and fishing.

The five outdoor recreation activities projected to have the fastest growth in participation rate across the RPA scenarios are developed skiing, challenge activities (e.g., caving and mountain climbing), equestrian activities, motorized water activities, and day hiking. The activities with the largest projected declines are motorized off-road activities (indicating a reversal from recent increases), motorized snow activities, hunting, fishing, and floating activities. The largest growth in number of participants is projected to occur for activities associated with visiting developed sites and nature viewing, where more than 100 million participants could be added by 2060. For most activities, the effect of the climate on future recreation participation was a slight increase or decrease compared with the "no climate change" projection. Climate effects dramatically lowered participation in snowmobiling and undeveloped skiing.

Outdoor recreation choices are strongly influenced by socioeconomic characteristics.

Non-Hispanic Whites continue to dominate participation in all outdoor recreation activity groups, with the exception of Native Americans, who are as likely to participate in backcountry activities. Males are more likely than females to participate in all activity groups except visiting recreation or historic sites and viewing and photographing nature. People that were young to middle-aged and had college educations and higher incomes also tended to participate more in recreation activities. The demographic groups consistently less likely to participate in outdoor recreation activities were African-Americans, people 65 or older, and people with less education and lower income. Females, Hispanics, and Asians were less likely to participate in some activities, but the pattern varied across activities.

Future outdoor recreation participation will reflect the preferences of a changing U.S. population.

The growing diversity of the American population, coupled with the relatively low participation rates of most groups except non-Hispanic Whites, suggest shifting recreation preferences can be expected. Similarly, the aging population may require different types of recreation opportunities. Recreation activities that have been dominated by rural residents are also likely to decline as the American population becomes increasingly urban. The outdoor recreation projections reflect these changing preferences. For example, several activities that rural residents are more likely to participate in, such as hunting, snowmobiling, and off-road driving, are projected to decline. Day hiking has one of the fastest projected increases in participation rate, reflecting high participation by Hispanics.

Growing recreation demand may be constrained by recreation resource availability.

A stable public land base, a declining private natural land base, and increasing outdoor recreation participants will result in declines in per-person recreation opportunities. The ability of recreation resources to absorb additional demand varies widely across the United States, but will likely stress recreation opportunities in the Eastern United States to a greater extent than the West. Pressure is likely to be greatest on local, State, and Federal facilities that are in close proximity to population centers.

The projected changes in participation in some recreation activities reflect the declining land base. Generally, land and water availability positively influence activity participation. Therefore, declines in the per capita area of forest and rangeland and of Federal land resulted in participation declines in spatially extensive activities like equestrian, hunting, motorized off-road driving, visiting primitive areas, and nature viewing. Similarly, participation in water-based activities like swimming, motorized boating, and nonmotorized boating were all positively correlated with the per capita availability of water area.

Chapter 4. Global and U.S. Context

The Millennium Ecosystem Assessment (MEA 2005) undertook a comprehensive review of the world's ecosystems, emphasizing the ability of these systems to provide goods and services that are crucial to humans. Ecosystem change and conversion to meet human needs for food, water, fiber, and fuel substantially changed the extent and quality of natural ecosystems globally between 1950 and 2000. These changes included conversions of natural ecosystems to agricultural uses, loss and degradation of coral reefs, increased water impoundments, increased water use, and increased number of species at risk of extinction. Between 1960 and 2000, the global economy grew sixfold and the global population doubled (MEA 2005).

Population and income are both key drivers in the projection of resource demands that affect the future condition of forests and rangelands. In this chapter, we provide a brief overview of recent global and national population and economic trends.

Population Growth

Global population grew from 6.1 billion in 2000 to 6.8 billion in 2009 and is expected to reach 9.6 billion by 2060 (United Nations 2009). The percentage of the global population living in urban areas surpassed the 50-percent mark in 2009, and future population growth in urban areas is expected to more than double between 2009 and 2050. Urban populations will expand at rates greater than overall population growth, resulting in a decline in the number of rural inhabitants. Urbanization is expected to continue rising in both the more developed and less developed regions, so that by 2050, urban dwellers are expected to account for 86 percent of population in the more developed regions and 66 percent of the population in less developed regions (United Nations 2010).

Unlike many developed countries where population is declining, the U.S. population continues to increase. The 2010 Census indicated that the U.S. population increased almost 10 percent between 2000 and 2010, when it reached almost 309 million. Regional population growth was faster in the South and West than in the Midwest and Northeast. Overall, the South and West accounted for about 84 percent of the U.S. population increase. The States with the highest numeric increases were, in descending order, Texas, California, Florida, Georgia, North Carolina, and Arizona. These six States accounted for 54 percent of the overall increase in the last decade.

Almost 84 percent of the U.S. population in 2010 lived in a metropolitan statistical area, and population in these areas grew at a faster rate than the overall U.S. rate (USCB 2011). Although the 2010 Census data on urban areas were not yet available, the growth in population in metropolitan statistical areas likely will be mirrored by growth in urban areas.

Although the South and West had the largest increases in population, the U.S. population is still concentrated on the two coasts. Although only one State, Michigan, lost population in the last decade, depopulation occurred in a number of counties, continuing decades of population loss in areas such as Appalachian counties in eastern Kentucky and West Virginia, many Great Plains counties, and a group of counties around the Mississippi delta. Many counties along the Great Lakes and the northern U.S. border either lost population or grew at very low rates (USCB 2011).

Economic Outlook

The global economy has gone through considerable change during the last several decades. The 1970s saw oil price shocks; the 1980s were a time of general deflation of commodity prices. During the 1990s, the industrial structure of many developed economies, including the United States, shifted in emphasis to service sectors as growth in their manufacturing sectors declined. The decade of 2000–10 brought considerably more change—particularly in the last years of the decade, when a global recession had major effects on the global and U.S. economy, especially in the real estate and housing construction sectors. At the end of the decade, high oil prices and high commodity prices were also influencing the pace of economic recovery, with persistent high unemployment, although some commodity prices began declining in 2011.

Global gross domestic product (GDP) increased 57 percent between 2000 and 2010, from $36.3 to $56.9 trillion (2005 U.S. dollars at market prices) (World Bank 2012). GDP growth in less developed regions has been at higher levels than in the developed world. The global economy moved toward recovery in 2010 with positive economic growth in most regions and rebounding world trade. Emerging-market economies are increasingly important to world economic growth and to the U.S. economy (Council of Economic Advisors 2011). In the latter part of 2011, however, global economic activity weakened.

Global GDP forecasts have been lowered, with global growth now forecast to increase 4 percent through 2012, and growth in the advanced economies projected at only 1.5 percent in 2011 and 2 percent in 2012. Even these low levels of growth depend on the United States and European countries adopting policies to address deficit reduction and the crisis in the Eurozone. Growth is expected to continue to be higher in emerging and developing economies than in developed economies (International Monetary Fund 2011).

The U.S. economy is still recovering from the recession that began at the end of 2007, which was both the longest and worst since the Great Depression. U.S. GDP now exceeds its pre-recession peak in real dollar terms (USDC Bureau of Economic Analysis 2012), and the private sector has added jobs. Although the U.S. economy shows signs of recovery, the continued weakness in the U.S. housing market, budget constraints faced by State and local governments, the need to reduce the Federal deficit, concerns about the fiscal situation in Europe, high oil and commodity prices, and political unrest in various parts of the world continue to complicate economic recovery in the United States and other regions (Council of Economic Advisors 2011).

Forests and Rangelands

The world has abundant forest and rangeland resources. The Food and Agriculture Organization (FAO 2010) estimated global forest area to be about 8.8 billion acres, covering 31 percent of the total global land area. The five most forest-rich countries, in descending order, are the Russian Federation, Brazil, Canada, the United States, and China. These countries account for more than one-half (53 percent) of the total global forest area. U.S. forest land accounts for about 7 percent of the world's forest area.

The rate of global deforestation shows signs of decreasing, but it is still high. The largest net losses are in South America and Africa. Large-scale planting of trees is significantly reducing the net loss of forest area globally, through a combination of afforestation and natural expansion of forest. The area of planted forest is increasing and now accounts for 7 percent of total global forest area (FAO 2010).

The lack of a common definition for rangeland hinders global estimates. White et al. (2000) estimated that grassland ecosystems (which are not synonymous with rangeland) cover some 40 percent of the Earth's land area (excluding Greenland and Antarctica). They are found in every region of the world, but the largest areas are found in sub-Saharan Africa and Asia. The five countries with the largest grassland areas, in descending order, are Australia, the Russian Federation, China, the United States, and Canada.

The United Nations recently released a report (FAO 2011) indicating that 70 percent more food needs to be grown by 2050 to support the growing world population. This growing demand will continue to put pressure on forest and rangelands both domestically and globally.

Conclusions

The increasingly globalized economy has had major effects on U.S. renewable resources. Reduction of trade barriers between countries, a key factor in increasing economic globalization, has increased the flow of goods, services, and capital internationally. The result has been developing countries increasing their share of world trade and increasing the importance of international markets in meeting U.S. domestic demands (Martin 2001). These effects have been most noticeable in the forest sector, where changes during the last few decades include restructuring in the pulp and paper sector and the loss of a significant portion of domestic furniture production to overseas producers.

Currently, U.S. forest products producers have increased exports relative to imports because of a variety of factors. Similarly, high agricultural commodity prices are providing strong export markets for U.S. farmers and causing increases in farmland values. Rising farmland values relative to other rural land values could increase the potential for the expansion of cropland, which would reverse a decades-long trend in the United States. At the same time, domestic policies to encourage biofuels production create incentives to convert land to energy crops, thereby competing with food crops and timber production. Concerns about water shortage, often linked to a changing climate, will affect the feasibility of future production, because irrigation is the largest consumptive use of water in the United States. Increased opportunities for travel have raised interest in U.S. forest and rangelands as destinations for increasing numbers of international tourists (e.g., to sites such as Yellowstone National Park that highlight the diversity of U.S. ecosystems). International travel and trade are also conduits for the introduction of invasive species, however, which often threaten the sustainability of these ecosystems.

Although the United States has significant forest and rangeland resources, pressures from competing demands that have higher economic returns (e.g., some types of agricultural production and urban development) will result in the loss of natural ecosystems. As incomes rise, the demand for ecosystem services and protection of natural ecosystems also tends to increase, creating potential conflicts between commodity production and environmental protection.

In the following chapters, we describe historical trends in resource conditions and use, then use a set of scenarios to project alternative futures. Those futures are strongly influenced by population and economic assumptions. Global and U.S. populations are projected to continue increasing in the future. The outlook for economic growth is more uncertain, particularly in the short term, but the longer term trend is expected to be positive. To a large extent, the Resources Planning Act Assessment outlook for U.S. resources is influenced by scenarios with varying assumptions about global economic growth, global wood energy consumption, forest products trade, domestic population and economic growth, and global climate change. Our analyses indicate the importance of these factors in assessing the alternative resource futures and likely challenges for future renewable resource management.

Chapter 5. Future Scenarios

The Resources Planning Act (RPA) Assessment addresses a wide range of economic and ecological phenomena. Individually, the economic, social, and biological systems are quite complex; integrating effects across these systems increases complexity. Because there are uncertainties about future political, economic, social, and environmental change, we used scenarios to explore a range of possible futures for U.S. renewable natural resources. The scenarios used in the 2010 RPA Assessment are described in this chapter.

RPA Scenarios

Scenarios define alternative futures and provide a framework for evaluating a plausible range of future resource outcomes. We selected a set of comprehensive global scenarios that were used in the Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report (TAR) and Fourth Assessment Report (AR4) to provide global context and quantitative linkages between U.S. and global trends. The range of scenarios considered in the IPCC Assessments provided a broad spectrum of potential futures from which we selected a subset that are relevant to evaluating potential U.S. future resource conditions and trends.

We developed three RPA scenarios that describe alternative national- and county-level futures that are linked to IPCC assumptions and projections of global population growth, economic growth, bioenergy use, and climate (IPCC 2007a). For continuity, we retained the scenario designations used in the IPCC TAR and AR4, with the addition of "RPA" to remind readers that these scenarios are tied to IPCC assumptions described in the Special Report on Emission Scenarios (SRES) (Nakicenovic and Swart 2000), but that some adjustments were made that are briefly described in this chapter. The RPA scenarios are, therefore, designated as RPA A1B, RPA A2, and RPA B2.[2] We developed a fourth scenario that uses the same economic and population assumptions as RPA A1B, but is not tied to IPCC assumptions about future bioenergy use. The fourth RPA scenario is called "historical fuelwood" (HFW). The RPA HFW scenario has all of the same global economic growth assumptions as the RPA A1B scenario, but it projects much less future expansion in U.S. and global wood energy consumption. Detailed information about the selection of IPCC scenarios and adjustments that were made to define RPA A1B, RPA A2, and RPA B2 are found in USDA Forest Service (2012).

In addition to the scenario-specific assumptions described in this chapter, a variety of additional detailed assumptions were needed for specific resource or sector analyses. For example, housing starts is an important variable in determining the outlook for some forest products. Resource- or sector-specific assumptions are described in their respective resource chapters and in the referenced supporting documents.

Table 1 describes characteristics of the four RPA scenarios. The global assumptions are identical to IPCC assumptions, except for the biomass energy assumption for RPA HFW. The U.S. population and gross domestic product (GDP) projections were updated as described in the following sections, but the rates of change over time are almost identical to IPCC rates of change for the United States. What is noteworthy is that projected GDP growth is considerably lower for the United States and other developed countries than the global growth rate. This difference in projected growth rates reflects the assumption that economic growth rates in the developing world will continue to outpace rates in the developed world, continuing the global trends described in chapter 4.

Six integrated assessment modeling groups used the IPCC SRES scenarios to estimate greenhouse gas (GHG) emissions. The results from the modeling groups became the basis of multiple climate projections associated with each scenario. The climate projections vary across scenarios in response to the associated levels of GHG emissions, but they also vary within a scenario because general circulation models (GCMs) differ in their approaches to modeling climate dynamics. Therefore, we selected climate projections from three GCMs for each of the three RPA scenarios to capture a range of future climates. For the RPA HFW scenario, the climate projections associated with RPA A1B were used. Table 2 lists the IPCC scenarios and associated GCM projections that were used to develop climate projections for the RPA scenarios.

[2] As described in the IPCC SRES (Nakicenovic and Swart 2000), modeling groups developed 40 future scenarios with varying levels of greenhouse gas emissions. The three RPA scenarios are based on the marker scenarios for A1B, A2, and B2.

Table 1. Key characteristics of the RPA scenarios.[a]

Characteristic	Scenario RPA A1B	Scenario RPA A2	Scenario RPA B2	Scenario RPA HFW
IPCC general global description	Globalization, economic convergence	Regionalism, less trade	Slow change, localized solutions	Globalization, economic convergence
IPCC global real GDP growth (2010–2060)	High (6.2X)	Low (3.2X)	Medium (3.5X)	High (6.2X)
IPCC global population growth (2010–2060)	Medium (1.3X)	High (1.7X)	Medium (1.4X)	Medium (1.3X)
IPCC global expansion of primary biomass energy production	High	Medium	Medium	Fuelwood demand follows historical trends in all countries[b]
U.S. GDP growth (2006–2060)	Medium (3.3X)	Low (2.6X)	Low (2.2X)	Medium (3.3X)
U.S. population growth (2006–2060)	Medium (1.5X)	High (1.7X)	Low (1.3X)	Medium (1.5X)

[a] Numbers in parentheses are the factors of change in the projection period. For example, U.S. GDP increases by a factor of 3.3 times between 2010 and 2060 for scenario RPA A1B.

[b] Not based on IPCC assumptions.

GDP = gross domestic product. IPCC = Intergovernmental Panel on Climate Change.

Table 2. Intergovernmental Panel on Climate Change scenarios and general circulation models used for the 2010 RPA Assessment climate projections.[a]

Scenario	GCM	Model vintage
A1B	CGCM3.1 (T47) MIROC3.2 (medres) CSIRO-Mk3.5	AR4
A2	CGCM3.1 (T47) MIROC3.2 (medres) CSIRO-Mk3.5	AR4
B2	CGCM2 CSIRO-Mk2 UKMO-HadCM3	TAR

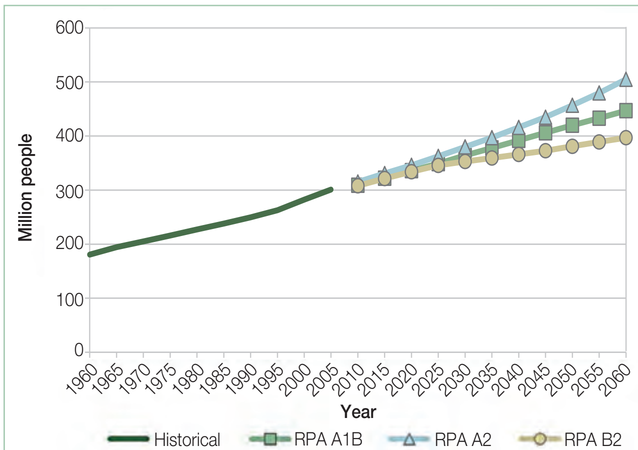
[a] AR4 climate projections were downloaded from the Web portal for the World Climate Research Program Coupled Model Intercomparison Project phase 3 and TAR climate projections were downloaded from the IPCC Data Distribution Centre. See Joyce et al. (in prep.) for details on the climate data and the downscaling procedures used.

We updated the IPCC projections of U.S. population and GDP, which were based on data from the early 1990s. Population and economic growth are significant drivers of change in resource demand and production. It was, therefore, important to have more current information to initialize the projections of U.S. population and economic growth. We disaggregated these updated estimates to obtain county-level income and population data (USDA Forest Service 2012). The county-level projections should not be taken as statistically reliable projections of possible economic or demographic futures for specific counties. Rather, the overall spatial pattern of change in response to alternative RPA scenarios is more important in our analyses, displaying the heterogeneity that would not be evident if we only made projections at the regional or national level.

U.S. Population Projections

The U.S. population projections for the IPCC A1B scenario were based on the 1990 Census. We updated those projections to align with the 2004 Census population series for 2000–50 (USCB 2004), with an extrapolation to 2060, and used this updated projection for the RPA A1B scenario. The population projections for RPA A2 and RPA B2 were updated to begin at the same starting point in year 2000 as RPA A1B, then to follow a projection path that maintained the same proportional relationship between RPA scenarios as in the original IPCC projections. Figure 11 illustrates the population projections for the RPA scenarios (RPA HFW has the same projection as RPA A1B) relative to historical population trends in the United States.

Figure 11. Historical and projected U.S. population, by RPA scenario, 1960–2060.[a]



[a] The population projection for RPA HFW is identical to that for RPA A1B.

County-level population projections were developed for the RPA scenarios (Zarnoch et al. 2010). Figure 12 shows the percent change in county-level population from 2010 to 2060 for the RPA A1B scenario. The spatial and temporal patterns are similar for the other RPA scenarios, with greater population change in RPA A2 and less population change in RPA B2.

U.S. Economic Projections

Macroeconomic trends (e.g., trends in GDP, disposable personal income (DPI), and labor productivity) influence the supply of and demand for renewable resources. The original IPCC data were based on economic data from the early 1990s, so we updated the GDP projections to start with the official U.S. GDP value for 2006 for all RPA scenarios (USDC Bureau of Economic Analysis 2008a).

We applied GDP growth rates provided by a commissioned report (Torgerson 2007) to develop an adjusted projection of GDP for the RPA A1B scenario. We revised the RPA A2 and RPA B2 GDP projections to maintain the same proportional relationship between the RPA scenarios as defined by the original IPCC GDP projections. Figure 13 shows the differences among the scenario projections for updated GDP in comparison to historical U.S. GDP.

Projections of personal income (PI) and DPI were also developed. The official U.S. 2006 statistics for PI and DPI were used to start the updated projection for the RPA A1B scenario (USDC Bureau of Economic Analysis 2008b). We calculated the RPA A2 and RPA B2 projections for PI and DPI to maintain the same proportional relationship across RPA scenarios that were used in calculating the trajectories for GDP. The national DPI and PI projections were also disaggregated to the county level (USDA Forest Service 2012).

The RPA scenarios were completed before the recent global economic downturn. We chose 2006 as the base year for the U.S. economic variables because they were the most recent data available when the RPA scenarios were constructed. Long-term projections are not intended to predict temporary ups and downs, meaning that recessions are not explicitly part of our projected 50-year trends. The range of RPA scenarios included in this assessment have varying rates of economic growth, however, both for the United States and globally, which provide a robust set of projections across the range of potential futures. In fact, the long-term U.S. GDP growth rates of the RPA A1B scenario are consistent with the historical GDP growth rate trend from 1950 to 2010 (through the recent recession), whereas the RPA A2 and RPA B2 scenarios have somewhat lower growth rates.

U.S. and Global Bioenergy Projections

We linked assumptions about the role of biomass in global energy projections to the IPCC global emissions scenarios, as we did with the population and income projections. In this case, we accounted for relevant regional land use projections and regional biomass energy projections provided by IPCC scenarios and their supporting database (Nakicenovic and Swart 2000). The IPCC scenarios all project that global energy production from oil will peak in the decade 2020–30, resulting in varying levels of expansion in alternative energy sources including bioenergy. For a detailed explanation of the RPA Assessment bioenergy assumptions, see Ince et al. (2011).

In all three IPCC-based RPA scenarios, expansion of biomass energy plantation area projected for global macroregions used in the IPCC Assessments (Nakicenovic and Swart 2000) was directly correlated with projected regional expansion in primary

Figure 12. Percent population change at the county level in the United States, RPA A1B, 2010–2060.

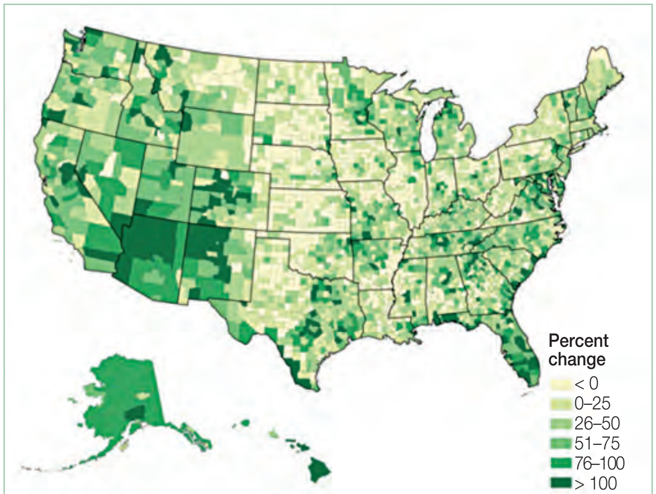
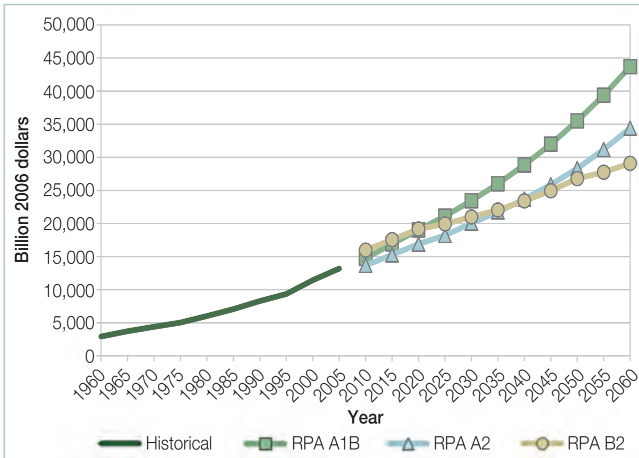


Figure 13. Historical and projected U.S. Gross Domestic Product (GDP), by RPA scenario, 1960–2060.[a]



[a] The GDP projection for RPA HFW is identical to that for RPA A1B.

biomass energy production. Comparing among IPCC scenarios, IPCC A1B had the largest global expansion in the area of biomass energy plantations and total biomass energy production, whereas expansions of biomass energy plantation area and biomass energy production were both smaller in the IPCC A2 and IPCC B2 scenarios. Projected expansion of biomass energy plantations occurred primarily on nonforest lands (agricultural and other lands) and primarily in Africa, Asia, and Latin America. Biomass energy plantations are not sufficient to supply the expanded bioenergy consumption of these IPCC scenarios, however, leading to significant projected expansion in fuelwood consumption from forests in the United States and globally.

The U.S. projections of expansion in wood energy consumption are prodigious in the IPCC-based RPA scenarios, but are by far the highest in the RPA A1B scenario, followed by the RPA A2 scenario, and lowest in the RPA B2 scenario (figure 14). In the RPA A1B scenario, for example, U.S. wood fuel feedstock consumption climbs to levels that dwarf U.S. consumption of wood for all other end uses (about five times higher by 2060 than all other wood uses), whereas in the RPA B2 scenario, U.S. wood fuel feedstock consumption climbs to a level just slightly higher than all other commercial uses. Although world roundwood fuelwood expansion factors are much lower than wood energy expansion factors for the United States (figure 14), worldwide fuelwood consumption is currently far higher than that of the United States, and projected worldwide consumption of fuelwood remains far higher than U.S. consumption throughout the projection period.

Because this expansion of wood energy consumption is higher for the United States than projections in the 2010 Annual Energy Outlook (USDOE EIA 2010), we developed the RPA HFW scenario, wherein projected U.S. and global fuelwood demand trends follow historical trends instead of the IPCC bioenergy projections. RPA HFW could be regarded as a scenario in which policies and technologies do not emerge that would enhance the role of wood in energy production, or in which alternative energy resources such as natural gas become more plentiful than projected by IPCC, reducing future expansion of wood energy. In comparison to the increases seen for RPA A1B, RPA A2, and RPA B2, RPA HFW results in wood energy expansion factors that are considerably lower (figure 14).

U.S. Climate Projections

The IPCC climate projections were first downscaled to the approximately 10-kilometer scale, then aggregated to the county scale. Three climate variables were downscaled for the RPA scenarios: monthly mean daily maximum temperature, monthly mean daily minimum temperature, and monthly precipitation. We also estimated mean daily potential evapotranspiration using the downscaled temperature values. Detailed documentation of the development of the RPA scenario-based climate projections and downscaling process can be found in Joyce et al. (in prep.).

At the scale of the conterminous United States, the RPA A1B scenario mean annual temperature and total annual precipitation show the greatest warming and the driest climate of all RPA scenarios at 2060 (figure 15). The RPA A2 scenario becomes the wettest, although the precipitation changes at the scale of the United States are small at 2060. The RPA B2 scenario projects the least warming of these three RPA scenarios. The individual RPA scenario-climate combinations highlight the variation within each scenario of the individual climate model projections. For example, within the RPA A2 scenario,

Figure 14. Projected expansion factors, 2006–2060, in the volumes of wood consumed for energy, by RPA scenario, including total U.S. wood fuel feedstock consumption, U.S. roundwood fuelwood consumption, and world roundwood fuelwood consumption.

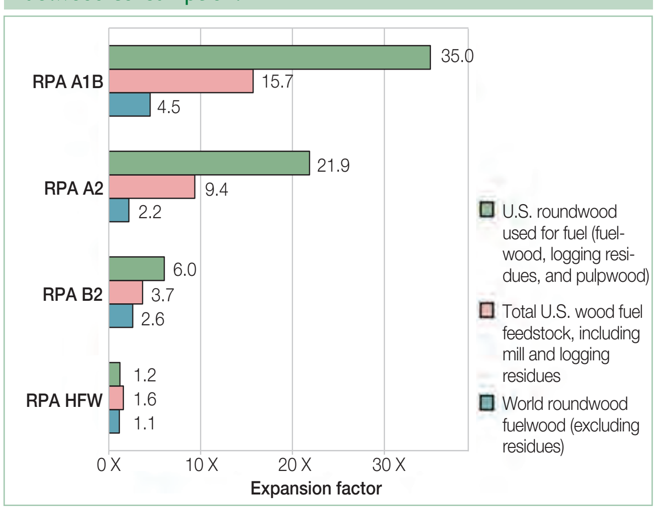
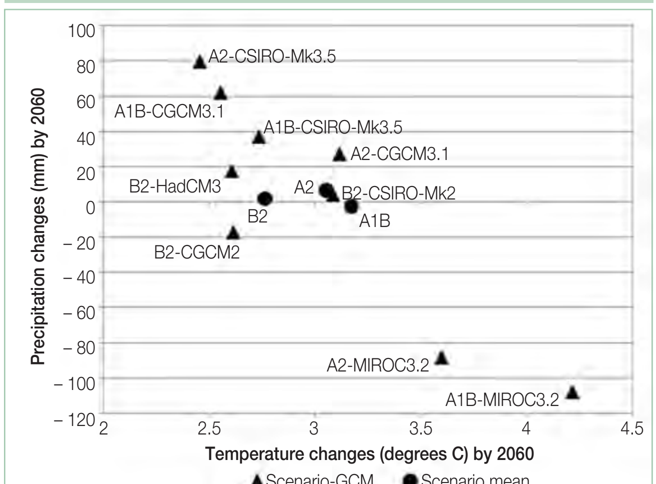


Figure 15. U.S. temperature and precipitation changes from the historical period (1961–1990) to the decade surrounding the year 2060 (2055–2064).[a]



[a] The Scenario-GCM pairs are defined in table 2.
C = Celsius. mm = millimeters.

the CSIRO-Mk3.5 model projects the least warming and the MIROC3.2 model projects the greatest warming. Although all areas of the United States show increases in temperature, the rate of change varies. Regional differences in precipitation projections vary greatly (Joyce et al., in prep.).

The IPCC projection period for these models was 100 years. By 2100, the RPA A2 scenario shows the greatest surface warming, in contrast to the results at 2060, the end of the RPA projection period, in which RPA A1B shows the greatest surface warming. By 2100, the GHG emissions associated with RPA A2 are greater than the emissions associated with both RPA A1B and B2.

Conclusions

The socioeconomic, bioenergy, and climate projections described in this chapter were used in projections of future resource uses and conditions. Although none of the resource and sector analyses use all of the scenario variables, all of the analyses use a subset of these variables. As a result, the RPA scenarios and their underlying assumptions provide a common framework for comparing results across resource analyses.

Chapter 6. Land Resources

The United States has extensive land and water resources. We begin this chapter with a brief overview of the land and water area of the United States, then focus on the U.S. land base. The United States does not have a consistent wall-to-wall, ground-based inventory of land use across all ownerships, but a wall-to-wall inventory of land cover from remotely sensed data does exist. Therefore, we present information about land use and land cover from both ground-based and remotely sensed sources.

Resource Highlights

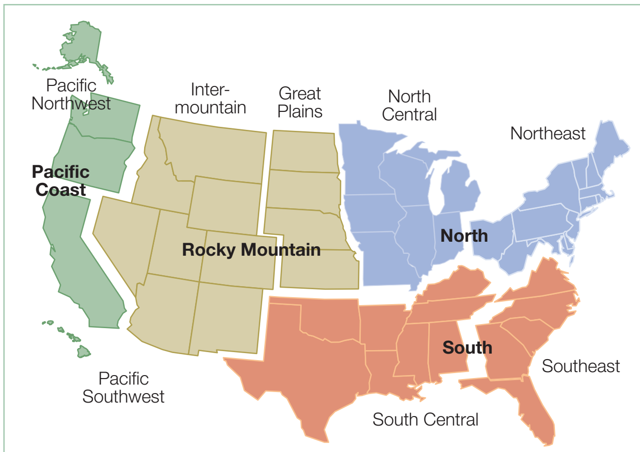
- Urban and other developed land area will increase in the future.
- Natural landscape patterns are affected by development patterns.
- Development pressures around public lands threaten ecological integrity.

In the first part of this chapter, we used data from the National Resources Inventory (NRI) to describe historical trends in major land uses in the conterminous United States (USDA NRCS 2009). The NRI data were also a key input to projecting major land uses to 2060. These land use projections were used in many of the resources analyses discussed in subsequent chapters.

Second, we used remotely sensed data from the National Land Cover Database (NLCD) to portray forest, grassland, and shrubland land cover[3] across all ownerships in all 50 States. We also used the NLCD to analyze landscape patterns that affect the ability of the resource base to provide goods and services from the Nation's forests and rangelands. We present results for the entire United States and for the four Resources Planning Act (RPA) Assessment regions (figure 16).

The final section provides an overview of protected areas in the United States. Protected areas on private and public ownerships are important resources in sustaining ecosystem services from forests and rangelands. Subsequent chapters will describe the extent of protected areas that contain forest and rangelands.

Figure 16. RPA Assessment regions and subregions.



Land Use and Cover Trends

The U.S. land area is about 2.3 billion acres (table 3), with about 1.9 billion acres in the conterminous United States. An additional 169 million acres is covered by water. More than 60 percent of U.S. land is privately owned. The Federal Government owns nearly 28 percent, more than one-third of which is in Alaska. State and local governments own about 9 percent,

[3] The NLCD does not define rangeland as a land cover class; therefore, the grassland and shrubland NLCD cover classes were used in these analyses.

Table 3. U.S. land and water area by RPA region, 2008.

Type of resource	North	South	Rocky Mountain	Pacific Coast	United States
	thousand acres				
Land area	412,621	532,887	741,872	572,987	2,260,367
Total water area	57,649	30,868	7,572	72,955	169,044
Inland water	12,692	18,641	7,572	16,396	55,301
Coastal water	3,676	4,125	0	19,836	27,637
Great Lakes	38,373	0	0	0	38,373
Territorial water	2,907	8,100	0	36,722	47,729
Total land and water area	**470,269**	**563,753**	**749,443**	**645,941**	**2,429,406**

Source: U.S. Census Bureau 2008

and more than 2 percent is held in trust by the Bureau of Indian Affairs. Overall ownership patterns have not changed in the last decade (Lubowski et al. 2006).

Land Use and Cover Trends, 1982–2007

The NRI provides data on land use and land cover on non-Federal land in the conterminous United States. The public land base tends to remain relatively stable over time; therefore, much of the effect of human-driven land use change occurs on the non-Federal land base. The changes in land use and land cover between 1982 and 2007 are shown in table 4, which presents the data in a matrix that shows both net changes in land use over time and the source of the area change (USDA NRCS 2011). Cropland, pastureland, and rangeland all declined during the 25-year period, but forest land increased slightly. The major increase occurred in the area of developed land.

Cropland had the largest decline in acres, with total acres declining about 15 percent during the 25-year period. The two largest changes in cropland occurred from the enrollment of 33 million acres of cropland in the Conservation Reserve Program (CRP) (included in other land cover/uses in table 4) and the conversion of 30 million acres to pastureland. Conversion to developed uses accounted for 11 million acres of change, or about 12 percent of the total decrease in cropland.

Although total acres of forest land remained relatively stable, there were a number of conversions to and from forest land from other land use categories. For example, forest land gained almost 18 million acres from pastureland, but lost about 17 million acres to developed land. In fact, forest land was the largest contributor (source of conversion) for developed land, followed by pastureland. Developed lands include urban, built-up areas and land developed for rural transportation. Conversions to urban or developed uses are usually permanent.

Wetlands are also inventoried in the NRI, but not as a separate land use or cover. In 2007, there were about 111 million acres of non-Federal palustrine and estuarine wetlands. Almost 60 percent of those wetlands (66 million acres) occurred on forest land (USDA NRCS 2009). Wetlands are generally very valuable habitat for wildlife and provide a variety of other services, such as flood control, aquifer recharge, and carbon sequestration (Mitsch and Gosselink 2007; Scodari 1997). The remaining wetlands are all the more important nationally, because less than 50 percent of the wetlands present in the conterminous United States in the 1700s remain (Dahl 1990, 2006). Wetlands continue to face conversion threats despite a series of laws and regulation aimed at wetland protection (see sidebar, Predicting the Fate of Wetland Habitats).

Table 4. Changes in major land cover and uses in the conterminous United States, 1982–2007.[a]

		2007 land cover/uses (million acres)						
		Cropland	Pastureland	Rangeland	Forest land	Developed land	Other land cover/uses	1982 total
1982 land cover/uses (million acres)	Cropland	326	30	7	9	11	37	**420**
	Pastureland	19	78	5	18	7	4	**131**
	Rangeland	7	3	392	3	5	8	**418**
	Forest land	2	5	2	372	17	5	**403**
	Developed land	—	—	—	—	70	1	**71**
	Other land cover/uses[b]	3	3	4	4	1	481	**495**
	2007 total	**357**	**119**	**409**	**406**	**111**	**536**	**1,938**

[a] To read this table: The number at the intersection of rows and columns with the same land cover/use represents acres that were in the same land cover/use category in both 1982 and 2007. The numbers to the left or right of this number represent acres lost to another land use during the period. The numbers above or below this number represent acres gained from another land use during the period. Comparing the "1982 total" column to the "2007 total" row represents the new acres gained or lost over the 25-year period.

[b] Other land cover/uses include land under contract in the Conservation Reserve Program of the U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS); other rural land; water areas; and Federal land areas.

Source: USDA NRCS 2011

Predicting the Fate of Wetland Habitats

A number of Federal programs and statutes have been directed at wetland protection. Much of the reduction in agricultural conversion of wetlands has been attributed to the Wetland Conservation Provisions of the Food Security Act of 1985, commonly called "Swampbuster," which withheld U.S. Department of Agriculture (USDA) farm program benefits from producers who converted wetlands to grow commodity crops (Williams 2005). A diverse set of statutes (e.g., Clean Water Act, Federal Aid to Wildlife Restoration Act, North American Wetlands Conservation Act), Executive Orders (e.g., Protection of Wetlands, Conservation of Aquatic Systems for Recreational Fisheries), and administrative policies (e.g., No-net-loss) also affect wetland conservation policy, making for a complicated system of protection and jurisdictional authority (Mitsch and Gosselink 2007).

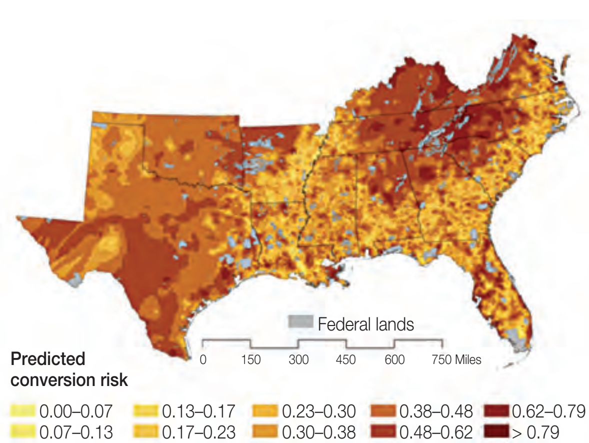
Despite this collection of laws and regulations, wetland conversion continues to occur as a consequence of permitting systems, exemptions, mitigation, and enforcement problems (Hansen 2006). Between 1992 and 1997, just less than 505,000 acres of palustrine and estuarine wetlands were lost in the United States; 75 percent of these losses were attributed to either development (49 percent) or agriculture (26 percent) (USDA NRCS 2000). The greatest loss of wetlands during this period occurred in the South Region (59 percent of the national losses), and 78 percent of the losses in this region were due to development (58 percent) or agriculture (20 percent).

We developed a model to predict the probability of wetland loss based on local characteristics of the wetland itself (e.g., type of wetland, incidence of periodic cultivation) and the wetland's landscape context (surrounding land uses and land covers). We focused our analysis of wetland conversion risk on the South Region, because the region is home to nearly one-half of the wetlands in the conterminous United States and had the majority of wetlands converted during the 1990s. We used National Resources Inventory (NRI) data (Nusser and Goebel 1997) to identify inventory points that were classified as wetland habitat in 1992 and that, by 1997, either remained wetland or were converted to a nonwetland status. Both local and landscape-level processes are thought to influence wetland fate (retained or converted) (Daniels and Cumming 2008). For this reason, we defined two sets of predictors: local predictors derived directly from the NRI point inventory, and landscape predictors derived from the 1992 National Land Cover Database (NLCD) (Vogelmann et al. 2001) that characterized land use and land cover in the vicinity of wetland points. The modeling approach related wetland fate to local features of the wetland and characteristics of the surrounding landscape (Gutzwiller and Flather 2011).

Findings

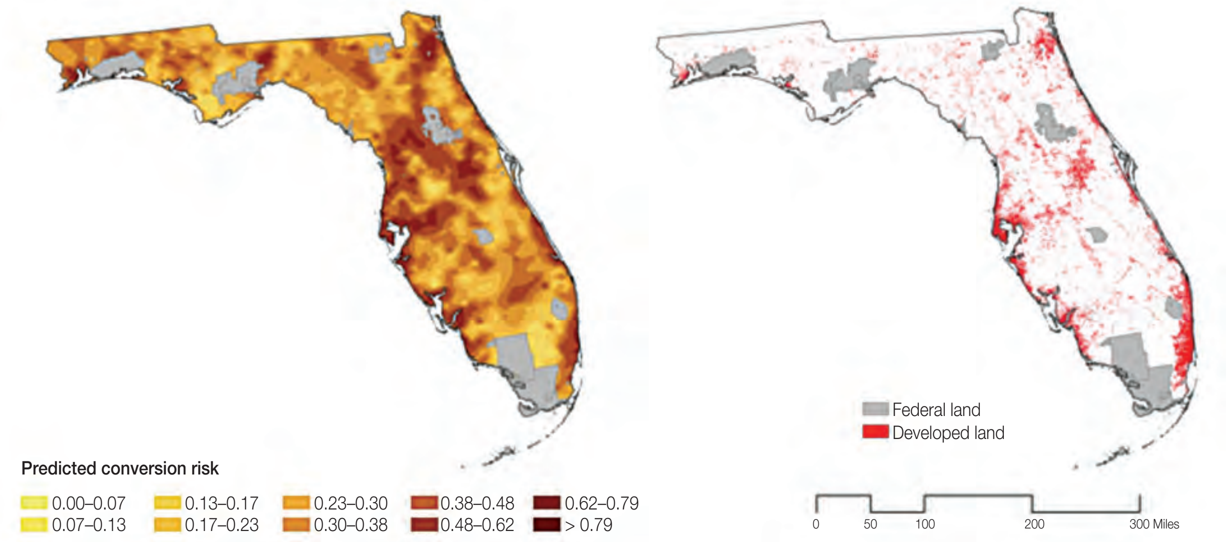
Overall prediction accuracy across the five test data sets was 75 percent, with nearly 80 percent accuracy on predicted wetland loss. Important predictors of wetland conversion were land use surrounding the wetland, wetland ownership, and proximity to developed land (including roads) and other wetlands. Predicted risks of wetland habitat loss (figure 17) were generally greater for highlands (Appalachian region and western parts of the study area) than they were for lowlands (coastal plains, piedmont, and Mississippi basin). Highlands are likely to be better drained than lowlands, and therefore, wetlands situated in highlands may be less extensive and more isolated. Indeed, based on the NLCD, wetlands in highlands were smaller and farther apart than were wetlands in lowlands. Compared to altering a wetland in a generally wet landscape (lowlands), there may be fewer financial costs associated with converting a wetland in better drained landscapes. Although the coastal plain and piedmont region was characterized by generally lower probabilities of wetland conversion relative to the highlands, there are notable areas of high risk interspersed throughout the South Region. Higher predicted risks of wetland habitat loss occurred in and near large urban areas in the region, as illustrated by specific sites in Florida (figure 18).

Figure 17. Predicted risk of wetland habitat loss, 1992–1997, for all National Resources Inventory (NRI) points that were wetland in 1992 for the Southeastern United States.[a]



[a] Gray polygons are Federal lands that were not sampled by the NRI.
Source: Gutzwiller and Flather 2011

Figure 18. Spatial correspondence between areas with high predicted risk of wetland habitat loss and urban areas in Florida, 1992–1997.[a]



[a] Gray polygons are Federal lands that were not sampled by the National Resources Inventory.
Source: Gutzwiller and Flather 2011

Implications

Conservation resources are scarce, so it is essential to focus on geographic areas where the risks for further wetland habitat loss are greatest. Our model and associated predictive map of conversion risk can be used to help prioritize wetland areas for conservation. Wetland habitats with high conservation value, high conversion risk, and low prediction errors would receive the highest priority for acquisition or other forms of long-term protection.

The risk of wetland habitat conversion can also be used in broad-scale evaluations of wetland habitat connectivity. Species dependent on wetland habitats, including many plants, amphibians, birds, and mammals, may benefit from landscapes in which wetland connectivity is high. A set of wetland sites may be functionally connected by being within the dispersal distance of a species. Functional connectivity may erode over time as wetlands with a high risk of conversion get transformed into some other land use or land cover, however. Network analysis methods (e.g., Minor and Urban 2007) can be used to identify wetland habitats that are essential for maintaining connectivity while also accounting for differential conversion risk. In this context, the quality of wetland sites for maintaining connectivity would be inversely related to their conversion risk. Such analyses would provide conservationists with fundamental information needed to rank the value of individual wetlands or wetland complexes for maintaining wetland habitat linkages.

The model can be used to aid planning decisions concerning projected urban development. In our study region, and especially in Florida, urbanization and housing development increased at a greater rate than they did in any other area in the country from the early 1980s into the late 1990s, a pattern that is expected to continue well into the 21st century (Wear 2011). Planners can use our model in conjunction with land-development forecasts to anticipate where wetland conversion pressures may be increasing (or decreasing) and use this information to guide development designs that may lessen wetland conversion pressures and ultimately reduce wetland loss.

Finally, our model can be used to assess the effectiveness of wetland conservation programs. The Wetland Reserve Program is an example of an important land-retirement program that authorizes USDA to purchase conservation easements to restore and protect wetlands (Williams 2005). But are the wetlands that landowners voluntarily enroll in this program those that face the greatest conversion risk? Characteristics of enrolled wetlands, including their location, can be used to estimate our model predictor variables, enabling prediction of wetland conversion risk for enrolled wetland habitats. If the land-retirement program was actually targeting at-risk wetlands, the average risk for enrolled wetland habitats would be expected to be higher than the average risk for unenrolled wetland habitats.

Future Land Use: Projections to 2060

Land use change is a major driver of resource change. We projected land use change for all counties in the conterminous United States for five major land use classes: pastureland, cropland, forest land, rangeland, and urban and developed uses. Details of the methods and results can be found in Wear (2011). All land use change was assumed to occur on non-Federal land within these categories; all other uses are held constant during the projection period, including Federal land, water area, enrolled CRP lands, and utility corridors. The land use projections do not assume any significant change in land use policy or regulations (i.e., projections are policy-neutral, based on historical land use relationships driven by future population and economic growth assumptions).

The land use projections are not linked to projections of land use change in Intergovernmental Panel on Climate Change (IPCC) scenarios because the IPCC data were not available at the national (individual country) level. The U.S. population and income variables that are drivers in the land use model are from the IPCC-based RPA scenarios, however. We were unable to incorporate climate effects into the land use change model because of the lack of county-level data on potential changes in productivity and/or associated returns to rural land uses across the United States. Depending on the changes in projected temperature and precipitation, it is possible that agriculture and forestry production possibilities may change in some RPA regions.

The land use model had two major components. The first used county-level population changes and personal income (PI) to simulate future urbanization, because urban uses were assumed to be the dominant land type in all land use conversions (in other words, land is converted to urban, but urban is not converted to other land uses). The second component allocated the remaining rural land among competing uses based on economic returns to the various rural land uses. The econometric models were fit to NRI land use change data from 1987 and 1997 to ensure the projected land use changes were generally consistent with observed urbanization intensities and rural land use changes. We held the real rents of both agricultural and forest land uses constant for the RPA A1B, A2, and B2 scenarios—in effect assuming that the relative returns to these uses remain constant through the projection period. For the RPA historical fuelwood (HFW) scenario, we accounted for a change in returns to forest use relative to agricultural uses.

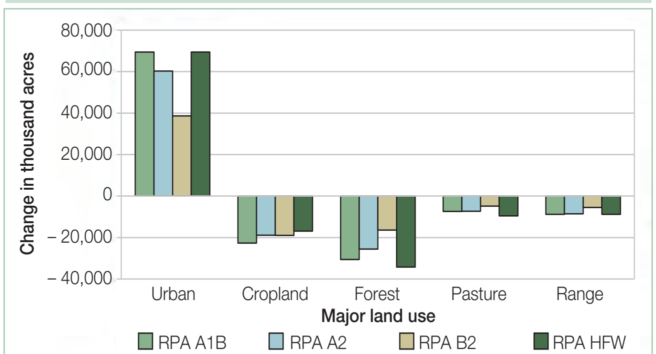
The changes in major land uses during the 50-year projection period for the RPA A1B, A2, B2, and HFW scenarios are shown in figure 19. In all RPA scenarios, increased urban and developed use is the dominant force in land use change, and all other land uses are projected to lose area.

The highest rate of urbanization occurs in scenarios RPA A1B and RPA HFW (which share the same population and income assumptions), indicating that the strong growth in PI in combination with moderate population growth created more development pressure than population growth alone (figure 20). Scenario RPA B2 has the lowest rate of urbanization. Urban and developed area increases by 69 million acres between 2010 and 2060 for RPA A1B, almost doubling the amount of urban area during the projection period.

The regional pattern of urbanization follows projected patterns of regional population growth (figure 20). Urban growth is projected to be highest in the South Region, which also has the highest projected population growth, gaining about 33 million acres. The North Region has the second greatest gain in urban areas (22 million acres), followed by the Rocky Mountain (8 million acres) and Pacific Coast (6 million acres) Regions. Although gains in urban acres tend to reflect current concentrations of urban areas, which are more concentrated in the Eastern United States, the rate of urban growth is highest in the Rocky Mountain Region, followed by the South, Pacific Coast, and North Regions.

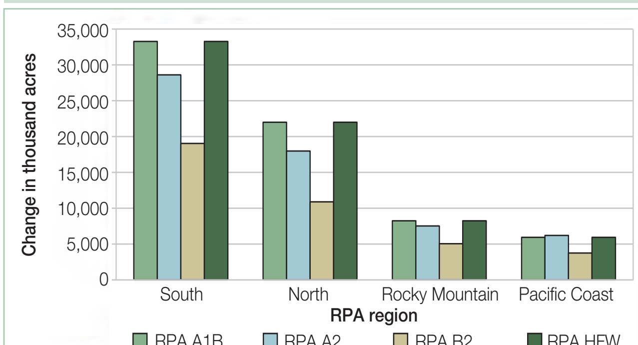
During the projection period, forest land declines by approximately 34 and 31 million acres in RPA A1B and HFW, respectively, whereas RPA B2 projects a loss of 16 million

Figure 19. Projected cumulative change in the area of major non-Federal land uses in the conterminous United States, by RPA scenario, 2010–2060.



Source: Wear 2011

Figure 20. Urban land area increases on non-Federal lands in the conterminous United States, by RPA region by RPA scenario, 2010–2060.

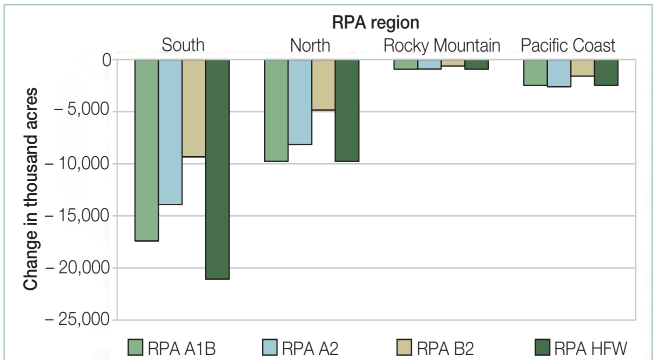


Source: Wear 2011

acres (figure 21). The South Region is projected to experience the largest decline in forest area by 2060, losing about 21 million acres in scenario RPA HFW. The large losses in the region reflect both an abundant forest resource and the highest projected population growth and urbanization. The difference in forest area loss for the South Region between the RPA HFW and A1B scenarios reflects the responsiveness of rural land uses in that region to relative returns to forest and crop uses (HFW has identical population and income projections as A1B, but forest returns are reduced relative to crop returns). The North Region has the second largest loss of forest land in RPA A1B (almost 10 million acres), followed by smaller losses in the Rocky Mountain and Pacific Coast Regions. Although losses of forest land are smaller in scenarios RPA A2 and B2, the pattern of forest land loss among RPA scenarios is similar among regions, with the exception of the Pacific Coast Region. In the Pacific Coast Region, the RPA A2 scenario has higher forest loss than RPA A1B, but the difference is quite small.

Cropland has the next greatest loss of acres, and those losses are concentrated in the Eastern United States, where most cropland is found. The losses are nearly equally split between the North and South Regions. Rangeland losses are concentrated in the Rocky Mountain Region, which has about one-half of the total rangeland losses. The remainder of rangeland losses is split between the South (primarily in Texas) and Pacific Coast (mostly southern California) Regions.

Figure 21. Change in non-Federal forest area in the conterminous United States, by RPA region by RPA scenario, 2010–2060.



Source: Wear 2011

Conclusions

Land use change is a dynamic process. Population and economic growth both tend to motivate conversion of other land covers to developed uses. The RPA land use projections to 2060 indicate the dominance of this influence, because most major land uses are projected to decline and only urban and developed uses increase. Forest land is the most heavily affected by these development pressures, especially in the Eastern United States. These net changes mask dynamic changes within and across land use categories, however. As shown in the historical trends from 1982 to 2007, land frequently transfers between major land use classes (e.g., cropland is converted to forest land and vice-versa). These types of changes are strongly influenced by policy, ranging from national agricultural policy to local zoning policies. For example, the CRP removed millions of acres from cropland in the last two to three decades.

The effects of land use change on forest and rangeland resources are discussed in more detail in subsequent chapters. We now turn our attention to examining how the spatial arrangement of land cover types may affect the ability of forests and rangelands to continue to provide an array of goods and services.

Land Cover Patterns in the United States

Many environmental processes are affected by, or depend upon, the spatial arrangement of natural resources within landscapes. Therefore, analyses of landscape patterns are needed to complement knowledge of the absolute areas of different land uses and land covers. Land cover pattern is one aspect of landscape pattern that can be evaluated by using the 2001 NLCD (Homer et al. 2007). A recent assessment of forest sustainability (USDA Forest Service 2011) provides conceptual models and examples showing why and how the results presented in this section can contribute to more effective natural resource management.

The NLCD provides land cover data for all of the United States, including Alaska, Hawaii, and Puerto Rico. The NLCD supports consistent and relatively high-resolution evaluation of several key patterns, including landscape context and fragmentation, as reported in this section. Although the NLCD is ideal for evaluating land cover patterns, it does not portray the human use of the land like the NRI and Forest Inventory and Analysis (FIA) systems do. For example, grassland cover may include a recreational use facility and land used for grazing. On the other hand, because the NLCD data cover the entire country wall to wall, they permit a spatial analysis of land cover fragmentation and juxtaposition that cannot be obtained from sample-based land use inventory systems like NRI and FIA. To avoid potential confusion of area statistics derived from different inventory systems, we present the statistics about landscape context and fragmentation as percentages of total NLCD areas rather than as absolute areas.

Landscape Context of Forest, Grassland, and Shrubland

Effective resource management takes into account the context within which natural resources occur. A context may be described in many ways, for example, by land ownership, by roadless designation, by dominant vegetation, or by topography. A description of landscape context in terms of nearby human activities such as farming and home construction is needed to inform conservation planning, because those activities introduce environmental risks while limiting land management options (Heinz Center 2008; Margules and Pressey 2000; Stein et al. 2009). There is ample evidence of widespread risks from human activities. For example, in 16 of the 31 Eastern States, the wildland-urban interface now encompasses more than 25 percent of total land area (Radeloff et al. 2005). Approximately 60 percent of the conterminous United States forest land is within 1,970 feet of either agricultural or developed land cover, and approximately one-third of the eastern forest exists within neighborhoods that also contain at least 10 percent agricultural land cover (Riitters 2011).

This section considers the anthropogenic landscape context of natural vegetation—forest, grassland, and shrubland—as defined by its co-occurrence with agricultural and/or developed land cover within a landscape. The "landscape mosaic" model (Riitters et al. 2009) was applied to the 2001 NLCD national land cover map (Homer et al. 2007). The model identified the landscape mosaic of each 0.22-acre land parcel on the land cover map according to the amounts of agriculture and developed land cover in the surrounding neighborhood. Subsets of forest, grassland, and shrubland parcels, defined by the original land cover map, were extracted to provide resource-specific statistics.

The landscape mosaic classification model (figure 22) uses the "landscape mosaic triangle" to classify a parcel of land according to the proportions of three generalized land cover types—agriculture, developed, and natural—in its surrounding neighborhood. "Natural" land cover includes water, forest, grassland, wetland, and shrubland. The acronyms in figure 22 refer to the landscape mosaic as explained in the caption of figure 22. Landscape background, a simplified version of the landscape mosaic model as indicated by the shading in figure 22, is called agricultural, seminatural, developed, or mixed depending on which types of land cover dominate the neighborhood.

Smith et al. (2009) reported landscape mosaics in the 38-acre neighborhoods containing forest and grassland. That analysis was updated for this report to add Alaska, Hawaii, and Puerto Rico, and to include shrubland with forest and grassland. For comparisons of the effects of neighborhood size, five additional neighborhood sizes from 11 acres to 185 square miles are reported elsewhere (Riitters 2011).

About three-fourths of the total area of the United States exists in a neighborhood characterized as having a seminatural background, with regional percentages ranging from 46 percent to nearly 100 percent (table 5a). More than 90 percent of forest (table 5b), grassland (table 5c), and shrubland (table 5d) appear in a seminatural background. Although the developed and agricultural backgrounds apply to 1.9 percent and 17.8 percent, respectively, of all land (table 5a), much smaller percentages of forest, grassland, and shrubland appear in developed and agricultural backgrounds. Anthropogenic environmental risks may be very high in predominantly agricultural or developed landscapes, but the overall percentages of forest, grassland, and shrubland exposed to that risk are relatively small. On the other hand, those same small percentages indicate that the risk of direct loss of natural vegetation is of much concern in those types of landscapes (Riitters et al. 2009).

The forest, grassland, and shrubland area in seminatural backgrounds is described in more detail in terms of its landscape mosaic in table 6. Overall, approximately two-thirds of all forest and grassland, and 90 percent of shrubland, are found in neighborhoods that contain only natural land cover types (mosaic class NN). There is substantial variation among RPA regions, and Alaska exhibits almost exclusively the mosaic

Figure 22. The landscape mosaic triangle model.

The axes of the landscape mosaic classification triangle show the proportions of natural (forest, grassland, shrubland, water, and wetland), agriculture (cultivated crops and pastures), and developed (urban and infrastructure) land cover types in the neighborhood. The shading and legend indicate the landscape background, and the acronyms within the figure indicate the landscape mosaic. In a mosaic acronym, the letters 'N' and 'n' refer to natural land cover, 'A' and 'a' refer to agriculture land cover, and 'D' and 'd' refer to developed land cover. A letter is upper case if that land cover occupies more than 60 percent of a neighborhood and lower case if it occupies from 10 to 60 percent of a neighborhood. A letter does not appear if that land cover occupies less than 10 percent of a neighborhood. The three corners of the triangle, indicated by double upper case letters, correspond to neighborhoods that contain only that one land cover type.

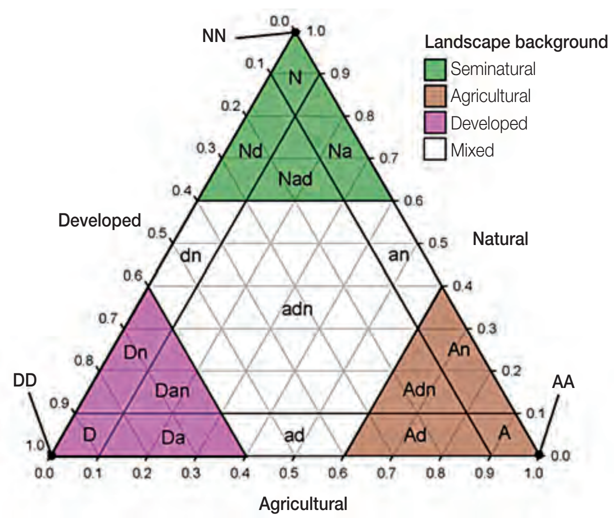


Table 5. Regional and national summary of landscape background for the year 2001 within a 38-acre neighborhood surrounding a 0.22-acre parcel of (a) any land cover, (b) forest land only, (c) grassland only, and (d) shrubland only. Each row shows the percentages of the total area in a region classified as each of four types of landscape background.[a]

RPA Region[b]	Seminatural	Agricultural	Developed	Mixed
	percent			
(a) Any land cover				
Alaska	99.9	0.0	0.0	0.0
North	45.9	38.8	4.0	11.4
Pacific Coast	84.2	10.4	2.7	2.7
Rocky Mountain	79.6	16.1	0.5	3.7
South	67.1	18.7	3.0	11.3
All regions	**74.1**	**17.8**	**1.9**	**6.3**
(b) Forest land only				
Alaska	100.0	0.0	0.0	0.0
North	87.4	3.4	0.4	8.9
Pacific Coast	98.9	0.1	0.1	0.8
Rocky Mountain	98.0	0.8	0.0	1.2
South	90.9	1.7	0.4	7.1
All regions	**93.4**	**1.6**	**0.2**	**4.8**
(c) Grassland only				
Alaska	100.0	0.0	0.0	0.0
North	63.2	15.5	0.7	20.7
Pacific Coast	95.2	0.9	0.6	3.3
Rocky Mountain	94.0	1.9	0.0	4.0
South	88.2	2.7	0.3	8.9
All regions	**92.7**	**2.2**	**0.1**	**5.0**
(d) Shrubland only				
Alaska	100.0	0.0	0.0	0.0
North	83.4	5.7	0.3	10.6
Pacific Coast	98.5	0.4	0.1	1.1
Rocky Mountain	99.3	0.1	0.0	0.5
South	94.0	1.5	0.1	4.3
All regions	**98.5**	**0.4**	**0.0**	**1.1**

[a] The data in this table differ slightly from an earlier RPA compilation (Table 2d.1 in Smith et al., 2009). The differences are attributable to exclusion of the separate dataset for roads and to the inclusion of Alaska, Hawaii, and Puerto Rico.

[b] Alaska is not included in the Pacific Coast Region total.

Source: 2001 National Land Cover Database

class NN because of the low amounts of agricultural and developed land there. Agriculture and developed land are most common and widespread in the North and South Regions, where typically 10 to 20 percent of forest, grassland, and shrubland is contained in seminatural background neighborhoods that contain at least some, but less than 10 percent of developed and agriculture land cover (mosaic class N). In those two regions, an additional 20 to 30 percent (the sum of mosaic classes Nd (natural-developed), Na (natural-agricultural), and Nad (natural-agricultural-developed) in table 6 of forest, grassland, and shrubland is typically contained in seminatural background neighborhoods with more than 10 percent agriculture or developed land. In comparison, agricultural and developed lands in the Rocky Mountain and Pacific Coast Regions tend to be concentrated closer to grassland and farther away from forest and shrubland. As a result, 10 to 15 percent of grassland is contained in seminatural background neighborhoods with more than 10 percent agriculture or developed land, roughly twice the percentages for forest and shrubland.

These results generally indicate that 90 percent of all shrubland is not exposed to anthropogenic risks associated with proximity to substantial (more than 10 percent) developed or agriculture land cover. In contrast, excluding Alaska, approximately one-half of all forest and grassland area is exposed to those risks. There is likely a very high risk of degradation of grassland and forest condition in seminatural landscapes containing 10 to 40 percent developed land cover, and such landscapes are also very likely to shift to developed landscape backgrounds over time as a result of urban sprawl (Riitters et al. 2009).

Fragmentation of Forest, Grassland, and Shrubland

Conversion of natural resources to other land uses isolates the remnant vegetation and exposes it to further degradation from edge effects encompassing a wide range of negative biotic and abiotic influences (Forman and Alexander 1998; Harper et al. 2005; Laurance 2008; Murcia 1995; Ries et al. 2004).

Table 6. Regional and national summary of selected landscape mosaics in landscapes with seminatural background within a 38-acre neighborhood surrounding a 0.22-acre parcel of (a) any land cover, (b) forest land only, (c) grassland only, and (d) shrubland only. Each row shows the percentages of the total area of the indicated land cover type in a region in each of the five landscape mosaic types.[a] Except for rounding errors, the row sums equal the corresponding table entry in the "seminatural" column in table 5.

RPA region[b]	All Natural (NN)	Natural (N)	Natural-developed (Nd)	Natural-agricultural (Na)	Natural-agricultural-developed (Nad)
			percent		
(a) Any land cover					
Alaska	99.3	0.3	0.2	0.0	0.0
North	22.5	10.0	4.4	7.8	1.2
Pacific Coast	67.2	9.0	6.3	1.5	0.2
Rocky Mountain	68.6	5.4	2.1	3.4	0.3
South	35.2	14.8	5.7	9.8	1.5
All regions	**57.0**	**8.0**	**3.5**	**5.0**	**0.7**
(b) Forest land only					
Alaska	98.8	0.7	0.4	0.0	0.0
North	44.9	19.9	7.3	13.5	1.8
Pacific Coast	78.7	12.2	7.1	0.8	0.1
Rocky Mountain	90.9	4.0	1.2	1.8	0.1
South	42.7	24.8	7.4	14.0	1.8
All regions	**64.0**	**14.9**	**5.2**	**8.2**	**1.1**
(c) Grassland only					
Alaska	99.7	0.2	0.1	0.0	0.0
North	15.8	16.8	10.1	17.1	3.4
Pacific Coast	64.5	16.2	10.5	3.5	0.6
Rocky Mountain	72.4	10.8	2.8	7.5	0.5
South	45.4	20.1	7.9	13.0	1.8
All regions	**67.7**	**12.1**	**4.2**	**7.9**	**0.8**
(d) Shrubland only					
Alaska	99.7	0.2	0.1	0.0	0.0
North	48.5	14.7	6.2	12.2	1.8
Pacific Coast	84.8	7.6	4.3	1.6	0.2
Rocky Mountain	92.1	4.0	2.0	1.1	0.1
South	68.8	12.4	4.7	7.2	1.0
All regions	**89.5**	**4.7**	**2.2**	**1.8**	**0.2**

[a] The data in this table differ slightly from an earlier compilation (Table 2d.2 in Smith et al., 2009). The differences are attributable to exclusion of the separate dataset for roads and to the inclusion of Alaska, Hawaii, and Puerto Rico.

[b] Alaska is not included in the Pacific Coast Region total.

Source: 2001 National Land Cover Database

At the local scale, actual edge effects naturally depend on circumstances such as the particular land use or the intensity of land use in the vicinity of edge. At the national scale, broader indicators of land cover patterns are appropriate to gauge the risks of edge effects (Heinz Center 2008). These broader indicators do not distinguish natural from anthropogenic fragmentation, which is important because disturbance and recovery are natural fragmenting processes, and natural mosaics of forest, grassland, and/or shrubland are characteristic of some areas. Although land use change is the dominant driver of current fragmentation (USDA Forest Service 2011), multitemporal data are needed to interpret these broader indicators with respect to anthropogenic fragmentation. To address a variety of questions about fragmentation in a nationally consistent way, the overarching problem is to characterize the type, extent, and location of natural resource spatial patterns. Land cover pattern indicators can inform policy regarding the needs for mitigation of fragmentation or the resulting ecological effects. Maps showing where the land cover is fragmented can suggest geographic regions where policies could be implemented.

Procedures described by Riitters (2011) were applied to the 2001 NLCD land cover map (Homer et al. 2007) to identify and map fragmentation of forest, grassland, and shrubland at the national scale. A pattern metric known as "area density" was used to describe each 0.22 acre parcel on the land cover map by the proportion (P) of a surrounding neighborhood that was a specified land cover type. Three specific land cover types were evaluated by looking separately at forest, grassland, and shrubland density. The analyses for each land cover type were repeated using six neighborhood sizes: 11 acres, 38 acres, 162 acres, 1,460 acres, 13,100 acres, and 118,000 acres (shown as triangles on the x-axis of figure 23). The maps of area density were then intersected with the original land cover map to extract values of forest area density for the forest parcels, grassland area density for the grassland parcels, and shrubland area density for the shrubland parcels. The extracted values were then expressed as the percentages of total area of each land cover type (forest, grassland, or shrubland) that met the criteria for intact ($P = 1.0$), interior ($P \geq 0.9$), and dominant ($P \geq 0.6$) land cover (figure 23).

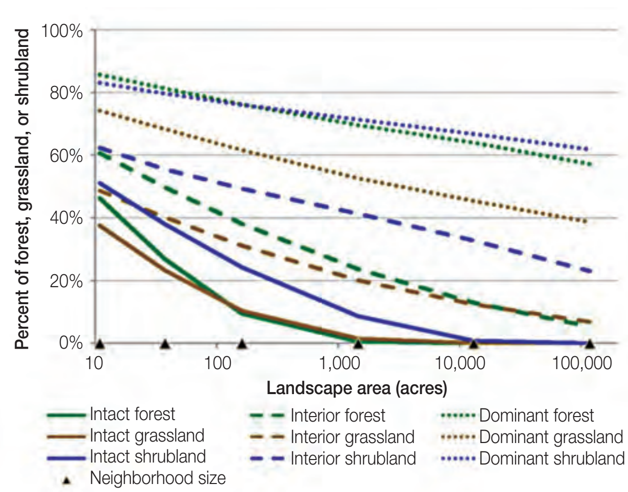
A finer scale analysis, using pattern metrics derived from mathematical morphology (Soille and Vogt 2009), indicated that a high percentage of each land cover type was within 98 feet of the nearest edge: 40 percent of grassland, 30 percent of shrubland, and 28 percent of forest (Riitters 2011). Percentages for larger edge widths may be estimated from the area density measurements because of the correspondence between neighborhood size and minimum distance to edge in an intact neighborhood (Riitters and Wickham 2003). From the complement of the intact percentages (solid lines in figure 23), it may be inferred that, (1) the percentage of edge increases rapidly with edge width for all three land cover types, (2) the percentage remains smallest for shrubland with increasing edge width, and (3) the percentage of forest edge approximates that of grassland for edge widths larger than approximately 1,970 feet (i.e., the edge width corresponding to an intact 162-acre neighborhood). Essentially, all grassland and forest resides in an edge condition for edge widths larger than 5,710 feet (an intact 1,460-acre neighborhood), and all shrubland is edge for edge widths larger than 3.2 miles (an intact 13,100-acre neighborhood).

Comparisons of the interior class (dashed lines in figure 23) indicate that grassland is the most fragmented and shrubland is the least fragmented of the three land cover types for all neighborhood sizes. Comparisons of land cover dominance (dotted lines in figure 23) indicate that grassland tends to be less dominant where it occurs than either forest or shrubland are where they occur, and that forest and shrubland dominance is similar for all neighborhood sizes. Less than one-half of all forest, grassland, or shrubland exists within an intact 11-acre neighborhood, and less than 10 percent of each land cover type exists within an intact 1,460-acre neighborhood (solid lines in figure 23). A sidebar examines in more detail the intact forest in 11-acre neighborhoods in the Eastern United States (see sidebar, Focus on Intact Eastern Forest).

In summary, all three land cover types tend to be dominant where they occur, yet fragmentation is so pervasive that the potential risk of short-range (98 feet) edge effects threatens 28 percent of all forest, 30 percent of all shrubland, and 40 percent of all grassland. Shrubland is the least fragmented land cover type, grassland is the most fragmented, and forest is fragmented like shrubland in smaller neighborhoods or for lower fragmentation thresholds and like grassland in larger neighborhoods or for higher fragmentation thresholds.

This comparative assessment of forest, grassland, and shrubland fragmentation may be used to suggest opportunities to improve the benefits that society draws from natural resources. One objective could be to increase the amount of relatively intact land cover. Recognizing that the management decision is ultimately where to convert land cover, the knowledge of current patterns can indicate where the additions will most efficiently increase intactness. As an example, the percentages of edge (98 feet) and interior-plus-intact land cover (162-acre neighborhoods) are summarized by county in figure 24. Note that the percentages shown in figure 24 are based on extant land cover area, not total county area. For example, counties in the Great Plains Subregion show a high percentage of forest edge, even though the total forest area in those counties is relatively small. Thus, figure 24 portrays the patterns of the existing land cover in whatever amounts those land covers actually occur. Restoring and promoting the intact condition will be more efficient in counties where the proportions of both edge and interior-plus-intact are relatively high already. For forest, that includes counties across most of the Eastern United States except in public lands along the Appalachian Mountains. Similarly, grassland restoration in western Kansas would increase the overall amount of interior of this geographically limited resource, and southern Colorado is an example of comparatively high edge and interior values for shrubland. But county-level information is only a partial guide, and the national maps of patterns could be used to identify and rank potential sites within counties, because patterns are mapped at the parcel level. For example, to reduce the occurrence of internal edge (perforations), the maps could be inspected to focus attention on filling holes in otherwise intact forest. To improve overall connectivity across landscapes, the maps can indicate where to expand or connect existing clusters of intact forest.

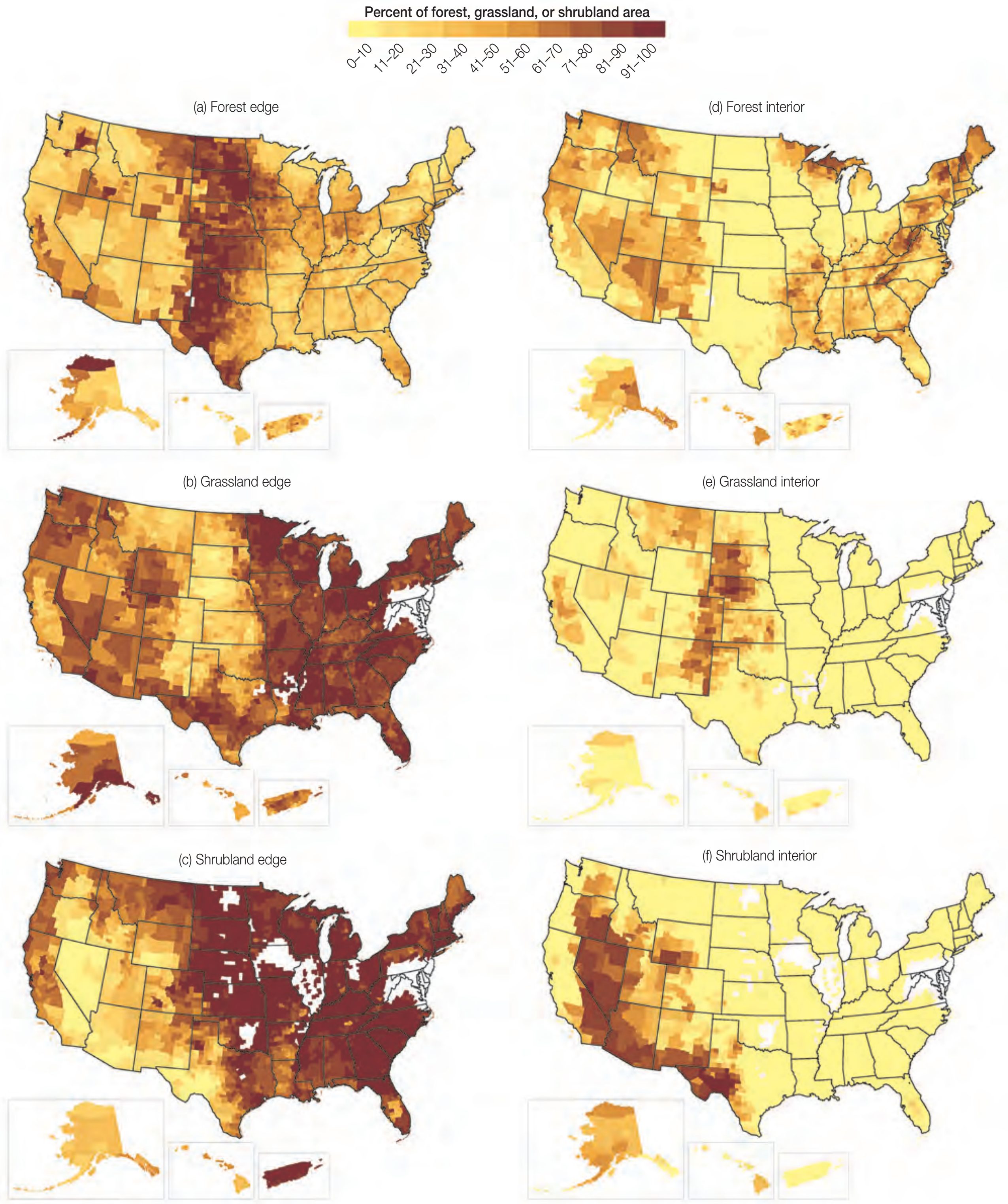
Figure 23. National summary of land cover fragmentation for forest, grassland, and shrubland for six neighborhood sizes, 2001.



Source: 2001 National Land Cover Database

Figure 24. County-level summaries of edge and interior forest, grassland, and shrubland, 2001.

Each county is shaded according to the percentage of the indicated land cover type in that county, which was labeled as (a) forest edge, (b) grassland edge, (c) shrubland edge, (d) forest interior, (e) grassland interior, and (f) shrubland interior. Edge includes area within 98 feet of a different land cover type, and interior includes both intact and interior area density classes as measured in 162-acre neighborhoods. Note that the percentages are based on extant land cover area of the indicated type, not total county area. Counties lacking a given land cover type are shown as missing data. The inset maps show Alaska, Hawaii, and Puerto Rico; map scale varies among maps.



Source: 2001 National Land Cover Database

Conclusions

Most of the total area of forest, grassland, and shrubland occurs in landscapes dominated by seminatural land cover, yet fragmentation is so pervasive that only a small percentage of that area is free of the ecological risks that are posed by proximity to human land uses. Overall, grassland is not only rarer but also more fragmented than either forest or shrubland. There is substantial regional variation in the degree of fragmentation and the type of ecological effects that might be expected. Fragmentation poses less risk in Alaska than in other areas simply because the overall intensity of human land use is relatively lower there. Anthropogenic land uses pervade the conterminous United States, and as a result the associated effects from fragmentation are likely to be widespread. Although trend analyses have been hampered by a lack of comparable national data, the land cover patterns observed in 2001 do not suggest that conditions have improved since the last RPA Assessment. If the historical patterns of land uses continue, then future fragmentation will pose higher risks to seminatural land cover that occurs on privately owned land or that is close to existing intensive land uses.

Focus on Intact Eastern Forest

The forest fragmentation measurements reported elsewhere in this assessment do not account for potential differences among forest types or ownerships. Those differences may be important when translating assessment findings to land management policy and action. The national analysis of forest fragmentation was refined for eastern forests in the 31 States east of the Mississippi River by incorporating field plot observations of forest types and ownerships from the Forest Inventory and Analysis Program (USDA Forest Service 2010). We focused on intact forest in these results. Intact forest was defined as an 11-acre neighborhood containing only forest land cover; all nonforest land cover was treated as a fragmenting agent (Riitters et al. 2012). Overall, 161 million acres of eastern forest land—equivalent to 44 percent of the total FIA forest land area—qualified as intact forest land cover.

Which Forest Types Are Intact?

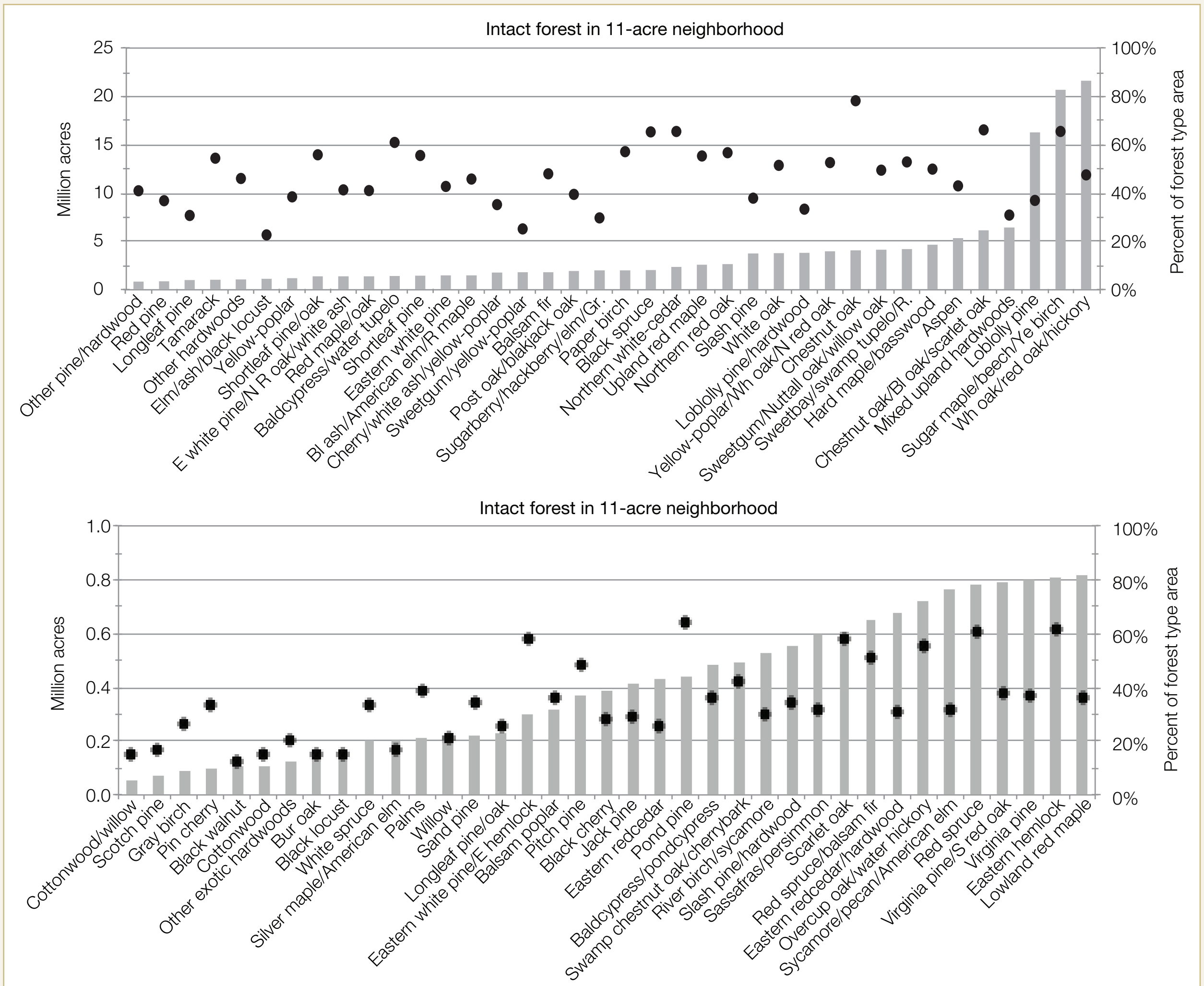
Fragmentation varies naturally among forest types because of the biophysical differences where those types occur and because human land uses tend to fragment some forest types more than others. That makes it more difficult to quantify and manage the benefits of intact forest on forest-dependent goods and services that are tied to specific forest types. For example, an intact black spruce forest offers habitat for a different set of species than the ones found in an intact longleaf pine forest, and the quality of intact forest habitat depends on which species are found in a given type of forest. Information about the current extent of intact forest can also inform land management policy by identifying forest types of special concern for conservation or remediation, for example the ones that do not have a high proportion of intact forest.

The forest-type analysis considered the 75 eastern forest types that occupy at least 173,000 acres each. Exotic forest types such as paulownia and eucalyptus were thus excluded, but that criterion also eliminated five native forest types that are relatively uncommon—spruce-pine, mangrove, table mountain pine, Fraser fir, and Atlantic white-cedar. Using the FIA statistical estimators, the total area of intact forest was calculated for each type. Those estimates were also expressed as the percentage of total forest land area of each forest type that was intact forest land cover.

The percentage of intact forest varied from 13 to 78 percent of individual forest-type area, with the median forest type having 38 percent of its area as intact (figure 25). As expected, lower percentages were obtained for some naturally fragmented forest types such as bur oak, cottonwood, and willow, and higher percentages were obtained for some forest types that tend to be inaccessible because of steep slopes or protected status (e.g., chestnut oak) or hydric soils (e.g., northern white-cedar, black spruce, and pond pine). Considering the forest types that are not naturally fragmented and that are usually found in accessible locations, typically less than one-half of the total area of those forest types qualified as intact forest.

Policy concerns are more likely to be driven by estimates of total area of intact forest instead of percentages of intact forest. It should be noted that the intact area associated with a forest type is the product of its intact percentage and total forest-type area. Because total forest-type area varies substantially among forest types (Smith et al. 2009), some forest types exhibit a large absolute area of intact forest even if the percentage of intact area is low. More than one-third of the total intact forest area in the East is associated with the three forest types—white oak-red oak-hickory, sugar maple-beech-yellow birch, and loblolly pine—that together comprise approximately one-third of total forest land area, even though the percentage of intact forest is less than 50 percent for two of them (figure 25). The exception is the sugar maple-beech-yellow birch forest type that contributed 13 percent of total intact forest land area, because it was the third most common forest type and exhibited the second highest percentage (65 percent) of intact forest. In comparison, the eight other forest types exhibiting more than 60 percent intact forest—chestnut oak, chestnut oak-black oak-scarlet oak, northern white-cedar, black spruce, pond pine, eastern hemlock, bald cypress-water tupelo, and red spruce—contributed a total of 11 percent of the total area of intact forest land because those types are relatively less common.

Figure 25. The area of intact eastern forest types in 2001(vertical bars) and the corresponding percentage of forest type area that is intact (circles). Forest types are sorted by intact area; note the scale change between the two charts. Forest types are as defined in USDA Forest Service (2010); some types are abbreviated using E (eastern), N (northern), S (southern), Bl (black), Gr (green), R (red), Wh (white), or Ye (yellow).

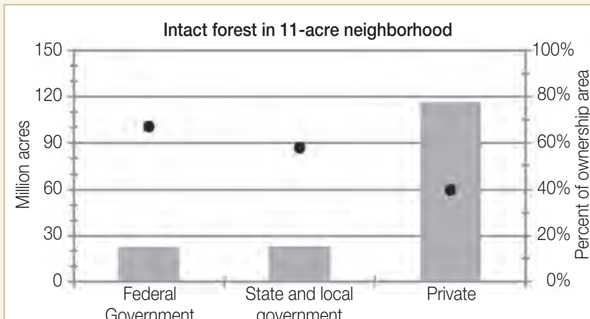


Sources: 2001 National Land Cover Database; USDA Forest Service, Forest Inventory and Analysis

Who Owns the Intact Forest?

Fragmentation varies among ownerships primarily because of differences in the land uses that occur on different ownerships. The summary of intact forest by ownership (figure 26) considered three ownership classes defined by the FIA inventory—private, State and local government, and Federal Government (USDA Forest Service 2010). The percentage of forest land that was intact forest was lower on private land than on public land, but nearly three-fourths of total intact forest area in the 31 Eastern States was on private land because 80 percent of all forest in the East is privately owned.

Figure 26. Eastern forest ownerships (circa 2001) characterized by the percentage of group forest land area that is intact (circles) and the total area of intact forest (vertical bars). Forest ownership groups are as defined in USDA Forest Service (2010).



Sources: 2001 National Land Cover Database; USDA Forest Service, Forest Inventory and Analysis

Protected Areas in the United States

Forests and rangelands of the United States are in protected status for a variety of purposes, but primarily to preserve functioning natural ecosystems, provide refuges for species, and maintain ecological processes (Anderson et al. 2010). The Federal Government holds almost 30 percent of the country's total land area. The National Park Service (79 million acres), National Wildlife Refuge System (145 million acres), National Forest System (NFS, 193 million acres), and public lands administered by the Bureau of Land Management (BLM, 250 million acres) all include forests and rangelands that are managed according to their varying legal mandates. State and local governments also manage forests and rangelands through State parks, State forests, and other holdings. Government and nongovernmental organizations protect natural values on private lands through ownership, conservation easements and other programs such as the CRP.

Although the Nation lacks a comprehensive inventory of the protected status of all public and private lands, significant progress has been made in the past decade by a collaborative effort involving Federal and State agencies and private conservation organizations. The resulting Protected Areas Database of the United States (PAD-US) includes detailed maps of the known, proposed, and protected areas for all 50 States, and the status of each protected area according to guidelines developed by the International Union for the Conservation of Nature (IUCN). Definitions of the IUCN categories are found in table 7. This section summarizes the Nation's protected areas by owner type and IUCN designation as shown in the PAD-US (Conservation Biology Institute 2010).

Public ownership generally offers protection from conversion to more developed uses. Public lands are not immune to natural resource threats that are traceable to land use changes in proximity to their boundaries, however (see sidebar, Housing Growth Near Public Lands). Because these boundary lands have high amenity values, they are subject to increasing development pressures from housing. The natural resource threats from this development are many and include increased recreational pressure, increased poaching of resources, increased fire incidence, increased pollution, and additional barriers to wildlife dispersal.

Not all public lands meet the IUCN criteria. The PAD-US includes an approximate area of 333 million acres of land formally classified as protected using the IUCN designations. About 30 percent of these lands are strictly set aside to protect biodiversity or are formally designated wilderness areas. More than 99 percent of the designated area is either Federal (274 million acres) or State (57 million acres) land (table 8). The remaining 511 million acres (21 percent of total U.S. area) held in Federal and State ownership is in the "unassigned" category. Overall, the protected lands in the East are not as extensive as in the West, reflecting the distribution of Federal ownership. Of the total area meeting IUCN protected area criteria, approximately 51 percent is found in Alaska, 21 percent in the Rocky Mountain Region, 11 percent in the Pacific Coast Region, 10 percent in the North Region, and 7 percent in the South Region.

National Wilderness Preservation System

The National Wilderness Preservation System (NWPS) encompasses about 109 million acres, managed by four Federal agencies (table 9). A wilderness area is a special congressional designation that is intended to protect the wild character inherent in the land, as outlined in the Wilderness Act of 1964. Most of the land in the NWPS is in the Western United States, with 52 percent of the total area in Alaska.

Although the Wilderness Act did not provide a mandate to achieve full representation of all ecosystems, it is interesting to examine to what extent ecosystems types are protected within the NWPS. Representation of ecosystem types within the NWPS is irregular. In terms of percentage of NWPS among Bailey's Ecoregion Divisions, the greatest portions are Tundra Regime and Subarctic Mountains in Alaska, Marine Regime Mountains in Washington, Oregon, and southeast Alaska, and Temperate

Table 7. Definition of International Union for the Conservation of Nature (IUCN) categories for the Protected Areas Database of the United States (PAD-US).

IUCN category	Definition
Ia	Strict Nature Reserve: protected area managed mainly for science.
Ib	Strict Nature Reserve: protected area managed mainly for wilderness protection.
II	National Park: protected area managed mainly for ecosystem protection and recreation.
III	Natural Monument: protected area managed mainly for conservation of specific natural features.
IV	Habitat/Species Management Area: protected area managed mainly for conservation through management intervention.
V	Protected Landscape/Seascape: protected area managed mainly for landscape/seascape conservation and recreation.
VI	Managed Resource Protected Area: protected area managed mainly for the sustainable use of natural ecosystems.
Unassigned	In the PAD-US database, this category includes public and private land that was evaluated by the cooperators and was determined to not have an applicable IUCN code. It includes, for example, a large share of National Forest System land and almost all Native American land.

Source: International Union for the Conservation of Nature 1994

Table 8. Protected areas from Protected Areas Database of the United States (PAD-US) by ownership and RPA region.[a]

RPA region	Owner	Designated IUCN category (thousand acres) (excludes unassigned area)							Row total
		Ia	Ib	II	III	IV	V	VI	
Alaska	Federal	151	53,764	6,840	4,284	67,462	28,899	58	161,458
	State	0	198	1,949	0	3,546	1,126	2,164	8,984
	Other	0	0	0	0	0	0	0	0
	Region total	151	53,962	8,789	4,284	71,008	30,025	2,222	170,441
North	Federal	8	1,630	366	32	1,248	3,344	656	7,283
	State	0	434	936	0	5,635	4,351	11,689	23,045
	Other	0	0	0	0	3	2,345	0	2,349
	Region total	8	2,064	1,302	32	6,886	10,040	12,345	32,677
Pacific Coast[b]	Federal	248	18,116	3,061	437	1,340	8,785	16	32,004
	State	0	0	722	0	330	3,639	1,080	5,770
	Other	0	0	0	0	0	23	0	23
	Region total	248	18,116	3,783	437	1,670	12,447	1,095	37,797
Rocky Mountain	Federal	645	24,670	6,020	6,037	7,577	15,453	582	60,983
	State	0	0	238	1	2,749	6,005	15	9,007
	Other	0	0	94	0	11	319	0	424
	Region total	645	24,670	6,352	6,038	10,337	21,776	597	70,414
South	Federal	11	1,060	3,518	95	3,239	3,598	670	12,191
	State	0	10	564	0	6,812	1,403	971	9,759
	Other	0	0	0	0	1	54	34	89
	Region total	11	1,069	4,083	95	10,052	5,054	1,675	22,039
National	Federal	1,064	99,239	19,805	10,885	80,866	60,078	1,982	273,919
	State	0	642	4,409	1	19,071	16,524	15,917	56,565
	Other	0	0	95	0	15	2,741	34	2,885
	National total	1,064	99,881	24,309	10,886	99,952	79,343	17,934	333,369

[a] Entries may not sum to row or column totals because of rounding.

[b] Alaska is not included in the regional total because it is listed separately.

IUCN = International Union for the Conservation of Nature.

Source: Conservation Biology Institute 2010

Table 9. Acres and percent of Federal land in the National Wilderness Preservation System (NWPS) by agency and RPA region, 2009.

Federal agency	North		South		Rocky Mountain		Pacific Coast		United States	
	Acres (thousands)	%	Acres (thousands)	%	Acres (thousands)	%	Acres (thousands)	%	Acres (thousands)	%
Bureau of Land Management	0	0.0	0	0.0	4,606	52.8	4,120	47.2	8,726	8.0
Fish & Wildlife Service	64	0.0	470	2.3	1,465	7.1	18,703	90.3	20,702	18.9
Forest Service	1,428	3.9	755	2.1	18,208	50.4	15,769	43.6	36,160	33.0
National Park Service	179	0.4	1,488	3.4	1,343	3.1	40,883	93.1	43,891	40.1
U.S. total	**1,671**	**1.5**	**2,712**	**2.5**	**25,621**	**23.4**	**79,474**	**72.6**	**109,479**	**100.0**

Steppe Mountains, mostly in Montana, Idaho, Wyoming, and Utah. Also represented is the Tropical/Subtropical Desert Division of the Southwest. In terms of the percentage of Bailey's Divisions designated as Wilderness, Alaskan Tundra and Subarctic Divisions, Marine Mountains, Temperate Steppe Mountains, and Tropical Desert are among the highest (Cordell in press).

Designation as a wilderness area is not sufficient to maintain its inherent characteristics. Numerous external and internal conditions and influences threaten wilderness resource values. Wilderness areas in many States are increasingly isolated fragments or remnants of historic ecosystems. Wilderness areas sometimes become ecological islands as surrounding landscapes become more developed with higher population density. This concern is most pronounced in the wildernesses of the East, but also occurs in the West as natural landscapes are increasingly affected by human development and use (Dawson and Hendee, in press).

Wilderness areas are particularly affected by exurban and rural sprawl (Cordell et al. 2005). The pressures of human development and private land ownership within the protected landscape create challenging issues for managers of public lands. Development within and around protected lands can affect both the ecology and management of these ecosystems by increasing forest, range, and wildlife habitat fragmentation, reducing air and water quality, and decreasing recreation opportunities and access. Continued increase in low-density residential development poses a threat to wilderness areas. Development near wilderness areas has also been associated with increasing recreation pressure, which, in turn, has been shown to alter vegetation and population demography of recreationally harvested game species (Braun et al. 1993).

Procedures used to evaluate development risks around national forests (Stein et al. 2005) were adapted and applied to 600 wilderness areas of greater than 640 acres to assess which areas are most threatened by development. Of the top 10 most threatened wilderness areas, 5 are in the Pacific Coast Region: Juniper Dunes Wilderness in Washington (BLM-managed), Table Rock (BLM) and Mountain Lakes (Forest Service) Wilderness Areas in Oregon, and the Ishi Wilderness Area in California (Forest Service). The remaining five were scattered widely across the United States: Hells Canyon Wilderness Area in Arizona (BLM), Swanquarter Wilderness Area in North Carolina (U.S. Fish and Wildlife Service [FWS]), Mingo Wilderness Area in Missouri (FWS), Kisatchie Hills Wilderness Area in Louisiana (Forest Service), and Soldier Creek Wilderness Area in Nebraska (Forest Service).

One of the complicated problems presented by climate change is that the current system of protected areas may not be equally effective under changing climatic conditions. Conservation is naturally aimed at protecting current conditions in specific places, but those conditions may disappear, or migrate, to other locations as a result of a changing environment. Unfortunately, the available climate projections at the county level are too coarse to enable projecting the protected status of the potential new conditions.

The data from the PAD-US provide a broad overview of the status of protected lands in the United States. We conclude this section with a brief discussion of trends in land conserved by private land trusts and State and local governments.

Private Land Trusts

Land trusts are one venue for protection of private lands. The 2005 National Land Trust Census Report (Land Trust Alliance 2006) provided information on national trends in private land conservation. In 2005, total acreage conserved through private means was 37 million acres, a 54-percent increase from 2000. This acreage is managed by local, State, and national land conservation groups. Local and State land trusts doubled to almost 12 million acres in 2005. Many of these acres are protected under conservation easements—accounting for a little more than 6 million of the total acres in 2005.

The primary focus of land trust efforts was protecting natural areas and wildlife habitat, followed by open space and water resources, particularly wetlands. The Western United States was the fastest growing region in both numbers of acres conserved and in the number of land trusts, especially for protection of rangeland.

State and Local Lands

State governments protected almost 9 million acres between 1998 and 2005, with 61 percent of those acres purchased in fee-simple title, and the remainder protected through conservation easements (Trust for Public Lands 2011b). States that both spent the most and conserved the most acres over that time period were California, Florida, New Jersey, New York, and North Carolina.

Support for State and local conservation often comes through ballot initiatives. Despite challenging economic times, voters have continued to support public funding of land conservation. Between 1990 and 2010, local governments were the most successful at passing ballot measures for land conservation, although successful State measures resulted in the most funding. The North Region had the highest rate of success at passing ballot measures and generated the most funding for land conservation (du Moulin and Alford, in press).

County-level ballot measures specifically targeted at forest land generated more than $1 billion between 1990 and 2010, whereas almost $5 billion was approved for conservation of farmland. Spending in 2009 and 2010 was dramatically less than previous-year levels, however, reflecting budget issues faced by many county and municipal governments. Nonetheless, a number of conservation initiatives were successfully passed in 2010 in 23 States, indicating continuing support for land conservation.

Conclusions

The Nation lacks a comprehensive inventory of the protected status of natural resources. The available data provide a first approximation according to IUCN definitions of protected area. Of the approximately 333 million acres classified as protected by IUCN definitions, approximately 110 million acres are strictly set aside to protect either biodiversity or wilderness settings. Primarily reflecting the extent of public ownership in different regions, about one-half of the total protected area is located in Alaska, one-third is in the West, and the remainder is in the East. Although many protected areas effectively preserve rare or endangered species and habitats, it is an open question whether the overall amount and location of protected area is appropriate for protecting all biodiversity values nationally. Furthermore, given the possibility of species and habitat migration with climate change, it is also not clear whether the current design of protected areas will serve to sustain biodiversity over the long term. To address these uncertainties, natural resource managers must consider biodiversity effects of land use and climate change on all land irrespective of its ownership and protected status.

Housing Growth Near Public Lands

Open lands are under increasing pressure from housing and road development to support a growing human population (Hawbaker et al. 2006; Radeloff et al. 2005; Stein et al. 2005; Stein et al. 2007). These development pressures are particularly evident on lands with high natural amenity values (Huston 2005; Radeloff et al. 2005)—lands that often occur in proximity to public lands in general and to national forests in particular (Radeloff et al. 2010).

Expanding human populations and the associated land use changes are the primary factors driving changes in biological diversity (Vitousek 1997). As private lands bear the growing burden of human-associated ecosystem stresses, public lands are becoming increasingly important for the conservation of biological resources (Flather et al. 2009; Robles et al. 2008). Land use activities on surrounding private lands affect the ability of public lands to sustain important ecosystem services, however. We reviewed the recent historical trends in housing development in and near national parks, national forests, and wilderness areas throughout the conterminous United States. In particular, we identified regions experiencing the most exurban growth near and within the boundaries of public lands to assess where housing development poses the most risk to conservation values.

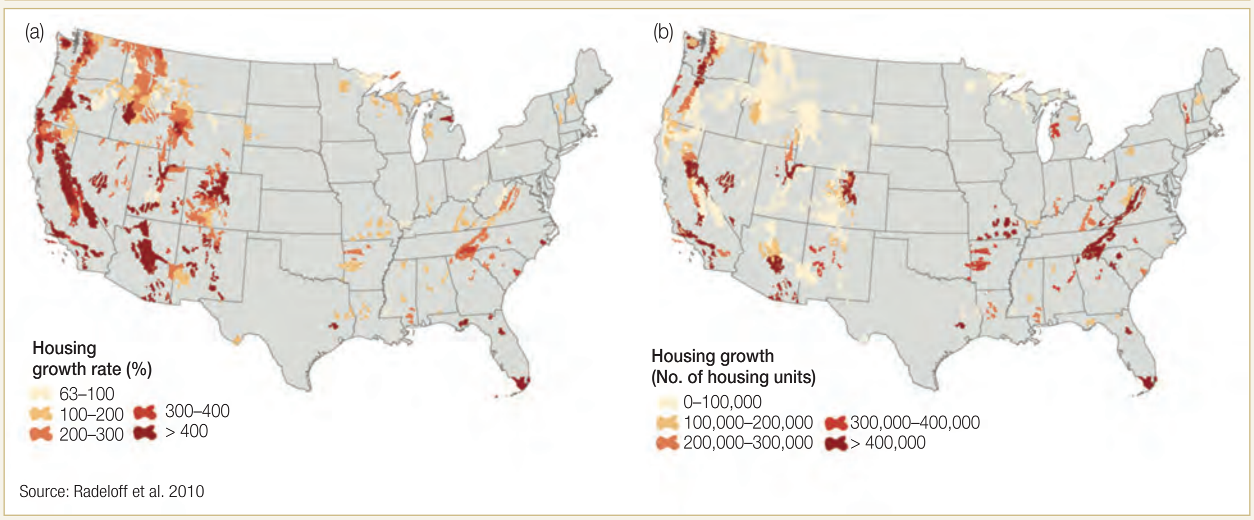
Findings

The spatial distribution of housing and the boundaries of national parks, national forests, and wilderness areas were linked to estimate the number and density of homes that occurred within approximately 30 miles of the boundary of public lands (Radeloff et al. 2005, 2010). From 1940 to 2000, a total of 28 million homes were constructed within 30 miles of the protected areas examined, with the majority of those homes (25.8 million) built near national forests. Although wilderness areas receive the highest level of protection against development and resource extractions within their boundaries, they are not immune to development in the surrounding landscape—a total of 16.1 million new homes were built within 30 miles of wilderness area boundaries between 1940 and 2000. National parks saw the lowest gain in new housing unit construction (1.5 million) within 30 miles during the 60-year period.

Private in-holdings are important, particularly for national forests, because there can be substantial areas within the administrative boundary of a national forest that remain in private ownership. Between 1940 and 2000, just more than 940,000 new homes were constructed on these private in-holdings—more than tripling housing density within this prized real estate.

The pattern of housing growth in the vicinity of protected lands varied geographically. The relative rate of housing growth by the year 2000 was the greatest in the West, because initial housing density was relatively low (figure 27a). Eastern protected areas show relatively lower relative growth rates, but have experienced the greatest absolute gain in new home construction (figure 27b). Several areas of the country had both relative and absolute high housing growth, including peninsular Florida; the southern Appalachians; the foothill and front ranges near major metropolitan areas in Colorado, Utah, and Washington; montane habitats in the arid Southwest; and southern California (figure 27)—the very same geographic areas that also support particularly high concentrations of imperiled species.

Figure 27. Relative (a) and absolute (b) housing growth rates observed within a 30-mile buffer around the outer boundary of each national park, national forest, and wilderness area over the period 1940–2000.



Implications

Establishing protected areas is an important conservation strategy that has long been thought to offer sanctuary from human activities (Flather et al. 2009). Growing human populations are extending the human footprint and are projected to have broad global effects on biodiversity conservation (Sala et al. 2000), however. Because public lands attract development, the potential ecological consequences of housing growth could be substantial. Such considerations will be particularly important in the coming decades as housing projections indicate that a total of 17 million new housing units may be built within 30 miles of these public lands by 2030 (Radeloff et al. 2010) if individual preferences for locating close to natural amenities continue into the future.

Chapter 7. Forest Resources

The United States has extensive forest resources that provide a variety of benefits to the American public. This chapter provides an overview of the extent and ownership of U.S. forests, the proportion of forests that are in protected status, and the threats to forest health. Projections of the future composition of U.S. forests under the Resources Planning Act (RPA) scenarios are presented, as are projected effects on future tree canopy cover.

Resource Highlights

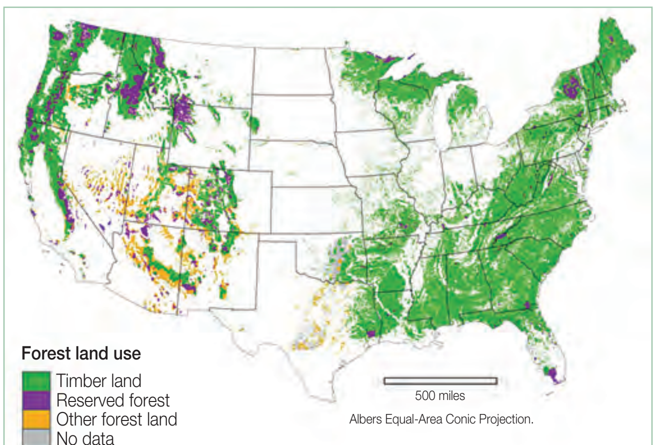
- Forest area will decline in the future.
- Forests face threats to their long-term health and sustainability.
- Declining forest area, coupled with climate change and harvesting, will alter forest-type composition in all RPA regions.
- Forest inventory is projected to peak between 2020 and 2040, then decline to 2060.
- Softwood inventories are projected to remain relatively stable, whereas hardwood inventories show large declines after 2030.
- Tree canopy cover across all natural landscapes will be affected by development and climate change.

Forest Extent and Ownership

The United States has about 751 million acres of forest land, with 623 million acres in the conterminous United States.[4] Forest land in the United States is widely but unevenly distributed (figure 28). Areas vary from sparse scrub forest of the arid Interior West to highly productive forests along the Pacific Coast and in the South, and from pure hardwood forests to multispecies mixtures and coniferous forest. More detailed information about forest resources can be found in Smith et al. (2009).

Almost two-thirds (514 million acres) of the Nation's forests are classified as timber lands.[5] An additional 75 million acres of forest are reserved for nontimber uses under the management of public agencies. The remaining 162 million acres do not qualify as timber land, but are important for watershed protection,

Figure 28. Timber land, reserved forest, and other forest land in the conterminous United States, 2007.



Source: USDA Forest Service, Forest Inventory and Analysis

[4] Measurements in areas not previously inventoried by the Forest Inventory and Analysis program will add about 50 million acres to this total. Those statistics were not available for the 2010 RPA Assessment, and all 2010 analyses are based on the 751 million total acres. Future reports will adjust historical areas for compatible forest trend analysis.

[5] Forests capable of producing 20 cubic feet per acre of industrial wood annually and not legally reserved from timber harvest.

wildlife habitat, grazing, and recreation. About 87 percent of these acres are found in the Interior West (figure 28) and interior Alaska.

Wood production is primarily from timber lands, of which 72 percent are in the East. Growing stock volumes on timber land increased in almost all RPA regions between 1953 and 2007, and volume per acre increased in all regions. Growth has exceeded harvest since the 1950s, so timber volume on timber land has increased by about 50 percent since that time. Two-thirds of that increase was on private lands and one-third on public lands, and the largest increases occurred in the North and South Regions (Smith et al. 2009).

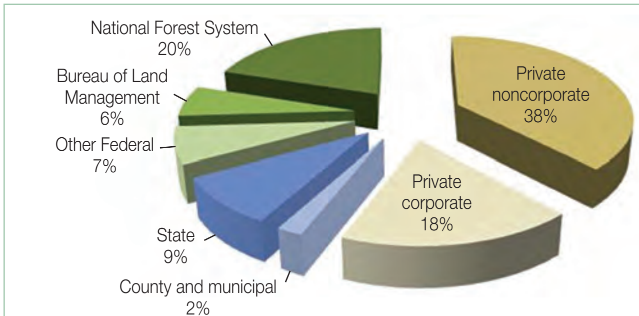
Most of the Nation's forests are naturally regenerated. Planted forests are found primarily in the South Region, which produces the majority of timber. Nationally, 63 million acres (8 percent of forest area) is planted; in the South Region, 20 percent is planted. Virtually all planted forest land is classified as timber land. Nearly all planted stands are established with native species, although not always the species that previously dominated in the area (e.g., loblolly pine has largely replaced longleaf pine in planted stands in the Southeast). The age structure of planted stands is markedly skewed towards the youngest age classes. Planted stands are supplying an increasing proportion of the Nation's timber supplies. In the South Region, planted forests accounted for 43 percent of softwood removals in 2007 (Smith et al. 2009).

Net annual growth has been steadily increasing, with only the Rocky Mountain Region showing a decline in net growth since 1996. The annual rate of growth since 1996 has been about 3.5 times the increase in mortality during the same period. Growth rates are highest in the South Region. Historically, millions of intensively managed and highly productive forest industry timber land acres have been the primary reason for the higher average productivity on private timber land. The future productivity of those lands is unknown as a consequence of ownership changes (Smith et al. 2009).

More than one-half of the Nation's forest land is in private ownership. In 2007, 11.3 million private forest owners owned 56 percent of U.S. forest land. These owners include private individuals, Native Americans, or corporate entities (figure 29). Although more than 60 percent of private forest owners own between 1 and 9 acres of forest land, most of the private forest land acreage is in holdings of at least 200 acres. More than 20 percent of private forest land is in holdings of at least 10,000 acres, owned primarily by corporations (Butler 2008). About 44 percent of forests are in public ownership, with the largest portion (147 million acres) administered by the Forest Service. The proportion of public ownership has remained stable for at least the past 50 years.

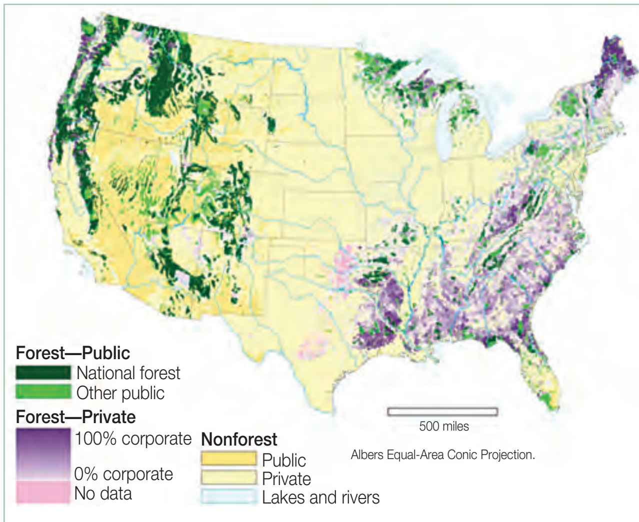
Ownership patterns vary greatly by East and West (figure 30). In the East, more than 75 percent of forest land is privately owned, whereas in the West, about one-third is privately owned. One of the largest changes in private ownership in the last two decades has been the divestiture of tens of millions of acres of forest industry lands to other types of private ownerships—lands sold primarily by integrated forest corporations to timber investment management organizations and real estate investment trusts. Within the category of family forest owners, the age of current owners and survey results indicate that turnover in privately held forest lands may have significant effects on future forest resource management, particularly in the East (Butler 2008).

Figure 29. Forest land in the United States by ownership category, 2007.



Source: Butler 2009

Figure 30. Forest land in the conterminous United States by ownership category, 2007.[a]



[a] Corporate land includes land held by timber investment management companies and real estate investment trusts.

Source: USDA Forest Service, Forest Inventory and Analysis

Forest Protected Area

Protected areas of forest can be considered from two perspectives. The 75 million acres of reserved forests mentioned previously are publicly owned forests that are reserved for nontimber purposes. Reserved forest land has tripled since 1953 and now accounts for 10 percent of all forest land in the United States. This reserved area includes State and Federal parks and wildernesses, but does not include conservation easements, areas protected by nongovernmental organizations, many wildlife management areas, and most urban and community parks and reserves. The majority of reserved lands are in the Western United States, where most Federal public lands are found (Smith et al. 2009).

A second perspective is offered by estimating the amount of forest land in protected areas as defined by the Protected Areas Database of the United States (PAD-US) described in chapter 6. Because PAD-US does not identify the specific land use or land cover that is contained in the protected areas, the PAD-US map was combined with a 2001 forest land cover map for the conterminous United States to estimate the area of forest land cover within the protected areas (Ruefenacht et al. 2008; USDA Forest Service 2004). Table 10 displays definitions of the categories of International Union for the Conservation of Nature (IUCN) protection. Table 11 shows the estimates of forest land within protected areas. Because these statistics refer to forest land cover area, they are not directly comparable to the forest land

Table 10. Definition of International Union for the Conservation of Nature (IUCN) categories for the Protected Areas Database of the United States (PAD-US).

IUCN category	Definition
Ia	Strict Nature Reserve: protected area managed mainly for science
Ib	Strict Nature Reserve: protected area managed mainly for wilderness protection
II	National Park: protected area managed mainly for ecosystem protection and recreation
III	Natural Monument: protected area managed mainly for conservation of specific natural features
IV	Habitat/Species Management Area: protected area managed mainly for conservation through management intervention
V	Protected Landscape/Seascape: protected area managed mainly for landscape/seascape conservation and recreation
VI	Managed Resource Protected Area: protected area managed mainly for the sustainable use of natural ecosystems
Unassigned	In the PAD-US database, this category includes public and private land that was evaluated by the cooperators and was determined to not have an applicable IUCN code. It includes, for example, a large share of National Forest System land and almost all Native American land.

Source: International Union for the Conservation of Nature 1994

Table 11. Protected forest land cover from Protected Areas Database of the United States (PAD-US) by ownership and RPA region in the conterminous United States.[a]

RPA region	Owner	Designated IUCN category (thousand acres) (excludes unassigned area)							
		Ia	Ib	II	III	IV	V	VI	Row total
North	Federal	7	1,366	198	25	467	3,128	476	5,666
	State	0	429	630	0	3,902	3,559	10,934	19,454
	Other	0	0	0	0	2	2,265	0	2,267
	Region total	7	1,795	828	25	4,371	8,952	11,410	27,387
Pacific Coast[b]	Federal	193	9,105	1,893	257	125	1,521	16	13,111
	State	0	0	75	0	71	2,457	493	3,096
	Other	0	0	0	0	0	8	0	8
	Region total	193	9,105	1,968	257	196	3,987	509	16,215
Rocky Mountain	Federal	378	15,799	3,394	2,309	901	4,506	103	27,391
	State	0	0	62	0	768	857	10	1,697
	Other	0	0	6	0	1	51	0	58
	Region total	378	15,799	3,462	2,309	1,670	5,414	114	29,146
South	Federal	11	961	1,184	73	1,996	3,086	635	7,945
	State	0	10	384	0	4,938	618	937	6,888
	Other	0	0	0	0	0	22	27	48
	Region total	11	971	1,568	73	6,934	3,725	1,599	14,881
National[b]	Federal	589	27,232	6,668	2,665	3,489	12,241	1,230	54,113
	State	0	438	1,151	0	9,679	7,491	12,375	31,135
	Other	0	0	6	0	3	2,346	27	2,382
	National total	590	27,670	7,826	2,665	13,170	22,078	13,632	87,629

[a] Protected areas were defined by The Conservation Biology Institute (2010) and forest land cover was defined by USDA Forest Service (2004).

[b] Excludes Alaska and Hawaii.

IUCN = International Union for the Conservation of Nature.

area estimates shown elsewhere in this assessment. The land cover map identified a total of 655 million acres of forest land cover in the conterminous United States. Of that area, 88 million acres occurred in a designated IUCN category (table 11) that represents approximately 13 percent of total forest land cover area. Of total protected forest land cover area, 36 million acres of forest land cover (41 percent) are in IUCN categories Ia, Ib, and II, which provide the strictest level of protection.

Approximately 97 percent of the forest land cover area designated as protected by PAD-US in the conterminous United States is either Federal (54 million acres) or State (31 million acres) land. Overall, the protected forest land cover in the East (42 million acres) approximates the total in the West (45 million acres). Approximately 33 percent is found in the Rocky Mountain Region, 31 percent in the North Region, 19 percent in the Pacific Coast Region, and 17 percent in the South Region (table 11). In comparison to PAD-US statistics for all protected land in chapter 6, these regional forest statistics reflect the higher percentage of forest in the East. Although total protected areas are more extensive in the West, they contain larger shares of nonforest land cover.

Forest Health

The forests of the United States continue to face a variety of threats to their long-term health and sustainability (USDA Forest Service 2009a). Native and exotic pests have killed trees on millions of acres of U.S. forests with significant environmental and social effects. Similarly, wildfires have severely affected forests and the waters and wildlife that depend upon them. Severe droughts and other climatic changes also lead to additional stress on forest ecosystems. In this section, we provide a broad overview of major trends and issues related to forest health. More detailed information can be found on the Forest Service's Forest Health Monitoring (FHM) Web site (http://fhm.fs.fed.us/).

Forest Insects and Pathogens

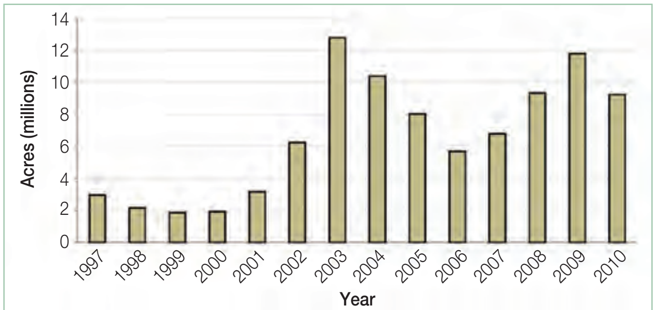
Forest insects and pathogens are crucial components of forest ecosystems that can periodically reach outbreak levels when susceptible forest conditions are combined with weather stress. Periods of less-than-normal precipitation and above-normal temperatures can stress trees and reduce their resistance to insects and pathogens. Analysis of trend data for the last decade from the FHM Program indicated an upward trend in tree mortality since 2000, with the highest levels reached in 2003 and 2009. This increase was largely because of bark beetle activity in the West after severe regional droughts in combination with susceptible forest stand conditions (figure 31).

Most of the increase in mortality from 2002 through 2004 resulted from a large outbreak of *Ips* beetles in pines in the Southwestern States of Arizona, Colorado, New Mexico, and Utah. Pinyon and ponderosa pine trees were stressed by severe drought conditions in this area from 2000 to 2003. Mountain pine beetle and other native conifer bark beetles have killed an increasing number of trees throughout the West. From 2000 through 2009, the Intermountain West experienced bark beetle-caused mortality in an estimated 22 million acres across all ownerships, with 18 million acres on national forests. These outbreaks are most widespread in dense, aging lodgepole pine forests that dominate the mountains of Colorado, Idaho, Montana, Utah, and Wyoming.

This level of mortality is unprecedented in its environmental and social effects. An estimated 100,000 beetle-killed trees fall per day in Colorado and Wyoming, escalating concerns about public safety and effects on public utilities and roads. Wildlife habitat and watershed conditions have also deteriorated in areas of high mortality because of the impaired ability of forests in high-elevation watersheds to provide shade and shelter that help to maintain the winter snowpack and prevent quick runoff during the spring melt and summer storms. Other species besides lodgepole pine are also being affected. Whitebark pine and other high-elevation pines are being killed by beetle outbreaks occurring on sites previously thought to be too cold for large epidemics. This mortality may, in part, be because of warmer-than-normal winter temperatures at these high elevations. These species are also being attacked by the invasive white pine blister rust, further threatening their survival (see sidebars, Whitebark Pine Decline and Alaska Yellow-Cedar Decline).

In the eastern forests, native pest insects are currently at low levels. For example, populations of the southern pine beetle are at historically low levels with very few spots reported throughout the South. This insect is, however, killing pitch pines in increasing numbers in New Jersey. Nonnative invasive species present some of the greatest threats to eastern forests. The emerald ash borer was first reported in the United States on ash trees in the Detroit, MI, area in 2002. Transport of infested ash trees and wood accelerates the spread of this insect. This

Figure 31. Total acres with outbreak levels of tree mortality, 1997–2010.



Source: USDA Forest Service, Forest Health Monitoring Program insect has since been widely distributed throughout the North Central United States, killing more than 50 million ash trees in 15 U.S. States and Canada. In southeastern Michigan and northwestern Ohio, the mortality rates for ash trees are nearly 100 percent. The Asian longhorned beetle has also been found infesting maples and other hardwoods in new locations. More than 20,000 infested trees have been found and removed near Worchester, MA, since this infestation was found in 2008.

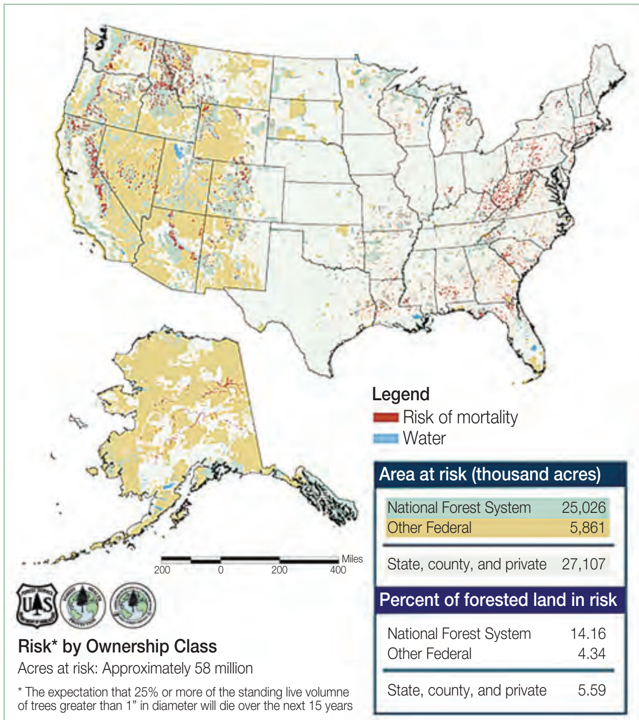
A national risk assessment identified areas where more than 25 percent of the trees of greater than 1-inch diameter are expected to die within 15 years because of insects and pathogens (Krist et al. 2007) (figure 32). More than 58 million acres of forest lands are at risk to increased activity by forest insects and pathogens, including bark beetles of western conifers, oak decline, southern pine beetle, root diseases, and gypsy moth. This national risk assessment is being used to develop broad prevention strategies for the major forest insects and pathogens threatening the forests of the United States.

Wildfire

Wildfire is a major disturbance in many forests of the United States. The annual amount of area burned varies depending on weather conditions, fuel loading, and forest stand conditions. Much of the recent increase in area burned is because of increased fuel loads and recent droughts and warm temperatures, especially in the Western United States. The total area burned in 2006 was the largest fire-affected acreage during the period 1960–2010 (figure 33).

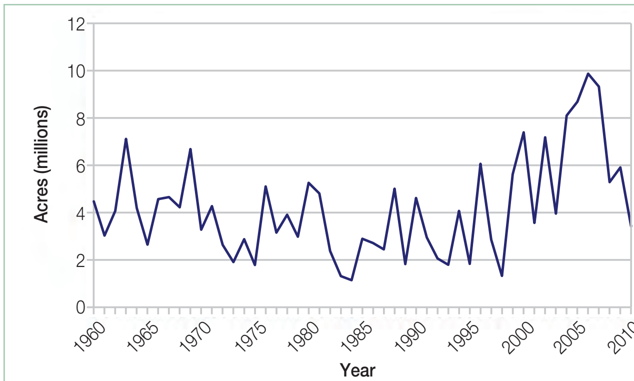
There is growing scientific evidence that climate change will increase the number and size of wildfires, both globally and in North America. The effects of climate change on wildfire occurrence, extent, and severity will vary in different regions of the country. Much of the recent increase in fire in the Western United States can be correlated with increasing temperatures, changes in precipitation patterns, and longer fire seasons since the mid-1980s. No single event, however, can be linked specifically to climate change. Climate change and changing wildfire patterns will cause changes in the distribution of individual plant species and in the dynamics of forest and rangeland ecosystems. Even where rainfall remains the same or increases, warming temperatures can greatly increase plants' need for water and increase drought stress and fire hazard. Overall, more fire is expected in the western forests and rangelands. Complex spatial land use patterns and active prescribed fire programs complicate predictions for the East. Forest management techniques, such as prescribed burning or thinning dense forests, can make forests more resilient to wildfire and decrease fire emissions (McKenzie et al. 2011).

Figure 32. Areas with potential risk of greater than 25 percent tree mortality because of insects and diseases.



Source: USDA Forest Service, Forest Health Monitoring Program

Figure 33. Total area of wildfires in the United States, 1960–2010.



Source: National Interagency Fire Center 2011

Whitebark Pine Decline

Whitebark pines are declining throughout their range because of a complex of stresses (Tomback et al. 2001). Extensive dieback of older trees and mortality of seedlings is being caused by white pine blister rust, an invasive pathogen. Large outbreaks of the native mountain pine beetle have affected extensive areas in recent years. High-elevation whitebark pines are being killed on sites previously thought to be too cold for serious beetle outbreaks (Logan et al. 2010). These changes in beetle activity have been linked to warmer winter temperatures that have led to quicker development and higher survival rates for over-wintering insects. A warmer and moister weather pattern may also favor white pine blister rust by producing frequent "wave years" of conditions that promote massive numbers of infections. Whitebark pine is a keystone species throughout the high mountain ranges of western North America. It is often the only tree species capable of surviving in harsh subalpine areas and is crucial in stabilizing soil and moisture and creating habitats that support a wide diversity of plants and animals. For example, the nuts of whitebark pine provide a critical food source for grizzly bears as they prepare for winter hibernation. Range-wide restoration strategies for whitebark pine are needed to reverse the current trends. The Forest Service is collaborating with partners, including the National Park Service, University of Colorado, and University of Montana, to develop and implement restoration and gene conservation strategies for whitebark pine and other threatened tree species (Schwandt 2006).

Whitebark pine in Crater Lake National Park

Photo: John Schwandt, Forest Service

Whitebark pine mortality in Yellowstone National Park

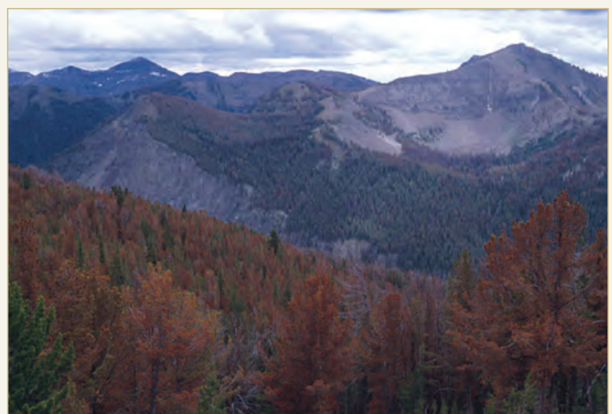


Photo: Ken Gibson, Forest Service, retired

Alaska Yellow-Cedar Decline

Alaska yellow-cedar stands have been declining in southeast Alaska during the last century. More than 500,000 acres of dead and dying trees have been mapped by aerial surveys. Analysis of the data reveals that this widespread tree mortality is concentrated at lower elevations and on wet soil types. The problem began about 100 years ago at the end of the Little Ice Age. Tree death appears to result from root freezing, predisposed by low snow accumulations since the 1900s. Shallow roots in anaerobic soil and a unique vulnerability to cold injury in early spring are associated with the decline (Hennon et al. 2006; Schadberg et al. 2008). Yellow-cedar has extremely valuable wood; thus, the problem has a considerable economic impact. This tree species also has ecological and cultural importance; Native people have long used its wood and bark. Knowledge of the cause of yellow-cedar decline and associated site risk factors is leading to a conservation strategy for this valuable tree species in the context of a warming climate with reduced snow.

Standing dead Alaska yellow cedar in Southeast Alaska

Photo: Paul Hennon, Forest Service

Dead Alaska yellow cedar

Photo: Paul Hennon, Forest Service

Forests Resources in the Future

Forests develop in response to their physical environment, biological dynamics, and decisions regarding their uses. Acting on different time frames, these forest dynamics ultimately determine the ecosystem services that flow from the Nation's forests. This section describes projections of forest resource conditions for the conterminous United States. The results are based on the United States Forest Assessment System (USFAS), a modeling system designed to project alternative futures for U.S. forests (Wear 2010). USFAS is a forward-looking adjunct to the ongoing inventories of forest conditions conducted by the Forest Inventory and Analysis (FIA) Program. The FIA system provides nationwide monitoring through repeated inventories that measure forest conditions at a high level of detail, and the USFAS addresses how biological, physical, and human factors could alter these forest inventories in the future.

We generated projections of detailed forest inventories along with the land use projections described in chapter 6 and forest product markets described in chapter 8. We modeled the effects of changing climate, market-driven timber harvesting, and land use change along with changes driven by successional transitions in forest conditions. This section summarizes projections and implications for the future of forests in the four RPA regions (figure 16).

Population and income projections and changes in rural land rents at the county level determine changes in land use (Wear

2011); changes in various climate metrics drive forest-type transitions; and forest market projections, driven by each RPA scenario's global resource conditions and projected economic conditions, determine harvest levels. More details on the regional results and modeling approach can be found in Wear et al. (in press).[6] For each RPA region, forest projections were generated for each of the RPA scenario-climate combinations (see table 2). Each of these nine alternatives contains a timber harvest model future based on various models of harvest choice. To link the forest projections to timber market projections from the U.S. Forest Products Module (USFPM) for the economic/bioenergy futures attached to the four RPA scenarios, we evaluated additional alternatives with either timber prices or harvest levels adjusted to match harvest projections for the RPA region. Comparisons of projections across the multiple climate realizations are described in the RPA supporting document on forest forecasts (Wear et al., in press).

Future Forest Area

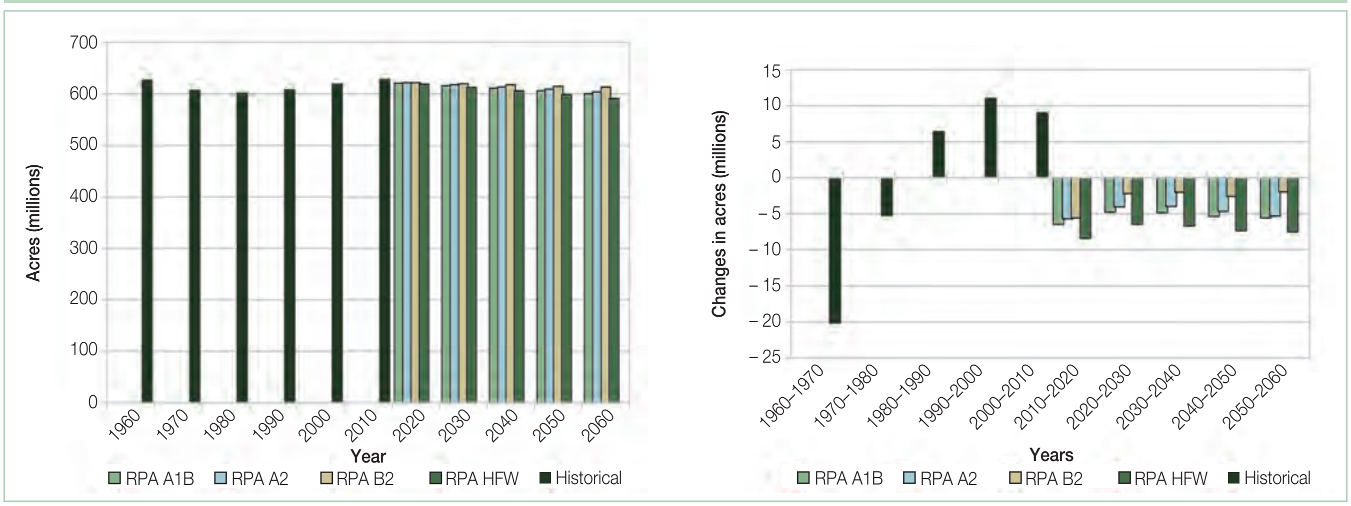
To account for changes in the area frame of the FIA survey, we used the RPA land use projections described in Wear (2011). Projected changes in forest area were used to rescale the projected forest inventory to reflect these land use dynamics. Non-Federal FIA forest area within a county is assumed to change in direct proportion to the area change projected by the land use model, and Federal forest area is held constant. The RPA land use projections described changes in forest area based on National Resources Inventory (NRI) definitions, whereas this section translates those changes to the FIA basis and a 2010 starting point.

Projected changes in forest land to 2060 indicate a reversal of the net accumulation of forest land in the United States between the 1980s and 2010 (figure 34). Historical land use changes during this period derive from the intersection of two countervailing dynamics: an expansion in developed uses of land and a more-than-compensatory transition of marginal agricultural land to forest cover. The latter derived from market-driven shifts in the returns to forests and agricultural production but was also encouraged by various conservation programs, including the Conservation Reserve Program. This accumulation offset observed declines in forests between the 1960s and 1980s, likewise driven by the comparative economics of agriculture and forest uses. Projections show urbanization continuing to dominate future land use, without a compensatory movement of land from agriculture to forest uses.

Effects of Future Climate

Climate projections provide another key input to defining future forest conditions. Various climate variables derived from these projections influence the forest inventory projections, usually expressed as long-run averages in these models. Forest dynamics models incorporate climate inputs in different ways for the Eastern and Western United States. In the East, paired inventories enable modeling of forest-type transitions on observed climate and inventory data. In the West, forest types are modeled using forest-type classification approaches comparable to tree species migration models (e.g., Iverson et al. 2008; Rehfeldt et al. 2006). Climate data are expressed as averages for the life of the forest in the East and as fixed-length averages (20 years) for forests in the West. These long-run averages change

Figure 34. Historical and projected forest area in the conterminous United States (left) and decadal changes in historical and projected forest area (right), by RPA scenario, 1952–2060.



[6] Some of these forecasts are examined at a finer scale of detail in two regional assessments: the Southern Forest Futures Project (Wear and Greis [in press]) and the Northern Forest Futures Project.

slowly, reflecting the long-term persistence of forest vegetation. Forest responses to climate changes in the East are especially muted. In the West, models enable climate thresholds to trigger forest-type switching sooner, so long-term trends (e.g., 50 years) are more informative than shorter run trends (e.g., 20 years). Climate also affects productivity through the association of projected climates with forest plots in comparable climates from the historical record.

Overall, because of the use of long-term averaging and the slow development of significant changes in these and other climate variables, climate effects are largely muted until toward the end of our 50-year projection period. The strongest climate signal is detected in projections of forest types for the western regions.

Future Forest Types

Forest-type composition is projected to change in response to spatially explicit land use changes, forest harvests and other disturbances, natural succession, and other management choices. Projections of the areas of various forest types are consistent with the projections of total forest area (described in figure 34), climate projections, and timber market projections associated with the four RPA scenarios.

In the South Region, we projected changes in five forest management types: planted pine, natural pine, oak-pine, upland hardwood, and lowland hardwood. Figure 35 presents the results for the RPA A1B-MIROC3.2 scenario, which is one of two RPA scenarios with more than 20 million acres of forest loss (the other is RPA historical fuelwood [HFW]). The RPA B2-HadCM3 scenario had the smallest total area change over time (figure 36). The upland and lowland hardwood types are projected to comprise between 51 and 53 percent of all forests in 2060, a decline from about 54 percent in 2010. The greatest changes, however, are found among the softwood types (planted pine, natural pine, and oak-pine). These forest dynamics are heavily influenced by the interaction of land use changes and management for forest products, which in turn is driven by timber market conditions and by the rate of forest planting.

The area of planted pine forest in the South Region, currently at about 39 million acres, or 19 percent, of forest area is projected to increase by 2060 (figure 35). Planted area ranges from 47 to 67 million acres in 2060, depending on future land use and market projections. The 67 million acres of planted pine projected for RPA A1B result from that scenario's high bioenergy demands and exceeds the projections from previous RPA Assessments. The forecast of 47 million acres for RPA B2 is more in keeping with earlier RPA analyses. Projected losses in the area of naturally regenerated pine forest types mirror the gains in planted pine forests. At more than 80 million acres in 2010, upland hardwoods are the predominant forest type in the South Region, more than double the area of the next largest forest type. Upland hardwoods are projected to decline for all RPA scenarios, and variations in projections are associated more with rates of urbanization than with timber market futures. The area of lowland hardwoods shows a smaller amount and rate of decline.

Hardwoods dominate forest types in the North Region, accounting for about 83 percent of forest area. Among hardwood forest types, maple-beech-birch and oak-hickory groups are the largest, accounting for 26 and 36 percent of total forest area in 2010, respectively (figure 37). Among softwood types, spruce-fir (9 percent) and white-red-jack pine (5 percent) account for the largest shares of total forest area, but these areas are concentrated in northern parts of the region. For all projections,

Figure 35. Area of forest by forest type groups for the RPA South Region, RPA A1B-MIROC3.2, 2010–2060.

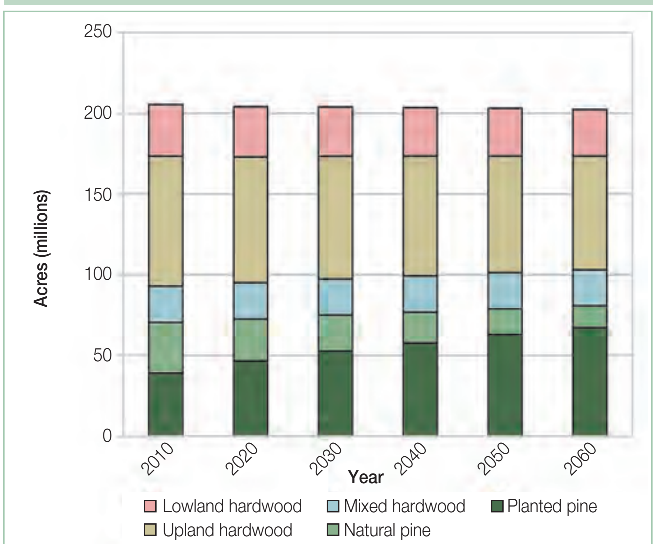
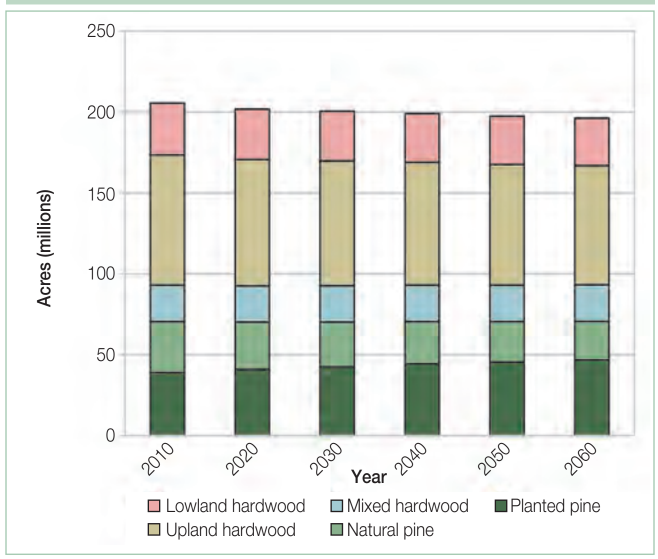


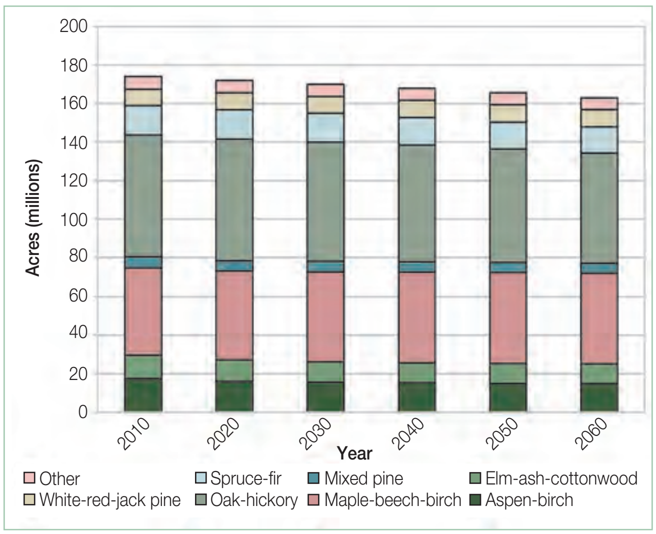
Figure 36. Area of forest by forest type groups for the RPA South Region, RPA B2-HadCM3, 2010–2060.



there is little change in the overall shares represented by hardwoods and softwoods in the North Region. Shifts among forest types within the hardwood and softwood groups result from the various RPA scenarios, however.

The area of oak-hickory, the largest forest type in the North Region, is projected to decline between 3 and 6 million acres (5 to 10 percent) between 2010 and 2060, with the greatest losses for the A1B-MIROC3.2 scenario (figure 37) and the least losses for the B2-HadCM3 scenario (figure 38). Rates of urbanization have the greatest influence on projections of change for oak-hickory forests across RPA scenarios. In contrast, the area of maple-beech-birch increases between 2010 and 2060 for all RPA scenarios, with increases ranging between 1 and 3 million acres (3 to 7 percent), and projections of these forest types vary in response to differences in area harvested. Among the hardwood types, elm-ash-cottonwood forests decline by the greatest percentage across RPA scenarios, falling by 13 to 20 percent (1 to 2 million acres) between 2010 and 2060. Aspen-birch projections are the most variable across hardwood types, and all RPA scenarios lead to losses in aspen-birch area: minimum losses are 1.4 million acres (7.7 percent) and maximum losses are 3.0 million acres (16.9 percent). For aspen-birch, change patterns indicate less forest loss as harvesting increases.

Figure 37. Area of forest by forest type groups for the RPA North Region, RPA A1B-MIROC3.2, 2010–2060.



The two dominant softwood types in the North Region show very different patterns of change across the RPA scenarios. Projected spruce-fir area decreases range from 8 to 17 percent of area and indicate an inverse relationship between area and harvesting. In contrast, projected area of white-red-jack pine is the most variable of all forest types, ranging from a 10-percent gain to a 16-percent loss, depending on the RPA scenario. Note that, unlike in the South Region, there is little change in the area of intensively managed (planted) forests projected for the North Region. This result reflects the lack of substantial historical precedent for such management in the North Region, but the large demands for biomass in RPA A1B suggest that structural changes, including adoption of new forest management regimes, might be anticipated.

The Rocky Mountain Region contains a diverse array of forest types, nearly all composed of a mix of conifer species (figure 39). The forest-type group comprising the greatest area in the region is the pinyon-juniper group, with about 50 million acres, or 35 percent, of the area classified as forest. The next largest are spruce-fir-hemlock, with 23 million acres (15 percent), and the Douglas-fir group, with 18 million acres (13 percent). Lodgepole pine and ponderosa pine comprise 12 and 14 million acres (8 and 9 percent), respectively. Aspen-birch, at about 8 million acres, represents about 5 percent of forest area and several other forest-type groups combine to make up the remainder of about 15 percent.

Figure 38. Area of forest by forest type groups for the RPA North Region, RPA B2-HadCM3, 2010–2060.

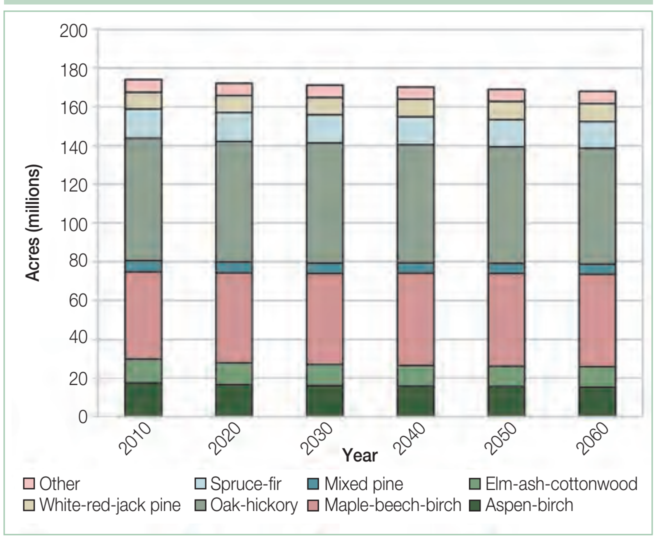
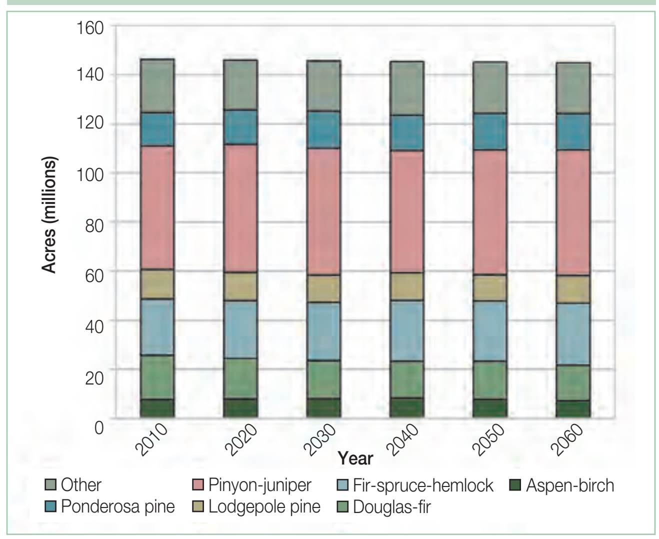


Figure 39. Area of forest by forest type groups for the RPA Rocky Mountain Region, RPA A1B-MIROC3.2, 2010–2060.

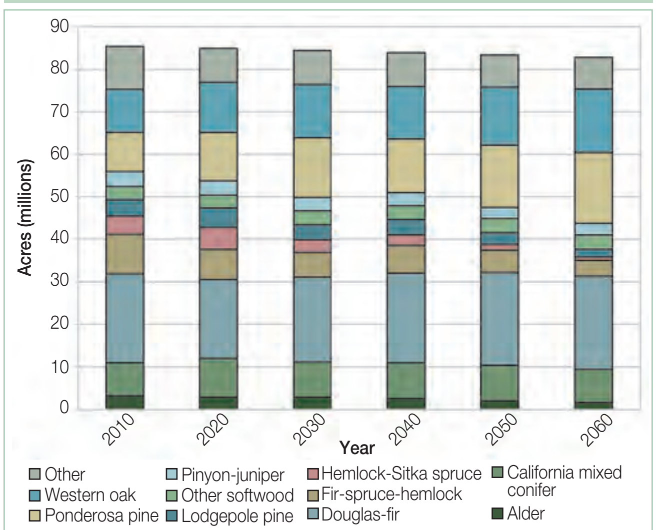


In the West, where inventory data are relatively scarce compared with inventory data in the East, future forest types are projected based strictly on climate projections and not on observed forest transitions between inventories. Compared with the East, the projection models for forest types in the West are more sensitive to differences in climate projections. This sensitivity enables more immediate effects of climate changes on future forest-type groups.

In the Rocky Mountain Region, projections capture multiple and offsetting forest dynamics across the varied conditions of the region but clearly show several strong trends in forest types (figure 39). Two forest types, Douglas-fir and lodgepole pine, are projected to decline across all RPA scenarios. For Douglas-fir, declines range from 20 to 38 percent of its 2010 area; for lodgepole pine, declines range from 6 to 28 percent. In contrast, the areas of fir-spruce-hemlock and ponderosa pine increase, ranging from 4 to 17 percent and 8 to 46 percent, respectively. Other forest types, including aspen-birch and pinyon-juniper, have relatively constant forest areas between 2010 and 2060.

The Pacific Coast Region contains a diverse complement of forest types in two distinct ecological zones. The west side of the Cascade Mountain Range contains wet and highly productive sites, and Douglas-fir and hemlock-Sitka spruce types dominate. The east side of the Cascade Range is much drier and much less productive, with forest types similar to the Rocky Mountain Region. Overall forest-type dynamics are dominated by changes on the west side forests. Hemlock-Sitka spruce area is projected to decline across all RPA scenarios between 2010 and 2060, whereas the area of Douglas-fir forests is projected to increase. Area of alder-maple also falls somewhat during this period. Among east-side forest types, area of fir-spruce-hemlock and lodgepole pine are projected to decline, whereas ponderosa pine area expands (figure 40).

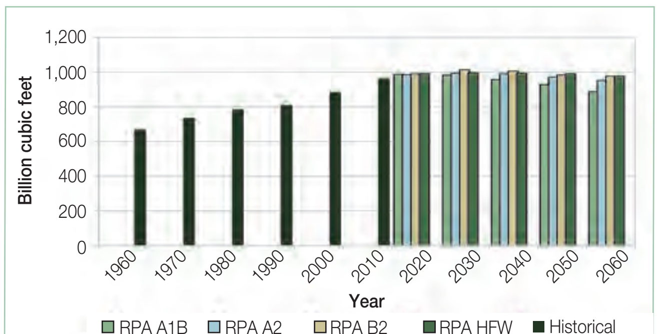
Figure 40. Area of forest by forest type groups for the RPA Pacific Coast Region, RPA A1B-MIROC3.2, 2010–2060.

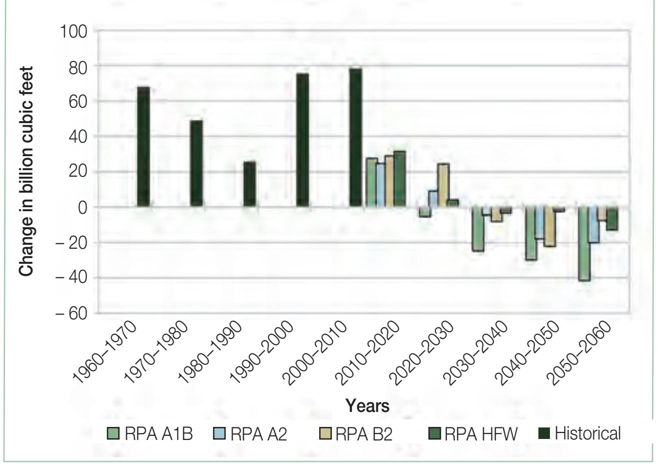


Future Forest Inventory

Shifts in climate affecting productivity, changing markets affecting growing stock removals, and land use change affecting the area of forests interact to determine the amount of inventory contained in the Nation's forests. The results shown in this section are based on the CGCM3.1 general circulation model (GCM) climate projections for RPA scenarios A1B, A2, and HFW and on the CGCM2 GCM for RPA scenario B2. Figure 41 shows projections of the growing stock inventory of U.S. forest land from 2010 to 2060 across the four RPA scenarios. All four demonstrate the same general pattern of change: a peaking of volume between 2020 and 2030 followed by a decline in volume to 2060. The magnitude of change differs, however, with only RPA A1B projecting less volume in 2060 than observed in 2010. Scenario RPA B2 shows only a slight reduction from its peak of about 1 trillion cubic feet and RPA A2 shows just a slightly higher volume in 2060, but with a strong downward trajectory. The RPA HFW (based on A1B economic assumptions) yields growing stock levels similar to RPA B2. The downward trajectory for RPA A1B reflects the very high levels of removals for this scenario in 2050–2060 coupled with large forest losses due to urbanization.

Figure 41. Total historical and projected growing stock inventories (top) and decadal changes in historical and projected growing stock inventories (bottom) for the conterminous United States, by RPA scenario, 1960–2060.





This peaking of inventory followed by declines would conclude a long period of inventory accumulation on the Nation's forest lands (figure 42). Between 1950 and 2010, growing stock inventories accumulated rapidly, as abandoned and cut-over forest lands were restocked, especially in the Eastern United States. Many of these stands are reaching their capacity in terms of biomass accumulation while projected forest area losses trim inventories.

Under all RPA scenarios, the greatest reduction in forest inventory occurs in the North Region. Under scenario RPA A1B, for example, large expansions in timber removals for biomass energy coupled with forest losses driven by urbanization lead to substantial declines of growing stock volumes in the region (figures 42 and 43). Very similar dynamics occur in the South Region, as well, but do not result in the same degree of inventory drawdown. The difference relates to a strong demonstrated forest investment response by forest owners in the South Region, who are projected to expand forest plantations in response to the strong timber markets observed for RPA A1B. The RPA A1B scenario also contains an expansion of productivity of planted pine forests in anticipation of genetic improvements and intensified management. This type of response has not been demonstrated and is not a part of the projections for the North Region. The tenability of this assumption (no expansion in intensive management in the North Region) is higher for the RPA B2 and RPA HFW scenarios, wherein output growth is modest, but is much less certain for the RPA A2 and, especially, RPA A1B scenarios, wherein output growth is greater.

The pattern of volume changes differs between softwoods and hardwoods in the United States. Figures 44 and 45 show that projected softwood inventories would likely remain relatively stable during the next 50 years, because of an expected investment response to higher wood energy demand in the form of timber plantations in the South Region and a relatively stable softwood inventory in the Rocky Mountain Region. The RPA A2, B2, and HFW scenarios show increases in softwood volume between 2010 and 2060, whereas RPA A1B, with the highest level of timber removals, indicates some declines in softwood inventory by 2060. In contrast, projections of hardwood growing stock inventories show strong declines in volume beginning in 2030 and progressing through 2060, as expected investment response to higher wood energy demand is negligible in the case of hardwoods and forest losses from land use changes are more often coincident with hardwood forest types (figure 46).

Figure 42. Projected growing stock inventories for the conterminous United States, by RPA region for the RPA A1B scenario, 2010–2060.

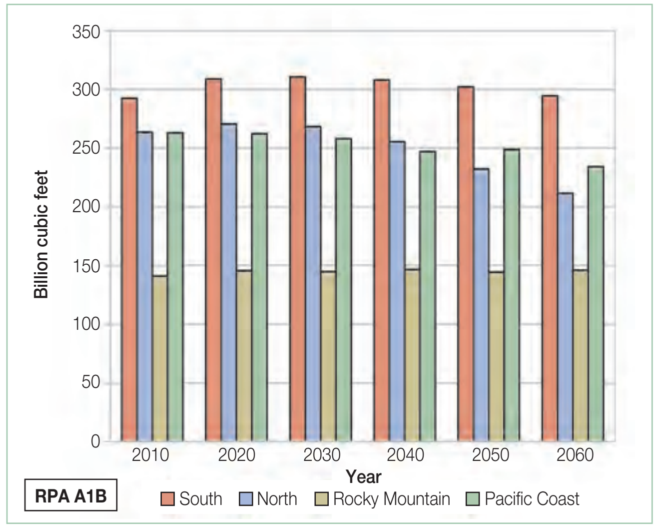
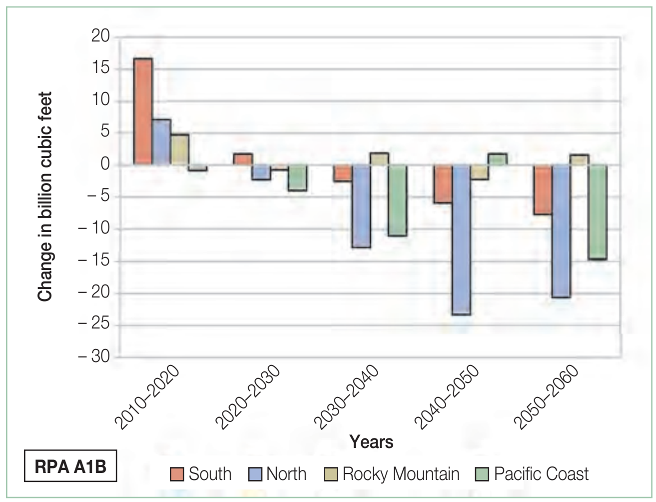


Figure 43. Projected change in growing stock inventories for the conterminous United States, by RPA region for the RPA A1B scenario, 2010–2060.



Conclusions

Forest resources in the United States have been remarkably resilient during the past 100 years, with the area of forests remaining relatively stable. The stability of the total forest area masks substantial change in the character of forest lands, however. As described in the previous chapter, forests are subject to considerable fragmentation, reducing their ability to provide some types of ecosystem goods and services. Ownership changes on forest land have also created uncertainty about future management and retention of forest lands, because lands once owned by the forest industry have been sold to firms and individuals whose primary focus is not active forest management. Forests continue to face a variety of threats to their

Figure 44. Projected softwood growing stock inventories for the conterminous United States, by RPA scenario, 2010–2060.

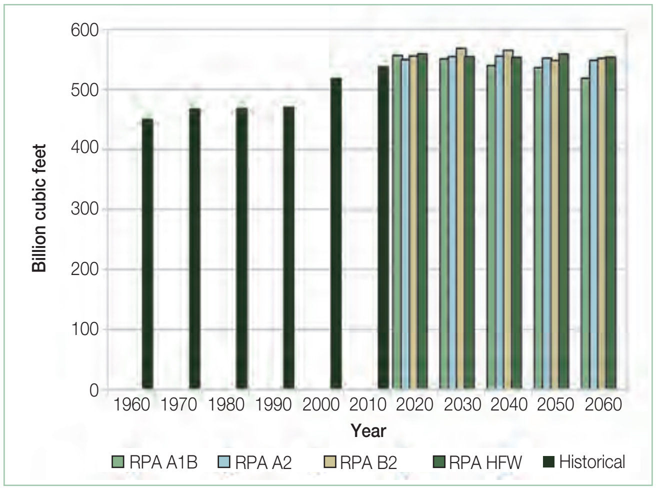


Figure 45. Projected decadal change in softwood growing stock inventories for the conterminous United States, by RPA scenario, 2010–2060.

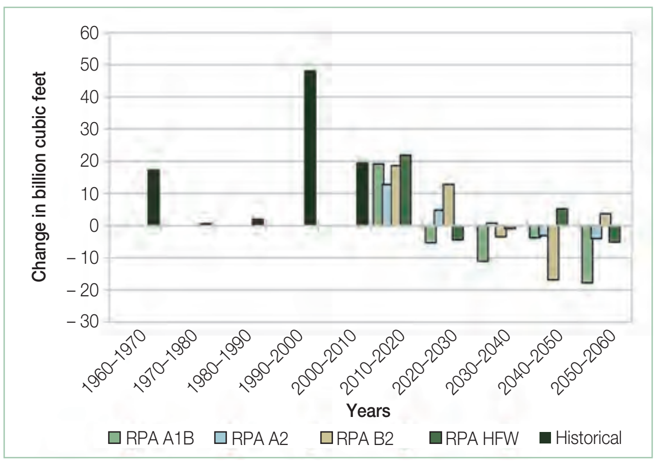
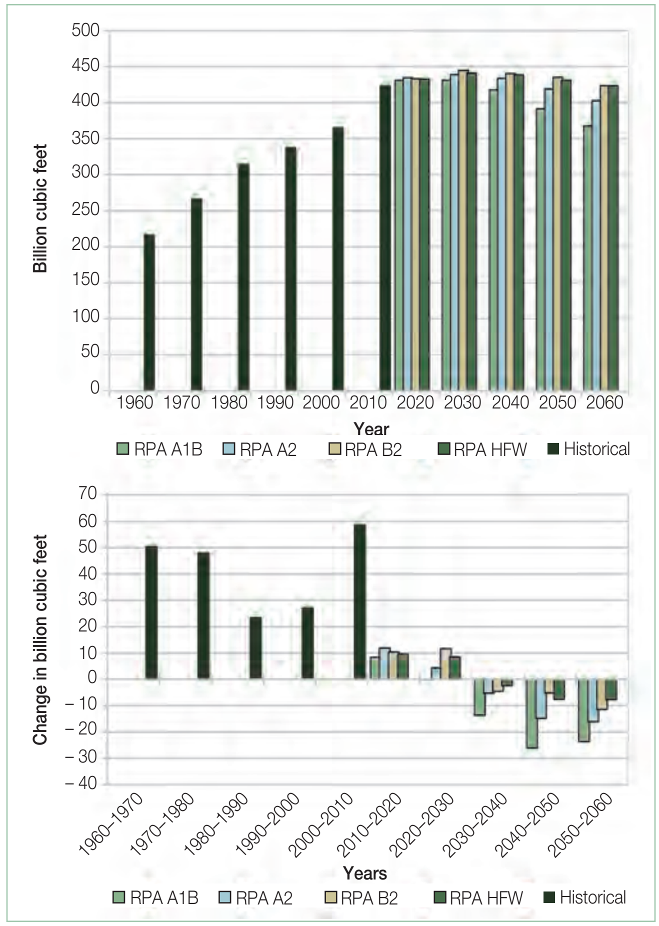


Figure 46. Total projected hardwood growing stock inventories (top) and projected decadal change in hardwood growing stock (bottom) for the conterminous United States, by RPA scenario, 2010–2060.



long-term health and sustainability. The interaction of climate change, wildfire, and insect and disease activity may exacerbate forest health issues by increasing the incidence and severity of wildfires, extending the range of both native and exotic pests and pathogens.

We are projecting losses in forest land in the future across all RPA scenarios, reversing the trend of forest land stability. The projections are dominated by conversions of forest land and other land uses to urban and developed uses. The effects of land use change, climate, and harvest pressure on the area of forest types and inventory volumes interact and the net results vary by region. Climate effects generally had limited effect on forest types and inventory during the projection period, but those effects were more noticeable in the Western United States.

Forest area losses are most pronounced under the RPA A1B and HFW scenarios, in which population- and income-driven urbanization consumes rural lands at the highest rate. The acceleration of forest loss for HFW relative to A1B reflects the role that strong wood products markets can have on retaining or even expanding forest land in parts of the United States. Even under these scenarios, with the largest losses in area and inventory, nowhere in the 50-year projections do these values fall below values observed since the 1980s for the United States. Although they represent trend reversals, these projections do not represent unprecedented future conditions.

Tree Canopy Cover in the Future

The previous sections in this chapter focused on forest resources on forest lands. Trees, however, are widely distributed outside of forest land across the United States, and those trees serve a variety of important functions. Whereas chapter 9 specifically addresses urban forests, this section examines tree canopy cover[7] across the conterminous United States and therefore includes tree cover across all land covers. (See sidebar, National Tree Cover Estimates.)

Land use change and climate change will influence future tree cover. We projected future tree canopy cover change first using only the county-scale RPA land use change projections, then using both the land use projections and climate projections. For the combined analysis, we developed an aridity ratio from the climate projections for each of the nine RPA scenario-climate combinations (table 2) and provided an index of the combined risk to both tree canopy cover loss and increased aridity based on projected changes in climate and canopy projections.

National Tree Cover Estimates

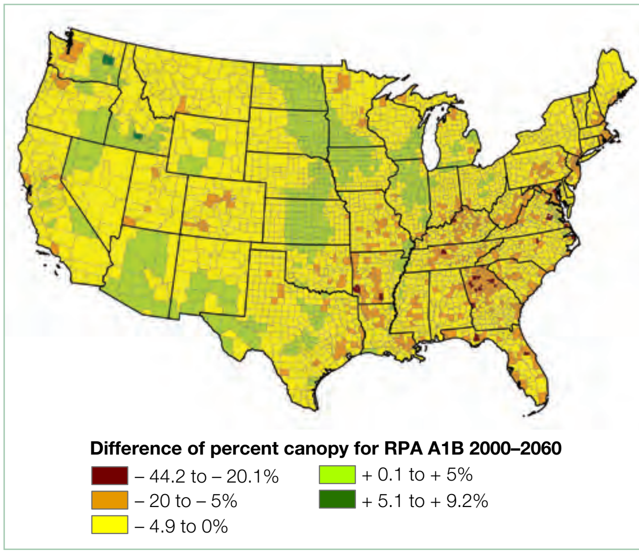
Forest Service research scientists (e.g., Nowak and Greenfield 2008) have produced State estimates of urban area and population statistics for each of the lower 48 States and estimates of tree cover based on 2001 National Land Cover Database (NLCD) tree cover maps. State-level data can be accessed from the Northern Research Station's urban forest site (http://www.nrs.fs.fed.us/data/urban). An accuracy assessment of all 65 NLCD mapping zones indicates that NLCD tree cover maps underestimate tree cover nationally by an absolute amount of 9.7 percent, however, compared with photo-interpreted estimates (Nowak and Greenfield 2010). Differences in photo-interpreted and NLCD tree cover estimates vary by mapping zone and NLCD land cover class. These estimated differences were used to adjust the NLCD tree cover map to produce estimates with each NLCD land cover-mapping zone combination that matched the photo-interpretation estimate. This adjusted cover map was then used to estimate projected changes in tree cover associated with land use and climate projections from the RPA scenarios.

Tree Canopy Change Under Varying Land Use Projections

We developed tree canopy cover projections to 2060 for RPA scenarios A1B, A2, and B2[8] by applying the land use projections to adjusted 2001 National Land Cover Database (NLCD) tree canopy values of land cover classes (Nowak and Greenfield 2010) and projected to 2060. The NLCD classes of developed land (classes 21 through 24) were associated with the RPA land use "urban" category. The NLCD forested land cover classes (classes 41 through 43) were related with the "forest" category. The NLCD classes for agriculture (81 and 82) were associated with a summed agriculture category derived from the "cropland" and "pastureland" categories. The methods and results are discussed in more detail in Greenfield and Nowak (in prep.).

The three RPA scenario results exhibited similar patterns of future changes in tree canopy cover across the United States. The RPA A1B scenario (figure 47), which has the most urban sprawl outside the more urbanized counties, had the largest change, a 1.6-percent decrease in canopy cover in the conterminous United States between 2000 and 2060 (relative change, -4.7 percent), whereas the RPA B2 scenario, which had the most urban growth within the already urbanized counties, had the smallest change, a 1.1-percent decrease. Rhode Island had the greatest tree canopy cover decrease in all RPA scenarios, ranging from 10 percent (RPA A2) to 5.5 percent (RPA B2); South Dakota had the largest increase, ranging from 0.2 percent (RPA A2 and B2) to 0.3 percent (RPA A1B).

Figure 47. Absolute difference in percent tree canopy cover, 2000–2060, for the RPA A1B scenario.



[7] Tree canopy cover and tree cover are identical, both referring to the amount or percentage of land area that, when viewed from above, is covered by tree canopies.

[8] The RPA HFW scenario was not evaluated because the land use projections for RPA HFW were not available until after this analysis was completed.

Even though tree canopy cover changes within a State or nationwide are relatively small (mostly less than 10 percent), changes at the county level can be much higher and more variable (see appendix A). The county with the greatest projected tree canopy cover loss is Dare County, NC, losing 44.2 percent in all three RPA scenarios. The counties projected to gain the most tree canopy cover are Val Verde County, TX (gaining 15 percent in RPA A2), and Lincoln County, WA (gaining 9.2 percent in RPA A1B and 8.1 percent in RPA B2). The increase in tree cover in these counties was mostly because of projected increases in developed land in Lincoln County and agricultural land in Val Verde County.

Because of expanding urbanization at the expense of agricultural and forested land uses, the tree canopy cover decreased in the more forested counties of the Pacific Northwest and east of the Mississippi, whereas the canopy cover increased in the agricultural, grassland, and desert counties of the Midwest and West. Tree canopy cover tends to be greater in the urban areas of grassland, desert, and agricultural counties than in rural areas, whereas tree canopy cover tends to be less in urban areas compared with rural areas in forested counties (Nowak and Greenfield, 2012a). Areas with projected increases of tree canopy cover (i.e., desert, grassland, and agricultural areas) are likely because of active human management associated with urbanization (e.g., tree planting). This projection of increased canopy cover is often dependent on sufficient water to sustain tree populations, and these increases may not occur if necessary resources, such as water for irrigation, become scarce.

Changes in Tree Canopy Cover and Changes in Climate

We summarized climate data from each of the GCMs (Coulson et al. 2010a, 2010b) into annual values from decadal averages, in this case, 2055 through 2064. The summarized precipitation and potential evapotranspiration values were used to calculate an annual aridity ratio, defined as precipitation divided by potential evapotranspiration. We used this ratio to determine which areas of the country would likely get drier because of projected climate change. The ratio was then multiplied by -1 so that positive numbers indicate increased aridity.

In all nine climate projections, the climate for the majority of the conterminous United States is projected to be more arid in 2060 as compared with 2000 conditions (1995 through 2004). Overall, the RPA A1B-MIROC3.2 results exhibited the maximum average increase (0.138) in the aridity ratio (figure 48) by 2060, whereas the RPA A2-CSIRO-Mk3.5 scenario had the minimum average increase (0.038) in aridity (figure 49). The scenario with median change (0.077) in average aridity index values was RPA B2-CGCM2 (figure 50). The most pronounced increases in aridity tend to be in the Pacific Northwest and east of the Mississippi River.

Figure 48. Change in aridity ratio, 2000–2060, for RPA A1B-MIROC3.2 (maximum average increase in aridity).

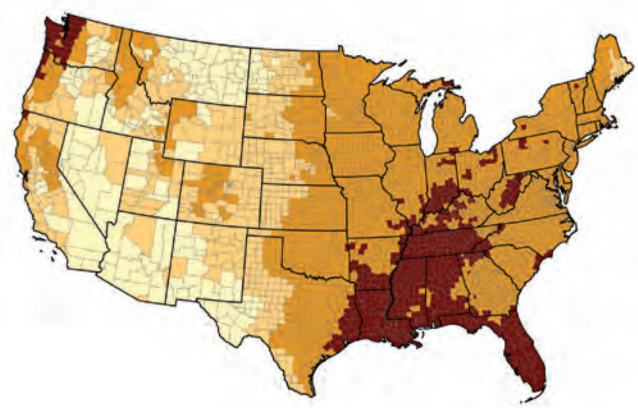


Figure 49. Change in aridity ratio, 2000–2060, for RPA A2-CSIRO-Mk3.5 (minimum average increase in aridity).

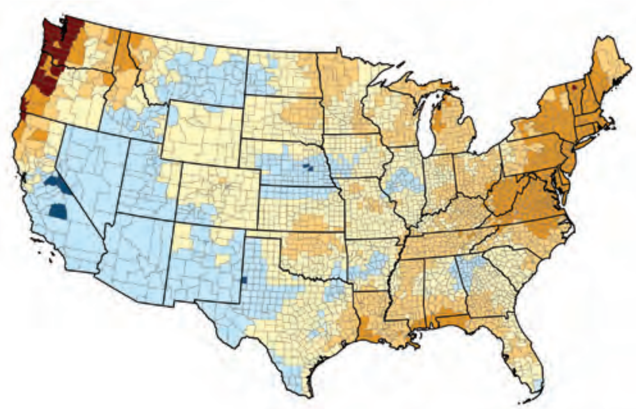
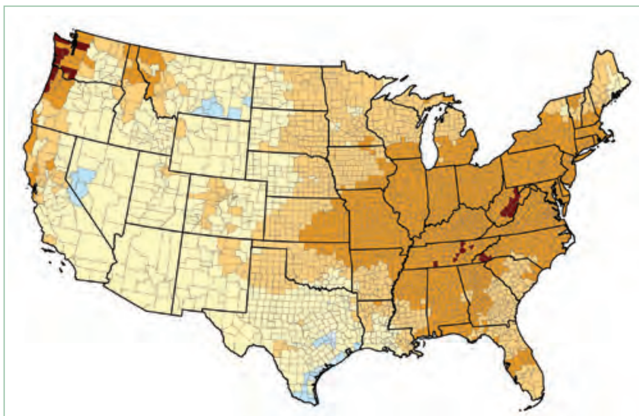
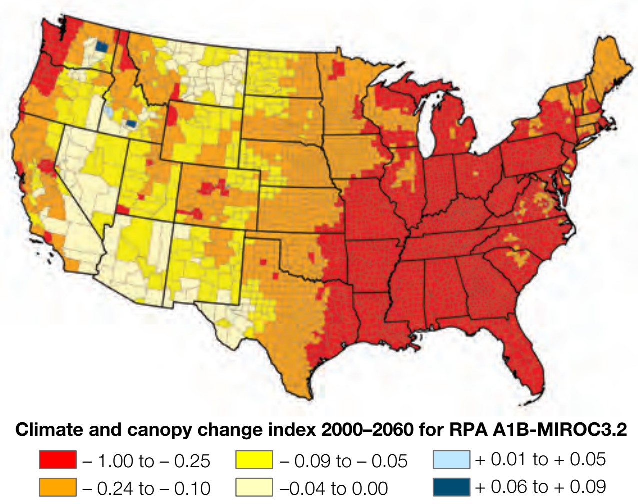


Figure 50. Change in aridity ratio, 2000–2060, for RPA B2-CGCM2 (median average increase in aridity).



We used the difference in tree canopy cover and difference in aridity values from 2000 to 2060 to develop a climate and tree canopy cover change index. This index was developed to determine areas that have relatively high amounts of environmental and/or climatic changes that are considered to be negative (i.e., tree loss and/or increased aridity). Cover and aridity change values were standardized based on the greatest change observed in the model (i.e., all values were divided by the maximum absolute value of change; this value was always negative and thus the index ranges from -1 to some positive value that is less than 1). Counties with values approaching -1 indicate areas with the greatest changes in terms of the combination of both getting more arid and losing tree canopy cover. Counties with positive values indicate areas with the greatest changes in terms of decreasing aridity and/or increased tree canopy cover.

Figure 51. Climate and canopy change index for RPA A1B-MIROC 3.2 in 2060 (maximum average increase in aridity). Negative index indicates greatest combined loss of tree canopy cover and increased aridity.



According to the index results, most counties will lose tree cover and become more arid, but some counties will gain tree cover and/or become less arid. With a few exceptions, the majority of areas with increased aridity and tree cover loss are in the Pacific Northwest and various counties in the East (figures 51 through 53). Various parts of the Great Plains and Intermountain Subregions and the desert Southwest are projected to become less arid and/or have increased tree canopy cover.

Conclusions

Future development and climate change will have significant and varying effects on tree cover in the United States, with most areas losing tree cover and becoming more arid by 2060. The increases in canopy cover are often because of projected changes from sparsely treed land uses to developed land uses, which tend to bring in trees and increase tree cover. Thus, the tree and forest landscapes of the United States are likely to undergo significant changes in the coming century. Managers and planners need to understand these changes to help sustain healthy and functioning landscapes to meet the needs of changing society.

Figure 52. Climate and canopy change index for RPA A2-CSIRO-Mk3.5 in 2060 (minimum average increase in aridity). Negative index indicates greatest combined loss of tree canopy cover and increased aridity.

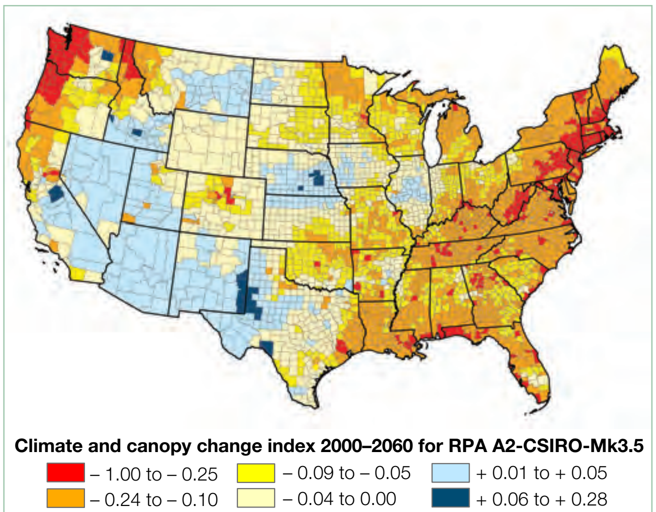
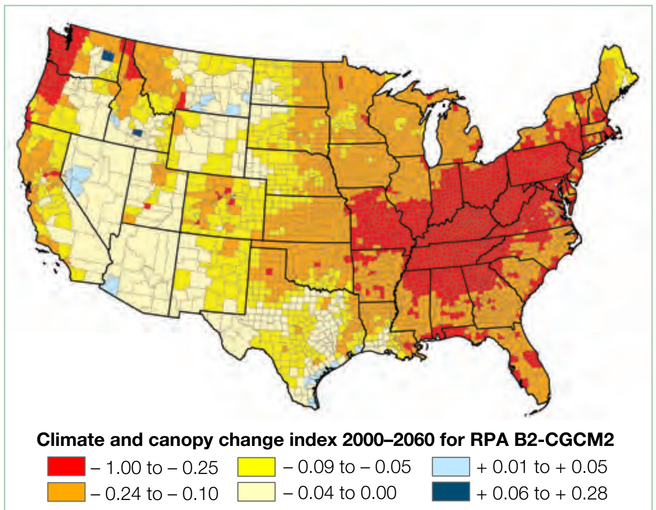


Figure 53. Climate and canopy change index for RPA B2-CGCM2 in 2060 (median average increase in aridity). Negative index indicates greatest combined loss of tree canopy cover and increased aridity.



Chapter 8. Forest Products

Forest products provide benefits to consumers, jobs in the forest industry, and timber revenues to forest owners. Timber harvest revenues and related forest management also help sustain forest ecosystem conditions and forest ecosystem services discussed elsewhere in this report. This chapter describes recent trends in U.S. forest product consumption, production, and net trade, and also discusses economic projections of production, consumption, net trade, timber harvest levels, and timber prices, as influenced by global scenarios regarding future economic growth, population, and biomass energy demand.

Resource Highlights

- The forest products sector was hard hit by the recession.
- Timber resources will continue to be adequate to meet demands unless there are very large increases in wood energy demand.
- Forest product futures are tied to domestic and global wood energy demands.

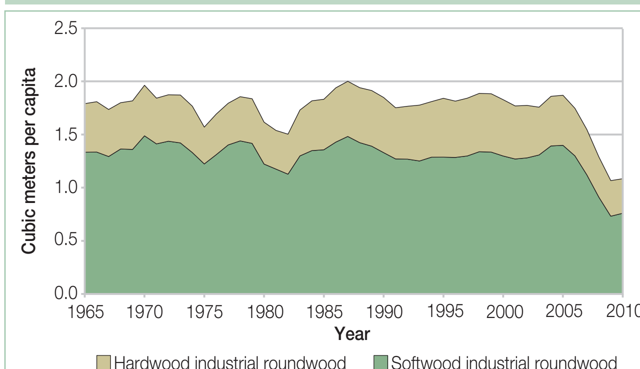
The volume of roundwood needed to make the wood and paper products consumed in the United States (including product imports) was growing at roughly the rate of population growth until recently (Skog et al. 2012). The roundwood equivalent of wood and paper product consumption per capita was fairly stable in the United States from the mid-1960s to 2005, but consumption has declined since the 2005 downturn in new housing construction (a major end use for wood products) and the subsequent economic recession (figure 54).

The net import share of U.S. wood and paper product consumption peaked at more than 20 percent in the past decade, but declined with the contraction in housing construction and weakening of the U.S. dollar in recent years (figure 55). The United States has been a net exporter of hardwood lumber and paperboard for years, and recently became a net exporter of wood pulp and total paper and paperboard. Although still a net importer of other major products such as softwood lumber, imports of those products have declined.

The estimated roundwood equivalent of annual forest product production (excluding roundwood imports) provides an estimate of annual timber harvest (Howard in prep.). U.S. timber harvest increased from 1965 to the late 1980s, peaked in 1988, and has declined since then (figure 56). U.S. timber harvest declined by just more than one-third (34 percent) from 1988 to 2010, based on roundwood equivalent estimates, with most of that decline occurring since 2005. In 2009, 89 percent of the timber harvest was industrial roundwood used for lumber, panels, paper, other industrial products, or export, and 11 percent was roundwood fuelwood. More than 40 percent of total wood harvest is used ultimately for energy, however, because large volumes of industrial wood and bark-mill residues and pulp byproducts are used for energy.

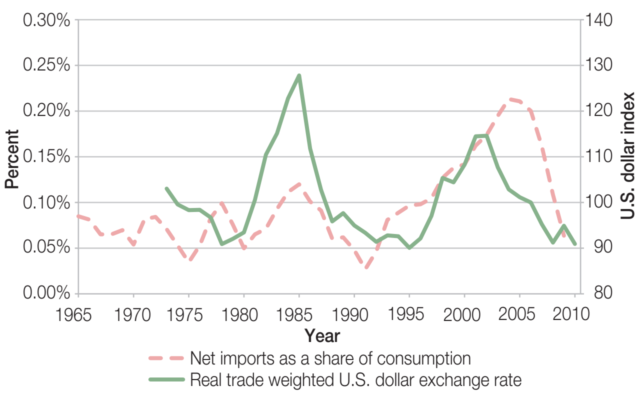
The future market outlook for forest products was projected from 2020 to 2060 for four Resources Planning Act (RPA) scenarios using the U.S. Forest Products Module/Global Forest

Figure 54. Industrial roundwood equivalent of U.S. wood and paper product consumption, 1965–2010.



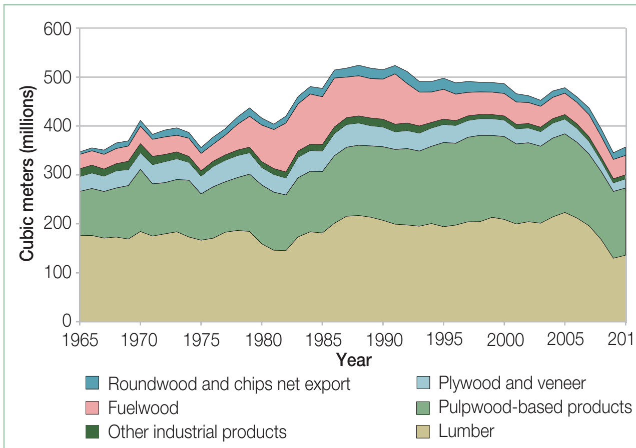
Source: Howard in prep.

Figure 55. Net import share of consumption in roundwood equivalents for wood and paper products (percent) and trade-weighted U.S. dollar index, 1965–2010.



Sources: Howard in prep.; Federal Reserve

Figure 56. Roundwood equivalent of U.S. forest product output, 1965–2010.



Source: Howard in prep.

Products Model (USFPM/GFPM) market modeling system (Ince et al. 2011). Key elements in all RPA scenarios are the projected future levels of global wood energy consumption, which for three of the RPA scenarios were based on interpretation of Intergovernmental Panel on Climate Change (IPCC) global biomass energy projections. The varying future levels of wood energy consumption have significant effects on projected wood raw material markets, global forest product trade, and U.S. forest product production. The assumed fourfold expansion of U.S. wood energy consumption by 2060 in the lowest of the three IPCC scenarios (B2) is roughly consistent with the projected doubling of U.S. biomass energy production by 2030 in the 2010 Annual Energy Outlook reference case (USDOE EIA 2010), whereas wood energy consumption is higher in the other IPCC-based scenarios and generally much higher than historical levels of wood energy consumption. Therefore, projections were also made for the RPA historical fuelwood (HFW) scenario.[9] The HFW scenario has all of the same global economic growth assumptions as the RPA A1B scenario, but it projects much less future expansion in U.S. and global wood energy consumption, as determined by historical fuelwood consumption relationships to gross domestic product (GDP) rather than the IPCC biomass energy projections. This scenario could be regarded as a scenario in which policies or technologies do not emerge that enhance the role of wood in the production of energy, or in which alternative energy resources such as natural gas become more plentiful than projected by IPCC, reducing future expansion of wood energy.

Global Outlook

The GFPM provided the global framework and context for the RPA analysis of U.S. forest product and timber market trends. This section highlights the use of the GFPM and some specific global modeling results for the RPA scenarios.

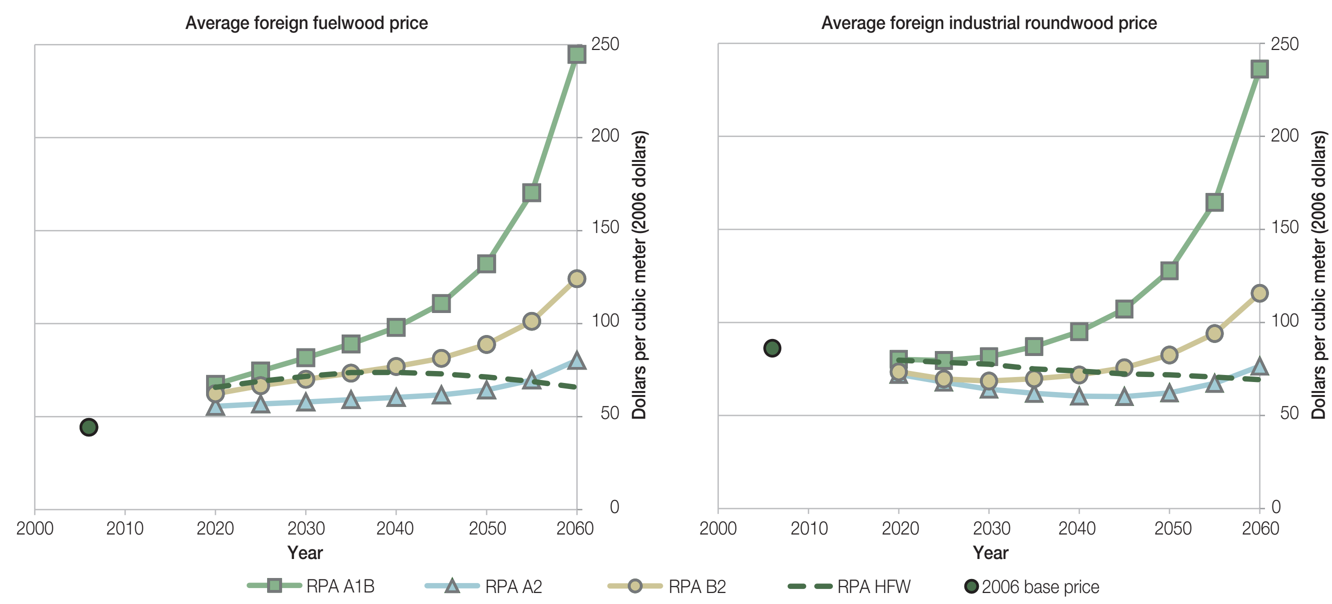
Within the USFPM/GFPM framework, the GFPM was used to project global market trends for forest products, fuelwood, and industrial roundwood in all foreign countries for each of the RPA scenarios. The results indicated that, on average, foreign fuelwood prices would increase under all RPA scenarios, leading to increased global competition for industrial roundwood depending on the level of projected global fuelwood consumption. The market effect is to increase the average global industrial roundwood price, particularly in RPA scenarios with high global fuelwood consumption, and in that case the projected global average fuelwood price converges with the average industrial roundwood price as early as 2030.

Figure 57 shows the USFPM/GFPM projections of average foreign real prices of fuelwood and industrial roundwood for the RPA scenarios. The average foreign industrial roundwood price is projected by 2060 to be higher than the 2006 average in both the RPA A1B and B2 scenarios, which feature the highest levels of global fuelwood consumption. The average foreign industrial roundwood price remains below the 2006 price average throughout the projection period in the RPA A2 and HFW scenarios, however, mainly because those scenarios feature less projected expansion in global fuelwood consumption and less competition for industrial roundwood from wood energy demands.[10]

[9] The HFW scenario is similar to the "A1B Low Fuelwood" scenario described in Ince et al. (2011), except the HFW uses the smaller U.S. timber supply shifts of the RPA A2 scenario.

[10] Price projections presented here are not identical to those reported by Buongiorno et al. (2012) because the analysis by Buongiorno et al. used the GFPM without USFPM and used different assumptions regarding global roundwood price elasticities, different projections of global fuelwood demands for the IPCC-based scenarios, and different specifications of demands for U.S. forest products.

Figure 57. Projected average foreign fuelwood (left) and industrial roundwood (right) prices by RPA scenario, 2020–2060, relative to 2006 average prices.



Global expansion in fuelwood consumption leads to a projected declining trend in total forest growing stock inventory of foreign countries by 2060 in the RPA A1B scenario, although forest inventory is projected to continue increasing in the other RPA scenarios with less expansion of fuelwood consumption. Figure 58 shows projections of annual foreign fuelwood consumption and forest growing stock inventory. In the RPA A1B scenario, wood use for energy leads to a leveling out of the total forest inventory of foreign countries by around 2050, followed by a declining trend to 2060. The projected forest inventory trends are also influenced to a lesser extent by projected trends in industrial roundwood consumption, which is highest in the RPA A1B and HFW scenarios (with highest global GDP growth).

Under the RPA A1B scenario, projected global consumption of roundwood (industrial roundwood and fuelwood) reaches 9.1 billion cubic meters annually by 2060, which is greater than the annual growth potential of world forests under the forest growth assumptions of the GFPM, hence, forest growing stock inventory is projected to decline by then. Total projected global roundwood consumption by 2060 is lower in the other RPA scenarios—6.2 billion cubic meters per year in the RPA B2 scenario, 5.2 billion in the RPA A2 scenario, and 3.9 billion in the RPA HFW scenario (not much higher than the 3.5 billion consumed globally in 2006). In all four RPA scenarios, most projected growth in roundwood consumption is attributable to wood energy, with global roundwood consumption in industrial wood products remaining generally in the range of 1.2 to 1.8 billion cubic meters per year throughout the projection period across all RPA scenarios.

Figure 59 illustrates the corresponding projections of total global roundwood use for energy and for industrial wood products across the four RPA scenarios. Global demand for industrial wood products is highest in the RPA A1B and HFW scenarios because those scenarios share the highest global GDP growth among RPA scenarios. Hence those RPA scenarios feature the highest consumption of roundwood for industrial wood products, but they are at opposite extremes in terms of projected global roundwood use for energy. In the RPA A1B scenario, global fuelwood demands are driven by IPCC biomass energy projections, whereas fuelwood demands are driven by more modest historical relationships to GDP growth in the RPA HFW scenario. The RPA A2 and B2 scenarios have lower projected roundwood use in industrial wood products because of lower forest product demand with lower GDP growth. Whereas the RPA B2 scenario has the lowest GDP growth and lowest consumption of roundwood in industrial wood products, the RPA A2 scenario has less global use of roundwood for energy than RPA B2. These variations in wood use and global markets are important in the RPA analysis because they influence the forest product production and trade outlook for U.S. producers, as explained subsequently in more detail.

Finally, growth in consumption of roundwood for industrial forest products is projected to be relatively modest in spite of worldwide population and income growth. This modest growth is partly because the GFPM (and USFPM) assume material productivity gains in forest products (higher future product recovery per unit of roundwood input and increased paper recycling, for example). It is also partly a reflection

Figure 58. Projected foreign fuelwood consumption (left) and forest growing stock inventory (right), by RPA scenario, 2020–2060, relative to 2006 levels.

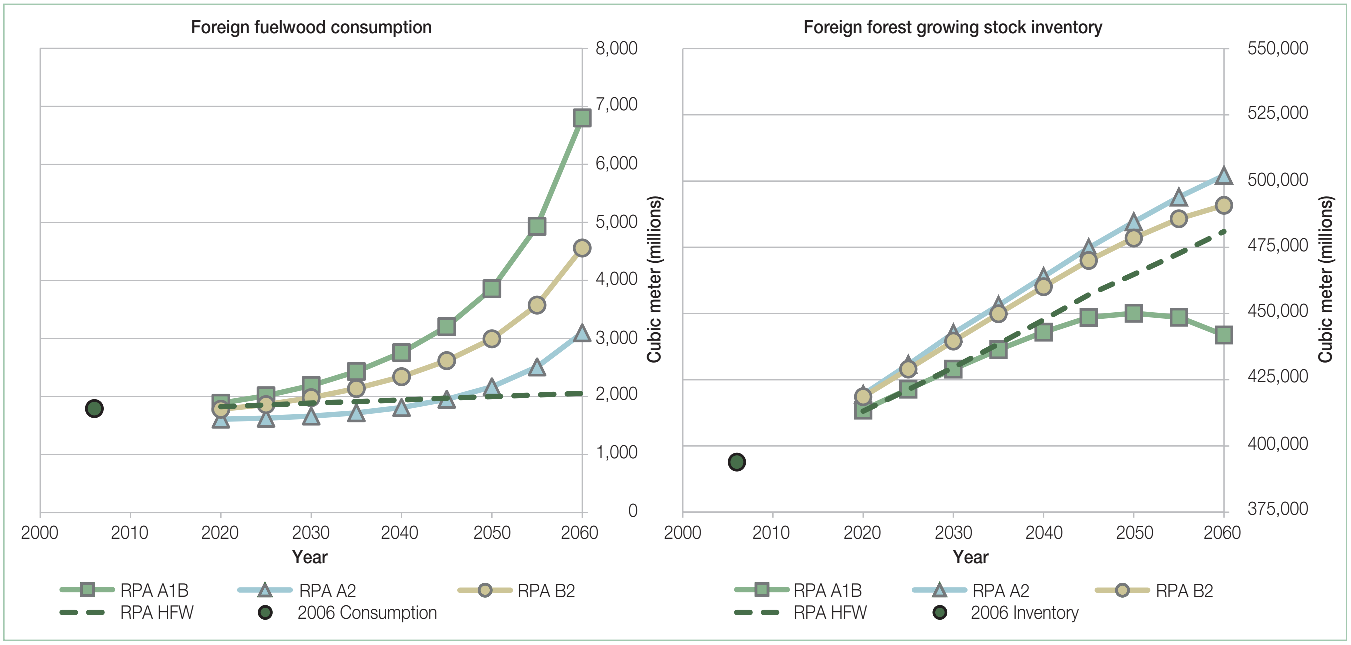
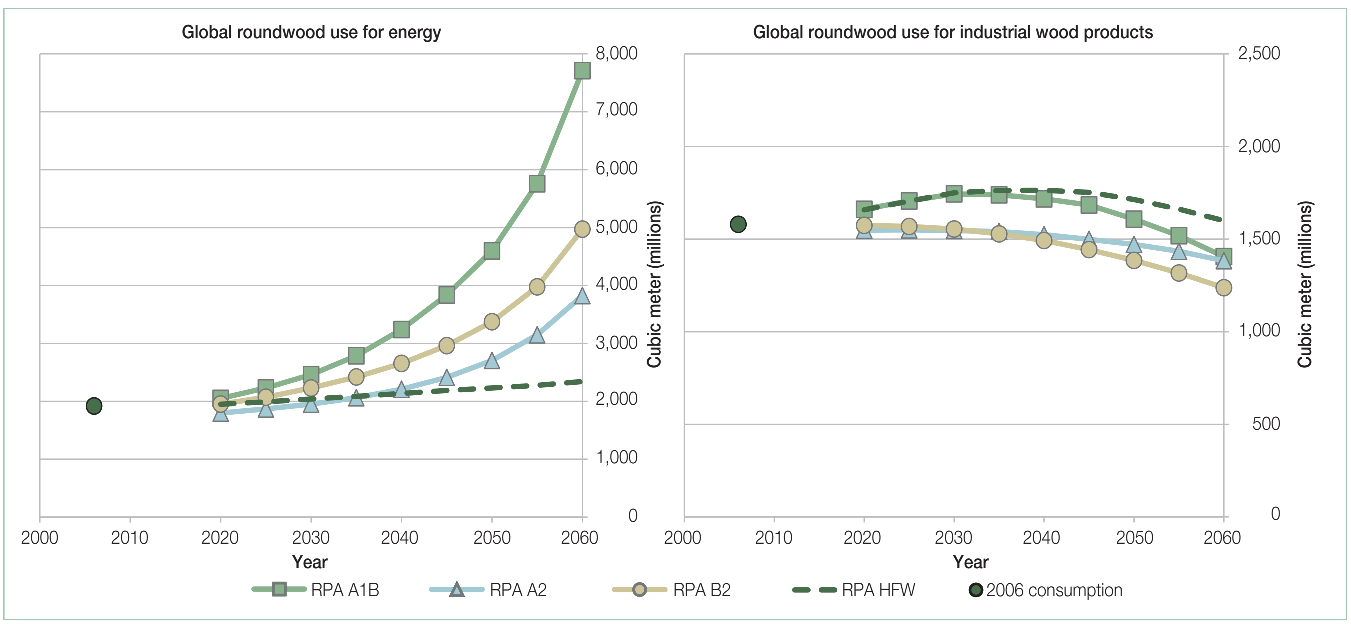


Figure 59. Projected global roundwood use for energy (left) and for industrial wood products (right), by RPA scenario, 2020–2060, relative to 2006 levels.



of limited projected growth in worldwide average per capita forest product consumption in the decades ahead (apart from the expansive wood energy consumption that varies by RPA scenario).

The modest projected increase in global forest product consumption results in only small changes in the real prices of forest products such as wood-based panels and pulp and paper products, although the large variation in roundwood price across RPA scenarios causes wider variation in projected lumber prices. The fairly moderate global trends mask cross-country variations: all RPA scenarios project the consumption of all wood products to grow more rapidly in Asia, in large part because of the fast economic growth of China and India. As a result, Asia is projected to be a large importer of industrial roundwood, and exports are largely supplied by South America (Brazil) and Europe (the Russian Federation). Asia is also projected to be the largest and fastest growing importer of paper and paperboard, and exports of paper and paperboard are supplied primarily from Europe, but also from North America.

Wood Energy Trends

Wood energy includes roundwood fuelwood harvest and wood and bark fuel residues generated in the production of forest products. Other wood byproducts are also used for energy, such as combustible black liquor generated at kraft pulp mills. As such, energy is a leading use of wood in the United States, and the largest use of wood globally. In addition, there is competition for the cleaner wood residues (wood chips or particles) as raw material in wood pulp or wood panel production (in particleboard or fiberboard). Excluding black liquor (a byproduct of pulpwood), roundwood fuelwood harvest provided roughly 40 percent of wood fuel feedstock in the United States in 2006, whereas wood and bark mill residues accounted for about 60 percent (Smith et al. 2009).

Residential fuelwood is used mainly for heating. Residential wood energy use is driven primarily by the price of alternative heating fuels. The wood pellet industry has expanded in recent years, with wider use of more efficient wood pellet furnaces, but pellets still account for a relatively small fraction of total wood energy, less than 10 percent or so (Spelter and Toth 2009). Wood pellet consumption in the United States has been driven primarily by use in residential heating. Most pellets are made from wood residues, but the use of roundwood has been increasing as sawmill production has declined (yielding less wood residue). Both domestic and foreign pellet demand have increased. Wood pellet exports to Europe have increased sharply since 2006 (Chudy 2011).

Industrial wood energy consumption is primarily driven by the need for steam energy and power generation in pulp and paper production, with a secondary driver being heat energy needs at lumber mills for kiln drying. In the United States, most industrial wood energy is consumed at pulp and paper mills and other wood product mills. Industrial use of wood and bark for energy at pulp and lumber mills is facilitated by ready access to fuel residues for energy.

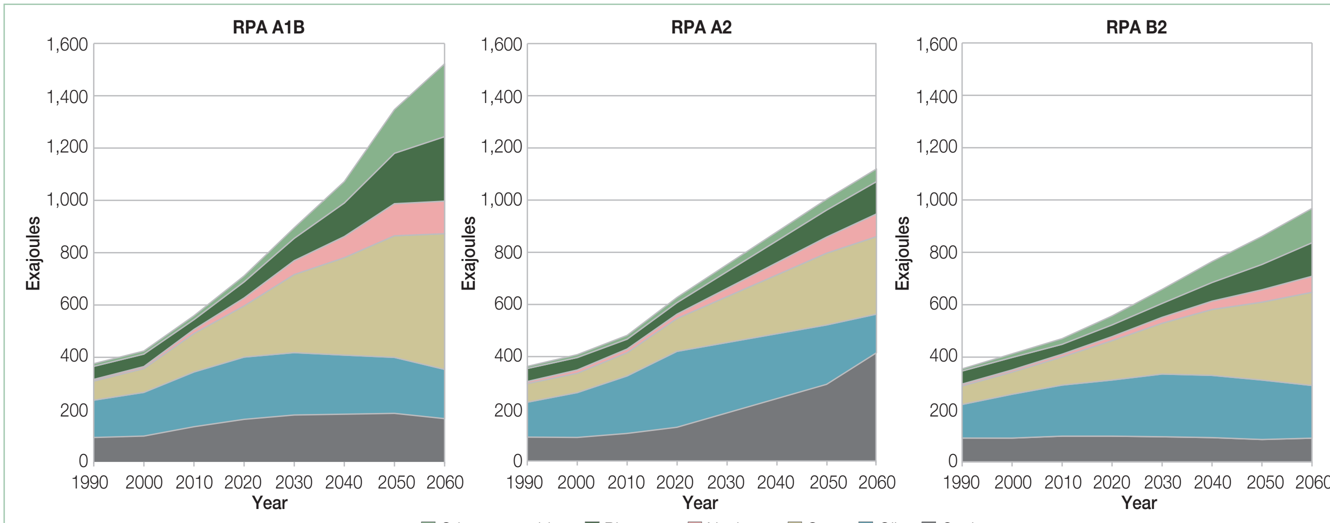
Use of wood for energy at electric power plants, including cofiring with coal, has also expanded at some locations, but use of wood depends on relative prices of fuel feedstocks and incentives or policies that support power production from biomass such as State renewable portfolio standards.

Technology for economical conversion of wood biomass to liquid biofuels has yet to be demonstrated, but production pathways are being explored, including conversion of wood cellulose and hemicelluloses to sugars, fermentation to ethanol or other fuels, and thermal conversion pathways such as gasification and conversion of syngas to alkane fuels via the Fischer-Tropsch process. Based on current prices, production of wood pulp still offers much higher revenue and value added for pulpwood than does production of wood-based biofuels such as cellulosic ethanol. Higher future market prices for ethanol or other biofuels or improved production cost efficiency could increase the competitiveness of biofuel production from wood. Also, joint production of wood pulp and biofuels at integrated forest product biorefineries is a potentially more lucrative opportunity that is being explored by the forest industry.

Wood Energy Projections

Wood energy assumptions for three of the RPA scenarios were based on global energy projections developed previously for IPCC (Nakicenovic and Swart 2000). The IPCC outlook reflects projected continued expansion in overall global energy consumption, with peaking of global petroleum (oil) production and consequent expansion in alternative forms of energy production, including biomass energy (figure 60). In all three

Figure 60. Global primary energy production for IPCC-based RPA scenarios.



IPCC = Intergovernmental Panel on Climate Change.

Source: Nakicenovic and Swart 2000

IPCC-based scenarios, global production of energy from oil peaks during the decade from 2020 to 2030, followed by expansion in other categories of energy production, primarily natural gas but also biomass, other renewable energy, and nuclear energy (and, in the RPA A2 scenario, coal energy). Biomass energy accounts for an expanding fraction of global energy production in all three scenarios, but the magnitude of expansion varies by scenario. In all three IPCC-based scenarios, nonforest biomass (from nonforest energy plantations and cropland residues) was estimated to account for much more than one-half of the projected biomass energy production by 2060, but global wood energy production also expands significantly, particularly in the high-growth RPA A1B scenario.

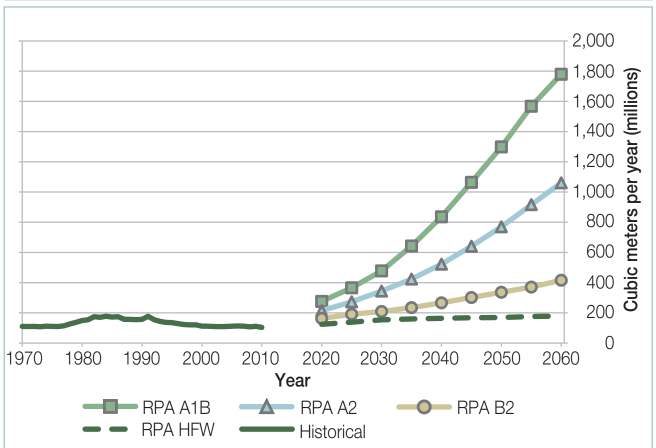
Projected rates of expansion for wood energy consumption in the United States are generally higher than the global rate of expansion in the IPCC-based scenarios. The distribution among countries of projected wood energy consumption was linked in the USFPM/GFPM model to the projected future distribution of GDP among countries. In all RPA scenarios, the United States retains a relatively large share of global GDP. Projected fuelwood consumption in foreign countries still remains much higher in aggregate than U.S. wood energy consumption in all RPA scenarios, however, because current U.S. fuelwood consumption is only a small share (less than 3 percent) of global fuelwood consumption.

Figure 61 shows historical U.S. wood fuel feedstock consumption and future consumption levels for all four RPA scenarios. The range of projected expansion in U.S. wood fuel feedstock consumption from 2006 to 2060 is from less than 2-fold in the RPA HFW scenario to about 4-fold in the RPA B2 scenario, 9-fold in the RPA A2 scenario, and 16-fold in the RPA A1B scenario. In three of the RPA scenarios (A1B, A2, and B2), U.S. and global wood energy demands are driven by IPCC projections of biomass energy production (after deducting estimated biomass energy from nonforest energy plantations and cropland residues), whereas wood energy demands in the RPA HFW scenario are driven by historical econometric relationships of fuelwood demand to GDP growth in each country (using the RPA A1B assumptions regarding population and economic growth, along with more modest RPA A2 assumptions regarding expansion in U.S. timber supply).

In recent decades, most U.S. wood fuel feedstock production has consisted of conventional fuelwood harvest and fuel residues (mill residue byproducts used as fuel, such as bark and other wood waste). More costly alternate sources of wood fuel feedstock (harvest residues and pulpwood) become important, however, in RPA scenarios with large increases in wood energy consumption, such as the RPA A1B scenario. Figure 62 shows projected U.S. wood fuel feedstock production by source for the RPA A1B scenario, which has the largest increase in U.S. wood fuel feedstock consumption among RPA scenarios (nearly 16-fold by 2060). The projections are based on relative feedstock costs, as determined by the USFPM/GFPM economic model. At high consumption levels, the more costly alternate sources of wood energy become dominant, including harvest residues, hardwood and softwood pulpwood, and mill fiber residues that would conventionally be used to make wood pulp, oriented strand board (OSB), and particleboard.

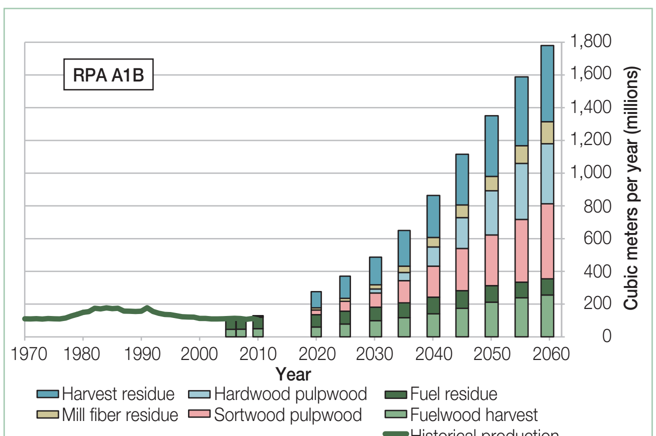
Compared with the RPA A1B scenario, the RPA A2 scenario features somewhat less expansion in U.S. wood fuel feedstock consumption (ninefold by 2060), and thus lower production of wood fuel feedstocks, as shown in figure 63. There is still a large projected expansion of pulpwood use in the RPA A2 scenario, however. In both the RPA A1B and A2 scenarios, the expansion of softwood pulpwood use for energy is facilitated by projected expansion of pine plantation area in the South Region coupled with declining regional wood pulp production.

Figure 61. Annual U.S. wood fuel feedstock consumption, 1970–2010, and projections, by RPA scenario, 2020–2060.



Source: Ince et al. 2011

Figure 62. Annual U.S. wood fuel feedstock production, 1970–2010, and projection of production, by feedstock source, RPA A1B scenario, 2020–2060.



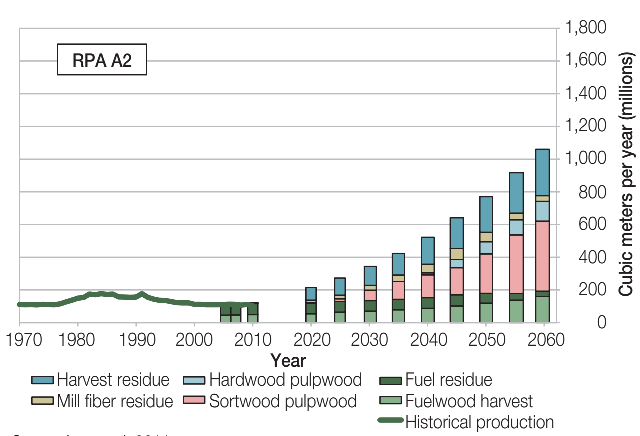
Source: Ince et al. 2011

Projections of wood fuel feedstock production for the RPA B2 and RPA HFW scenarios are generally much lower, as shown in figures 64 and 65, where expansion of wood fuel feedstock consists mainly of harvest residues. According to the USFPM/GFPM economic model, higher levels of wood energy consumption would result in the use of more costly industrial roundwood feedstocks, such as pulpwood roundwood, in the RPA A1B and A2 scenarios, but not in the RPA B2 or HFW scenarios.

Timber Harvest and Price Trends

Figure 66 shows the historical trend in annual U.S. timber harvest volume from 1970 to 2010 (based on roundwood equivalent estimates) and market equilibrium projections of annual U.S. timber harvest volumes from 2020 to 2060 for the four RPA scenarios. Projections of U.S. timber harvest generally depart from historical timber trends of recent decades (figure 66), particularly in the RPA scenarios that feature significant expansion in wood energy consumption and shifts in forest product trade. Total U.S. timber harvest has declined since the late 1980s, but projections for the RPA scenarios show a range of increasing timber harvest levels. The largest increase occurs in the RPA A1B scenario, followed by RPA A2 and B2, reflecting primarily the magnitudes of biomass energy output projected by IPCC for those scenarios. Even in the RPA B2 scenario, U.S. timber harvest is projected to reach levels much greater than the peak harvests of the 1980s. Only in the RPA HFW scenario that follows historical relationships for wood energy consumption does U.S. timber harvest remain within the range of historical levels during the projection period. Projected expansion in U.S. and global timber harvest levels might also be problematic under the current regulatory environment. With a tripling of U.S. timber harvest and elevated timber prices (as in the RPA A1B scenario by 2060), there would be more intensified timber

Figure 63. Annual U.S. wood fuel feedstock production, 1970–2010, and projection of production, by feedstock source, RPA A2 scenario, 2020–2060.



Source: Ince et al. 2011

Figure 64. Annual U.S. wood fuel feedstock production, 1970–2010, and projection of production, by feedstock source, RPA B2 scenario, 2020–2060.

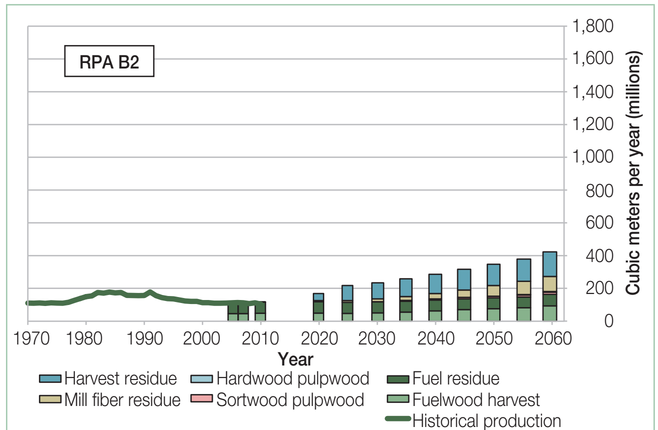
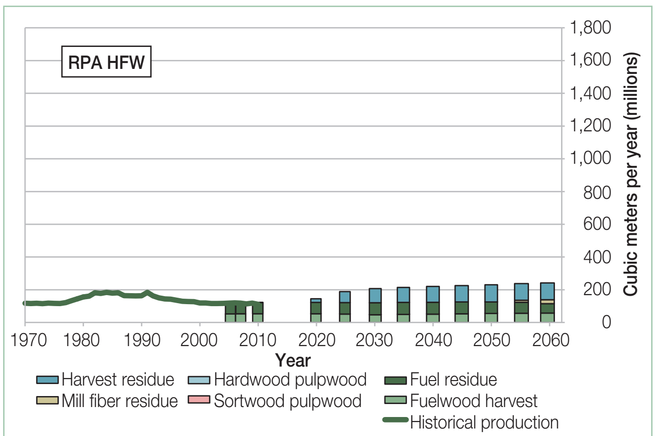
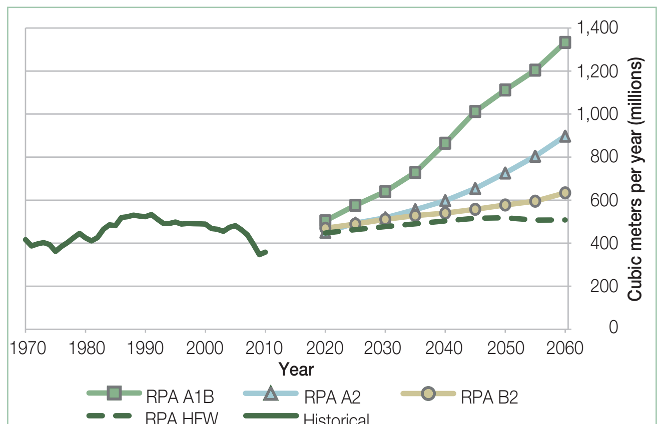


Figure 65. Annual U.S. wood fuel feedstock production, 1970–2010, and projection of production, by feedstock source, RPA HFW scenario, 2020–2060.



Source: Ince et al. 2011

Figure 66. U.S. timber harvest volumes, 1970–2010, and projections, by RPA scenario, 2020–2060 (excluding harvest residue volumes).



Source: Ince et al. 2011

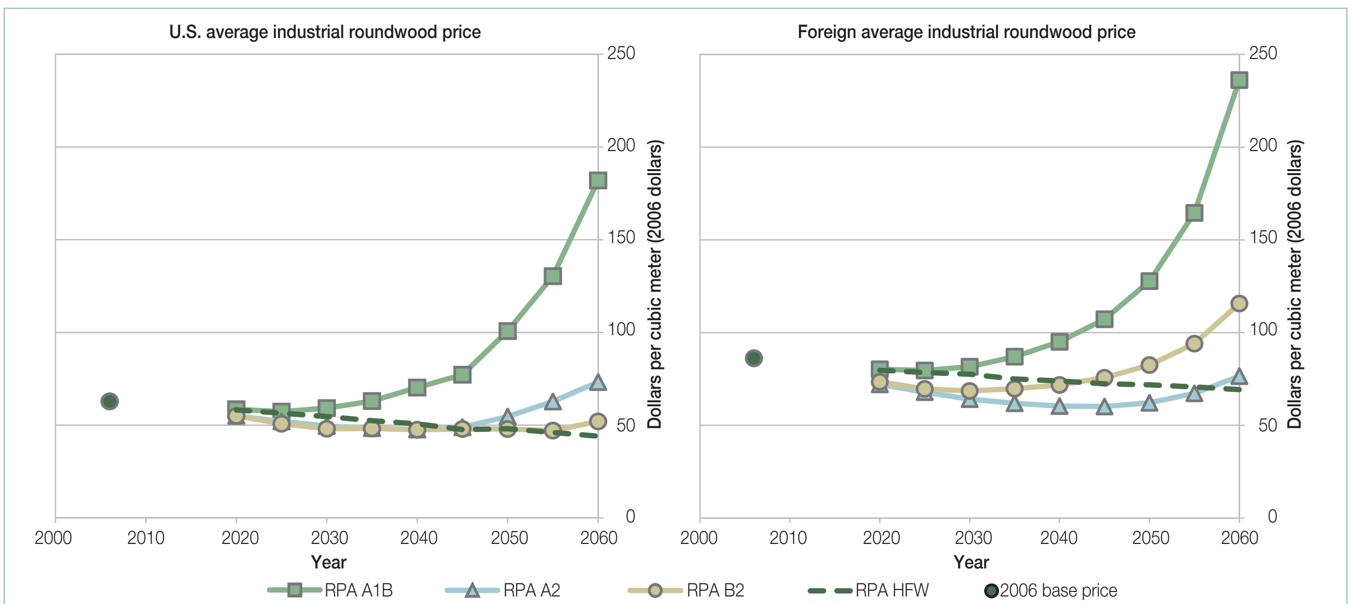
management, and thus a projected expansion of more than 70 percent in the area of pine plantations in the South Region in the RPA A1B scenario, but only around 20 percent in the RPA B2 scenario.

Wood energy demands are the main long-run driver of projected timber harvests in the RPA scenarios, and thus timber harvests are highest for RPA A1B and much lower for the RPA B2 and HFW scenarios. The difference in projected timber harvest between the RPA A1B and HFW scenarios is mainly a result of the wood energy demand assumptions, with the RPA A1B wood energy demands based on high global biomass energy projections from IPCC, and the RPA HFW demands based on much more conservative historical relationships of wood energy demand to GDP growth in each country. Projected U.S. timber harvest remains within the range of its recent historical levels in the RPA HFW scenario, but increases to higher levels in the other three scenarios.

Because of different levels of timber demand, the projected prices for delivered industrial roundwood vary widely across the RPA scenarios (figure 67). The future wood energy consumption levels of the IPCC scenarios were implemented in the USFPM/GFPM model by imposing fixed trajectories of minimum wood fuel feedstock consumption, as determined by IPCC biomass energy projections (after deducting estimated biomass supply from nonforest biomass plantations and cropland residues). With such inelastic shifts in wood energy demands ranging from a 4-fold expansion in the RPA B2 scenario, to 9-fold in RPA A2, to 16-fold in RPA A1B, the RPA scenarios resulted in a wide spectrum of projected equilibrium real prices for industrial roundwood, with the highest projected roundwood prices in the RPA A1B scenario. On the other hand, average U.S. real prices for industrial roundwood were projected to decline in the RPA B2 scenario and the RPA HFW scenario, in which U.S. and global wood energy demands were based on historical relationships to GDP growth. Declining U.S. roundwood price projections in the RPA B2 and HFW scenarios (figure 67) show that projected growth in U.S. timber supply is more than adequate to meet projected U.S. timber demands in those scenarios, in which logging residues supply most of the projected U.S. expansion in wood energy and there is only modest demand pressure on industrial roundwood markets. At the other extreme, high wood energy demands in the RPA A1B scenario result in heavy use of pulpwood for energy, and real U.S. industrial roundwood prices are projected to increase more than threefold.

Projected industrial roundwood prices in foreign countries increase much more on average than in the United States in the RPA A1B and B2 scenarios (figure 67), mainly because of high global wood energy consumption in those RPA scenarios. Thus, even though the RPA A1B scenario results in very high U.S. industrial roundwood prices, it also results in a reduction in the size of projected U.S. trade deficits for wood products because of even higher average foreign roundwood prices. By contrast, the U.S. trade deficit in wood products continues unabated into the future under the RPA A2 scenario, in which there is the least expansion in global fuelwood consumption. In general, the projections show that U.S. and global fuelwood demands and corresponding industrial roundwood price projections could imply some improvement in the U.S. trade position compared with historical experience. These results, however, reflect assumptions about U.S. and global wood energy demand trends that are unique to the RPA scenarios, and there are other

Figure 67. Projected weighted average delivered industrial roundwood prices for United States (left) and for all foreign countries worldwide (right), by RPA scenario, 2020–2060, relative to 2006 prices.



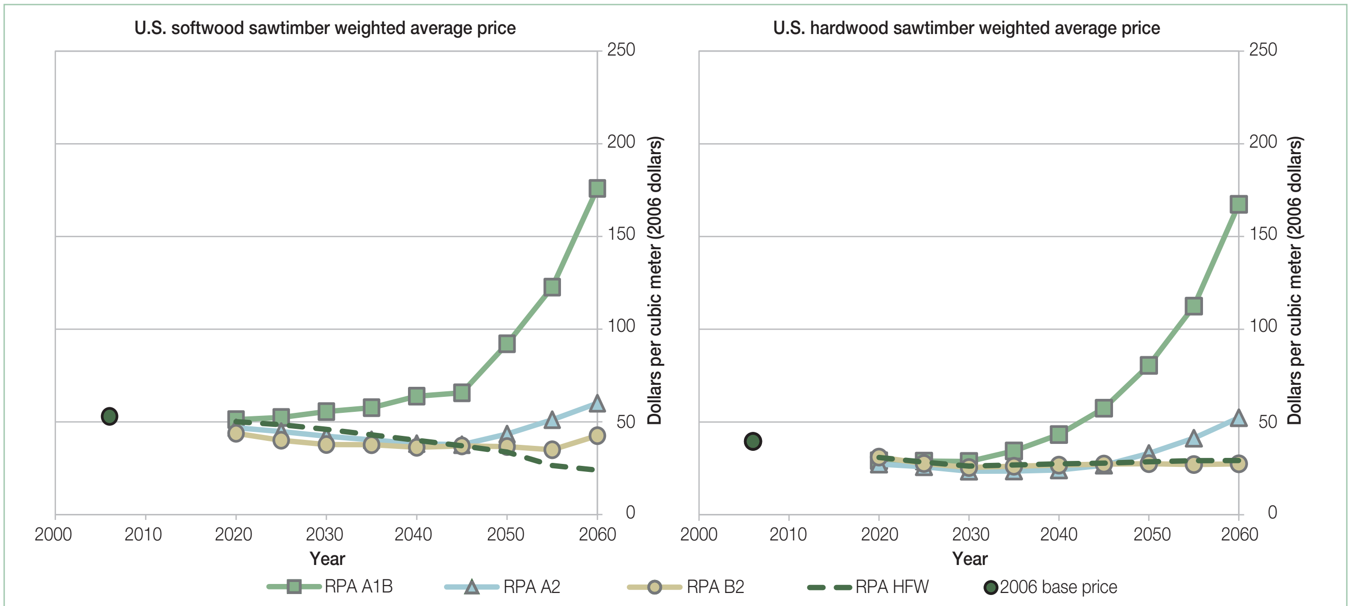
factors and trends that could influence future timber prices. Increased wood energy consumption will not necessarily result in trade gains for U.S. producers of forest products, but it could happen under certain assumptions (e.g., in RPA scenarios for which expansion of global demands for wood energy cause foreign roundwood prices to increase more than in the United States).

Differing levels of timber demand and industrial roundwood prices also result in differing projections of real timber stumpage prices. For example, average U.S. sawtimber stumpage prices remain relatively flat to declining in the RPA B2 and HFW scenarios, in which there is modest expansion in wood energy consumption, and in the RPA A2 scenario, there is only a slight increase in stumpage prices. By contrast, there is a threefold-to-fourfold increase in average U.S. sawtimber stumpage prices in the RPA A1B scenario (figure 68).

declined from 83 to 70 percent, whereas structural panels increased from 9 to 17 percent, and nonstructural panels increased from 8 to 13 percent. These trends reflect the expanding use of composite and engineered wood products in the U.S. market.

Solidwood product consumption in new residential construction was sharply reduced by the recent decline in housing construction. According to the U.S. Census Bureau, total new privately owned housing units started (housing starts) dropped from 2.07 million in 2005 to fewer than 1 million in 2008, 0.554 million in 2009, and 0.587 million in 2010. U.S. housing starts had previously not been less than 1 million since at least the 1950s. By 2009, this housing downturn had resulted in solidwood product consumption in new residential construction sinking to levels not seen for at least 50 years (figure 69). New housing construction dropped out of its traditional place as the

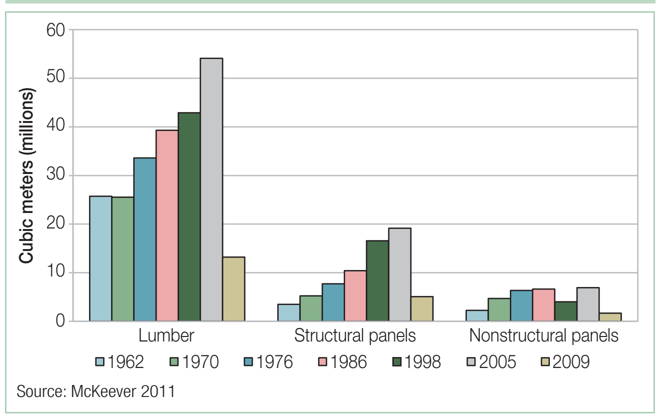
Figure 68. Projected average U.S. softwood (left) and hardwood (right) sawtimber stumpage prices, by RPA scenario, 2020–2060, relative to 2006 prices.



Solidwood Products Trends

Solidwood products include primarily lumber and wood panel products. They are used extensively to meet needs in construction, manufacturing, and shipping segments of the U.S. economy. U.S. solidwood product consumption is closely linked to construction activity because of the use of lumber and wood panels in housing and commercial construction and the related use of wood in furnishing, flooring, and cabinets. Consequently, overall U.S. solidwood product consumption levels have tended to follow new housing starts, a leading indicator of construction activity, and consumption notably declined with the decline in housing starts from 2005 to 2009. Also, between 1965 and 2008, the lumber volume share of solidwood product consumption

Figure 69. Solidwood products used for new residential construction in the United States, by product category, selected years, 1962–2009.



Source: McKeever 2011

largest single end use for solidwood products, but 60 percent of solidwood products were still consumed in general construction because of continued demand in residential repair and remodeling and in commercial construction uses. Thus, construction in general remains the principal market for lumber and wood panel products, although demand has shifted recently from new housing construction to residential repair and remodeling.

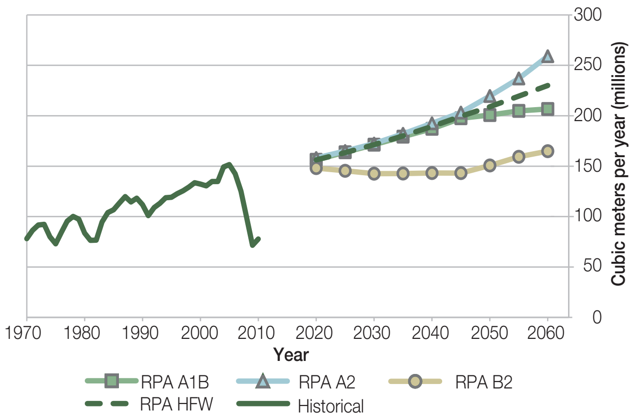
In addition to construction, a number of manufacturing industries, such as flooring, furniture, and cabinetry, make products entirely from wood. Many of these industries, however, have relocated to other countries in recent years, a situation that has particularly affected hardwood furniture and fixtures manufacturing. U.S. production and consumption of hardwood lumber and sawlogs have declined as a result of off-shoring of manufacturing, declines in housing demand, and the recent recession.

Solidwood Products Projections

RPA projections of U.S. lumber consumption (figure 70) are driven by projected future housing starts and real GDP growth (highest for RPA A1B). Housing construction is projected on the basis of demographic analysis to recover to trend levels by 2020 (as shown by RPA projections of single-family housing starts in figure 71), and projected housing starts are greatest for the RPA A2 scenario, which projects the greatest population growth. The RPA B2 scenario has the lowest projection of U.S. lumber consumption because it has the fewest projected U.S. housing starts and the lowest assumed rate of growth in U.S. GDP. Projected housing starts and GDP growth in the RPA HFW scenario are the same as in RPA A1B, but the economic analysis shows that lumber consumption would be higher in the RPA HFW scenario because of less competition for industrial roundwood from wood energy and lower lumber prices (figure 72).

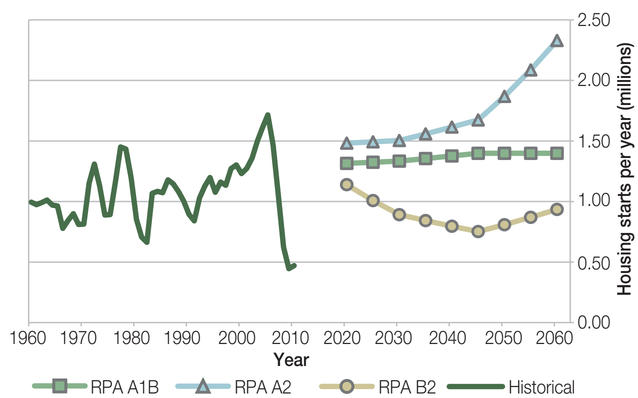
U.S. lumber prices, as projected by the USFPM/GFPM model (figure 72), are influenced by projected sawtimber price trends (figure 68), and thus projected lumber prices of the RPA A1B scenario are about $100 per cubic meter higher by 2060 than for the other RPA scenarios. Projected lumber prices are also influenced by future efficiency gains in lumber production that are programmed into the USFPM/GFPM model and by projected values of harvest residues and mill residues that are sold for energy. Thus, the weighted average real price of lumber in the United States (in constant 2006 dollars) was projected to gradually decline in all of the RPA scenarios until after 2040, when expansion of wood energy demands cause notable price increases in timber and consequently lumber prices, particularly in the RPA A1B and A2 scenarios. U.S. lumber demands are fairly inelastic with respect to change in price, however, and thus lumber consumption is not projected to decline in either the RPA A1B or A2 scenarios (figure 70).

Figure 70. Annual U.S. lumber consumption, 1970–2010, and projections, by RPA scenario, 2020–2060.



Source: Ince et al. 2011

Figure 71. U.S. single-family housing starts, 1960–2010, and projections, by RPA scenario, 2020–2060.



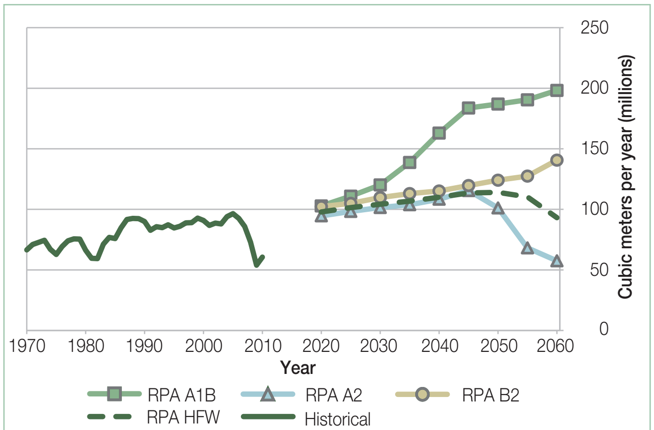
Source: Ince et al. 2011

Figure 72. Projected weighted average U.S. lumber price trends, by RPA scenario, 2020–2060, relative to 2006 price.

Source: Ince et al. 2011

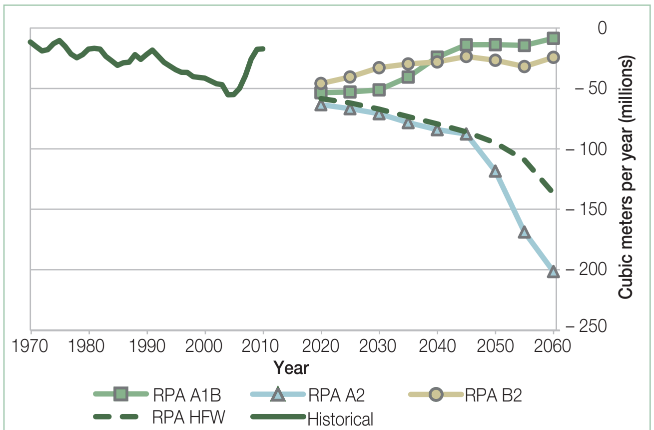
RPA projections of U.S. lumber production (figure 73) are determined by projected lumber consumption plus projected net exports (figure 74). The RPA A1B scenario has the greatest projected U.S. lumber production because it has a high level of projected U.S. lumber consumption and the greatest U.S. net exports of lumber. U.S. lumber producers slightly improve their trade position in the RPA A1B scenario (although the United States still remains a net importer) because of high levels of global fuelwood demand and higher foreign industrial roundwood prices (figure 67). By contrast, the RPA A2 and HFW scenarios have the least projected global fuelwood demands and lowest projected foreign industrial roundwood prices (figure 67). Thus, U.S. lumber producers do not substantially improve their trade positions in the RPA A2 or HFW scenarios, and lumber imports are high, resulting in the lowest projected levels of U.S. lumber production in RPA A2 and HFW scenarios, despite high levels of housing starts and high levels of lumber consumption in those scenarios. Clearly the effects of wood energy demand on global roundwood prices and lumber trade have an overriding influence on projected domestic lumber production, according to the global economic analysis of the USFPM/GFPM model. Also, as expected, lumber production and net trade projections of the RPA HFW scenario are most closely in line with the long-term historical trends before the recent housing downturn.

Figure 73. Annual U.S. lumber production, 1970–2010, and projections, by RPA scenario, 2020–2060.



Source: Ince et al. 2011

Figure 74. Annual U.S. lumber net exports, 1970–2010, and projections, by RPA scenario, 2020–2060.



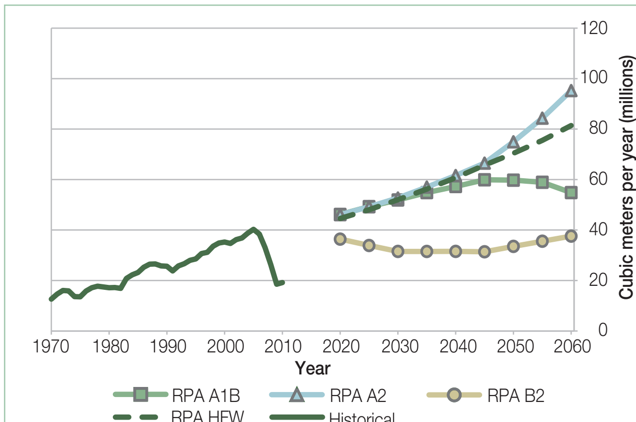
Source: Ince et al. 2011

The next leading category of U.S. solidwood products is structural wood panels, including chiefly OSB and softwood plywood, both of which are used primarily in housing and other construction applications. The historical trends and projections for U.S. structural wood panel consumption follow a very similar pattern to those of lumber, because they are driven largely by the same factors that affect housing and other construction (figure 75). Among structural panel products, the consumption share of OSB had risen to about 60 percent of the total U.S. market since it was first introduced in the late 1970s to 2010 (Adair 2010). It is projected to occupy 80 percent of the market by 2060, as softwood plywood is increasingly confined to specialty markets. OSB has gained market share largely because of lower costs, because OSB is made from pulpwood roundwood, whereas plywood is made from typically more expensive veneer logs or sawlogs.

Because OSB is made primarily from pulpwood roundwood, and Southern pine pulpwood is the leading timber raw material used for OSB production in the United States, the pattern of projected U.S. structural wood panel production (figure 76) is rather different from the lumber production pattern. Specifically, in the RPA HFW scenario, there is virtually no projected use of pulpwood for energy (figure 65) but there are still fairly abundant and expanding supplies of pulpwood, particularly Southern pine pulpwood. Thus, there is a large projected increase in U.S. OSB production that contributes to a large projected expansion in U.S. structural panel production in the RPA HFW scenario (figure 76).

The projected U.S. net exports of structural panels (including mainly OSB) are also highest in the RPA HFW scenario

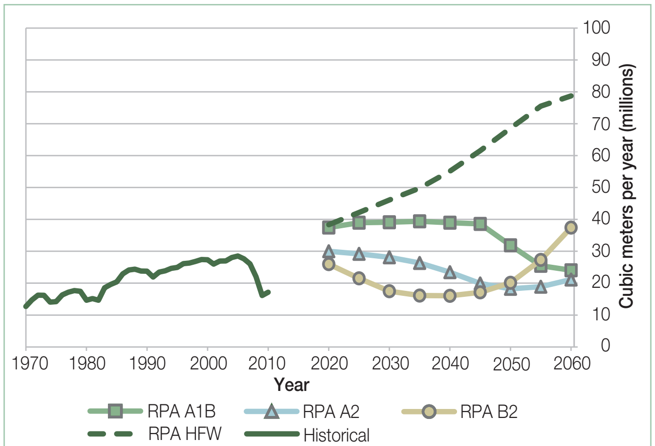
Figure 75. Annual U.S. structural wood panel consumption, 1970-2010, and projections, by RPA scenario, 2020–2060.



Source: Ince et al. 2011

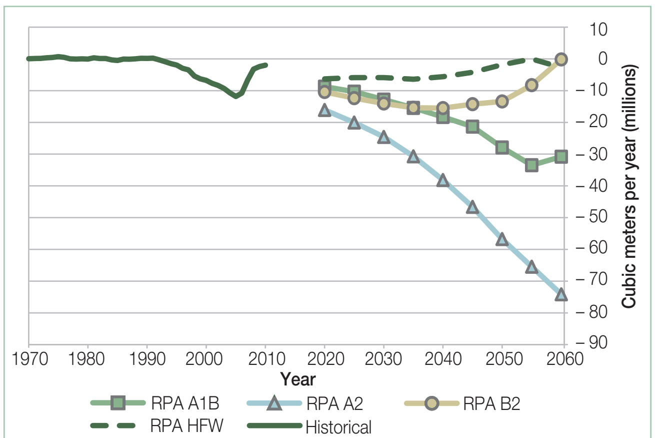
(figure 77), because of relatively abundant U.S. pulpwood supplies in that scenario with little competition from wood energy. By contrast, in the RPA A1B and A2 scenarios, there is strong competition for pulpwood from wood energy that severely limits expansion of U.S. OSB production in those scenarios (figure 76), especially in the latter decades when pulpwood use for energy really expands in the RPA A1B and A2 scenarios (figures 62 and 63). Also, in the RPA A2 scenario, there is a reversion to the long-run historical trend of declining net exports, because U.S. producers gain no significant advantages in roundwood prices relative to foreign producers and because high housing demands draw in higher structural wood panel imports. Therefore, projected net exports of structural panels in the RPA A2 scenario are more in line with the declining long-term historical trend (before 2005) and much lower than in the other RPA scenarios (figure 77).

Figure 76. Annual U.S. structural panel production, 1970–2010, and projections, by RPA scenario, 2020–2060.



Source: Ince et al. 2011

Figure 77. Annual U.S. net exports of structural wood panel products, 1970–2010, and projections, by RPA scenario, 2020-2060.



Source: Ince et al. 2011

The results show that since structural panels have become largely dependent on pulpwood as raw material (via the advent of OSB technology since the 1970s), the U.S. structural wood panel industry has become vulnerable to potential disruptive effects from large-scale expansion in wood energy use (as in the RPA A1B or A2 scenarios). Without large-scale expansion in wood energy consumption, and assuming a recovery in U.S. housing construction, the U.S. structural panel industry (and particularly the OSB industry) is expected to experience significant growth in output (as in the RPA HFW scenario), however.

Pulp and Paper Trends

U.S. paper and paperboard consumption increased historically in line with U.S. GDP growth until 1999, when consumption peaked and subsequently declined. The decline reflects structural changes in paper and paperboard markets. The largest U.S. demands for paper and paperboard are for packaging and printing applications, which are linked to industrial production and advertising expenditures. Growth in U.S. industrial production since 2000 has fallen to a much lower level than in the second half of the 20th century, however, offset by a structural shift in manufacturing of consumer goods to overseas locations. Shifts in advertising expenditures from print media to electronic media have also negatively affected demands for graphic paper products (newsprint and other printing paper grades).

Declining demands have led to industry downsizing and consolidation, which have helped to improve the productivity and competitiveness of U.S. producers. A weaker dollar exchange value in recent years also helped improve the global cost competitiveness of U.S. producers. Thus, for the first time in decades, the United States became a net exporter of total paper and paperboard in 2009 and 2010, but U.S. paper and paperboard consumption and production have nevertheless gradually declined since 1999.

Declining trends in paper and paperboard production since the late 1990s, along with earlier increases in paper recycling, have had major effects on trends in U.S. wood pulp production. For most of the 20th century, U.S. wood pulp production was increasing, but production peaked in the mid-1990s. The utilization rate of recovered fiber in U.S. paper and paperboard (tons of recycled fiber used per ton of product output) has remained fairly level since the late 1990s, thus, more recent changes in U.S. wood pulp production were determined primarily by changes in U.S. paper and paperboard production and shifts in net trade. U.S. wood pulp production has been slightly declining since 2001, whereas there has been an increase in U.S. net exports of wood pulp. Pulpwood consumption at U.S. pulp mills has also been slightly declining during the last decade, and pulpwood use at OSB mills declined more rapidly with the drop in housing construction since 2005.

Real price trends indicate that pulpwood has become relatively more abundant in the United States since the late 1990s, a result of increasing supplies (continued timber growth and maturation of pulpwood plantations), a general declining trend in consumption, and efficiency gains in harvesting and conversion technology. Supply gains, however, have been partly offset by some recent shifts in nonwood costs of production, particularly increases in the price of diesel fuel used in timber harvesting. Nevertheless, between 1998 and 2008, the real price of delivered pulpwood in the United States dropped by 42 percent, according to the Bureau of Labor Statistics producer price index for pulpwood adjusted for inflation. Consolidation in the paper industry helped to avoid a similar collapse in real paper and paperboard prices.

Pulp and Paper Projections

Historical data and projections for total U.S. paper and paperboard consumption are shown in figure 78. Projections diverge modestly by RPA scenario, mainly because of varied GDP growth. GDP is the primary driver of paper and paperboard demands in the USFPM/GFPM model, so projected consumption is greatest in the RPA A1B and HFW scenarios, which feature the greatest U.S. GDP growth, and projected consumption is less in the RPA A2 and B2 scenarios that feature less GDP growth. Divergence in consumption, however, is narrowed by inelasticity of paper and paperboard demands with respect to price, and thus there is not much variation in projected consumption among the RPA scenarios, all showing a similar gradual decline in total consumption over time. U.S. consumption is projected to decline primarily in the newsprint and printing and writing paper grades, with consumption remaining fairly stable in packaging paper and paperboard grades and increasing for tissue and sanitary paper products.

There are, however, distinct differences in projected U.S. paper and paperboard production and net exports among the RPA scenarios (figures 79 and 80). According to the USFPM/GFPM model, the greatest projected U.S. production and net exports of paper and paperboard occur in the RPA HFW scenario, because there is virtually no competition for pulpwood from wood energy demands in that scenario. The RPA HFW is the only scenario in which U.S. paper and paperboard production is projected to expand in the long run, which is primarily a result of projected expansion in U.S. net exports of paper and paperboard. U.S. paper and paperboard production and net exports are projected to decline over the long run in the other three RPA scenarios. In terms of foreign trade, however, U.S. producers fare distinctly better in the RPA A1B and B2 scenarios, because high global fuelwood consumption causes relatively high foreign roundwood prices in those scenarios (figure 67). U.S. producers do not gain advantages over foreign producers

Figure 78. Annual U.S. paper and paperboard consumption, 1970–2010, and projections, by RPA scenario, 2020–2060.

Source: Ince et al. 2011

Figure 79. Annual U.S. paper and paperboard production, 1970–2010, and projections, by RPA scenario, 2020–2060.

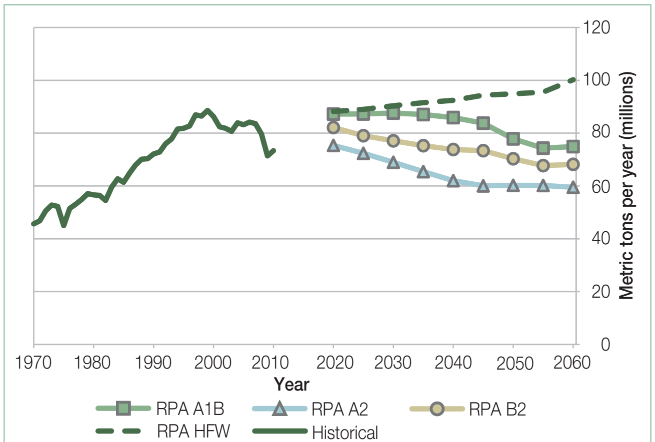
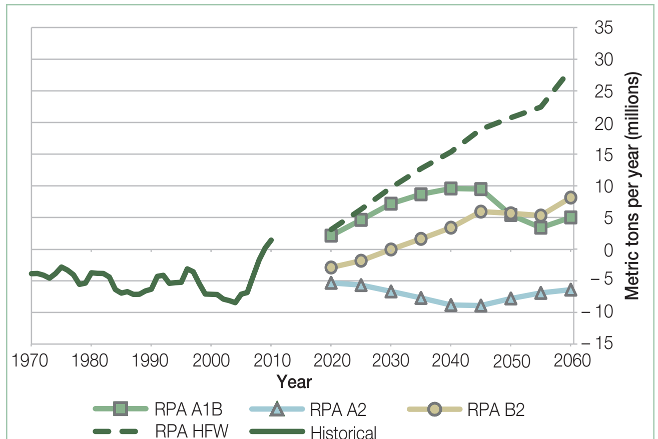


Figure 80. Annual U.S. net exports of paper and paperboard, 1970–2010, and projections, by RPA scenario, 2020–2060.



Source: Ince et al. 2011

in the RPA A2 scenario, in terms of roundwood costs. In that scenario, there is also fairly strong domestic competition for pulpwood from wood energy, so projected U.S. paper and paperboard production and net exports remain relatively low.

The RPA analysis indicates that projected U.S. consumption, production, and net trade in forest products are directly influenced by assumptions about future expansion in U.S. and global wood energy demands. Across RPA scenarios, projected effects of expansion in U.S. and global wood energy consumption are to dampen expected growth in forest product consumption (because of price effects on demands) and to provide, in some cases, enhanced global competitiveness and a movement toward lower trade deficits and, in some instances, trade surpluses of selected forest products. There is also some vulnerability to high wood energy demands for U.S. forest product producers, however, particularly those who depend on pulpwood as raw material, such as the OSB industry and producers of pulp, paper, and paperboard. Production and net exports of those products are depressed in RPA scenarios with competing demands from wood energy for pulpwood. With less competition for pulpwood from wood energy, however, there are prospects for U.S. expansion in output and net exports of pulpwood-based products (OSB, paper, and paperboard products), as in an RPA scenario with high economic growth but limited expansion in wood energy consumption, such as the RPA HFW scenario.

Timber Dynamics and Sustainability

Both hardwood and softwood timber harvest are projected to increase with higher levels of U.S. wood energy consumption (figures 81 and 82). In the RPA HFW scenario, however, with only a doubling in U.S. wood fuel feedstock consumption by 2060, the projected softwood and hardwood timber harvest trends are relatively flat and remain within the range of historical harvest levels. In the RPA B2 scenario, with fourfold expansion in U.S. wood fuel feedstock consumption, the projected U.S. softwood timber harvest begins to increase toward the end of the projection period, and hardwood timber harvest nearly doubles during the projection period. Hardwood has some advantages as a wood fuel feedstock because of higher density, and thus higher energy content per unit volume, although in the United States, softwoods have been more commonly grown in productive industrial timber plantations. With much larger increases in wood energy consumption in the RPA A1B scenario, softwood timber harvest more than doubles (with expansion in the area of pine plantations in the South Region), and hardwood timber harvest roughly triples (with expansion in the area of short-rotation woody crops such as hybrid poplars on agricultural land). In the RPA A1B scenario, most of the projected increase in hardwood and softwood timber harvest is attributable to expanded use of hardwood and softwood roundwood as fuel feedstock, and much of the expansion would derive from plantations (both forest plantations and woody crop plantations on agricultural land).

Among RPA regions, the South has accounted for the largest share of domestic timber harvest in recent decades, producing 57 percent of U.S. timber harvest in 2006, for example (Smith et al. 2009). Unlike the U.S. trend, timber harvest in the South Region did not peak in the late 1980s, but in the mid-1990s, and then declined. In the RPA projections, the South Region continues to be the largest timber-producing region in the United States, accounting for at least one-half of total timber harvest throughout the projection period in all RPA scenarios. Just as the South Region retains the lead among RPA regions in overall timber production, it also has the largest share of projected wood fuel feedstock production in all RPA scenarios.

Figure 83 shows projected average U.S. stumpage prices of hardwood and softwood sawtimber and nonsawtimber for the RPA scenarios (weighted averages of all RPA regions). The

Figure 81. Annual U.S. softwood timber harvest volumes, 1970–2010, and projections, by RPA scenario, 2020–2060.

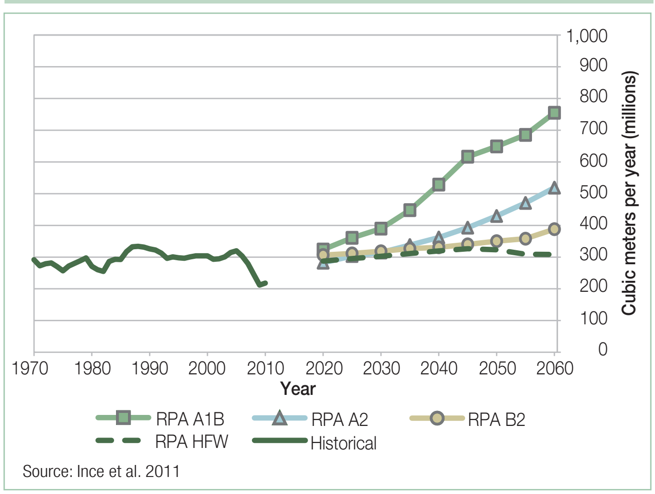


Figure 82. Annual U.S. hardwood timber harvest volumes, 1970–2010, and projections, by RPA scenario, 2020–2060.

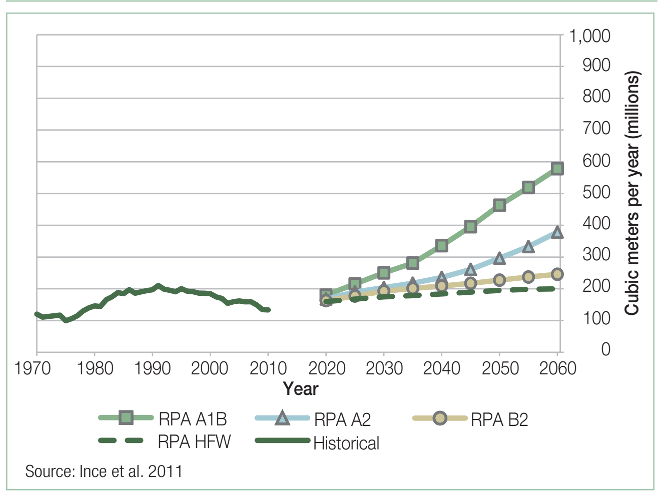
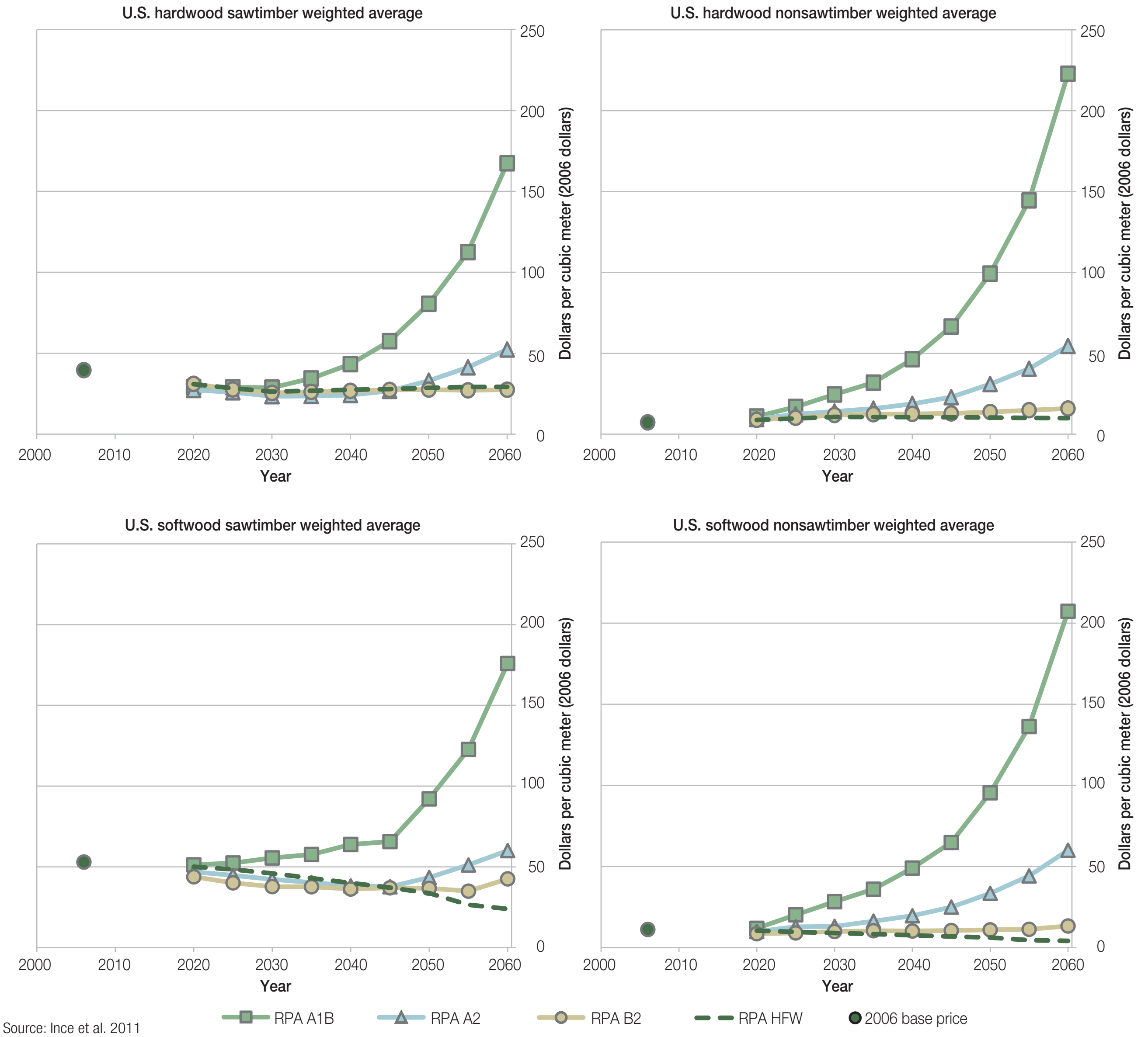


Figure 83. Projected average U.S. stumpage prices of hardwood and softwood sawtimber and nonsawtimber, by RPA scenario, 2020–2060, relative to 2006 prices.



Source: Ince et al. 2011

projected real price trends for timber stumpage are relatively flat to declining in the RPA B2 and HFW scenarios. This flat growth indicates that projected timber supplies are expanding sufficiently to accommodate at least the level of timber harvest projected in the RPA B2 and HFW scenarios. In all RPA scenarios, the overall U.S. consumption of industrial roundwood for forest products is projected to gradually decline (more or less in line with historical U.S. industrial timber harvest trends). These results support a key finding that real U.S. timber prices are not projected to increase significantly over the long run without substantial increases in wood energy consumption. Sawtimber stumpage prices are projected to increase only in the RPA A1B and A2 scenarios, with large expansions in U.S. wood energy consumption.

High levels of timber demand result in price increases for both sawtimber and nonsawtimber stumpage and, in the RPA A1B scenario, the nonsawtimber price eventually climbs higher than the sawtimber price by about 2040 and beyond. This outcome is because nonsawtimber has larger harvest residue and fuelwood components and higher average bark content than sawtimber, and with very high and inelastic fuel feedstock demands, the projected price of nonsawtimber can exceed the price of sawtimber. On the other hand, nonsawtimber prices are projected to increase much more modestly in the RPA A2 scenario, whereas nonsawtimber price projections are relatively flat to declining in the RPA B2 and HFW scenarios (figure 83).

In general, real U.S. timber stumpage prices are not projected to increase without substantial increases in wood energy consumption (e.g., at least equal to or greater than the fourfold expansion of the RPA B2 scenario). If U.S. and global wood energy consumption follow historical relationships to GDP growth (as in the RPA HFW scenario), U.S. timber stumpage prices are projected to gradually decline in real terms during the projection period, despite assumed recovery in housing construction and relatively robust GDP growth. In essence, substantial increases in real U.S. timber prices are not expected to be sustained over the long run in the absence of significant and unforeseen structural changes in U.S. forest product demands that would substantially increase timber demand.

Projected increases in timber demand and timber prices under scenarios such as RPA A1B would result in projected structural changes in U.S. wood supply, including expansion in the area of pine plantations in the South Region and in supply of agricultural short-rotation woody crops (SRWC). Higher prices for woody biomass make plantation forestry and agricultural SRWC more economically feasible in latter decades of the projection period. In the RPA A1B scenario, planted pine area in the South Region is projected to expand by more than 70 percent, from 39 million acres currently to 67 million acres by 2060, and just more than 20 million acres of agricultural land are projected to be planted in agricultural SRWC nationwide by 2060. These structural changes in timber supply help to offset effects of expanded timber harvest on forest inventory, although timber inventory volume is nevertheless projected to gradually decline toward the end of the projection period in the RPA A1B scenario. The cumulative U.S. timber harvest in the RPA A1B scenario from 2010 to 2060 exceeds the timber harvest in the RPA HFW scenario by 66 percent, or 16.4 billion cubic meters (578 billion cubic feet). Despite this large difference in timber harvest, the projected U.S. timber growing stock inventory in the RPA A1B scenario is only about 90 billion cubic feet (about 9 percent) less by 2060 than in the RPA HFW scenario. If not for the gains in plantation area and timber productivity, the large cumulative timber harvests of the RPA A1B scenario would certainly lead to more substantial depletion in U.S. timber inventory. The lower projected timber demand and lower projected timber prices in the RPA B2 and HFW scenarios provide little incentive for any appreciable expansion of agricultural SRWC supply or expansion of pine plantation area in the South Region. Improvements in plantation productivity and yield could potentially expand the future role of plantation forestry or SRWC in any case.

In addition to structural change in timber supply, the RPA analysis indicates that relative volumes of wood consumed as wood products and wood energy could vary substantially depending on the future wood energy projections. This variation is illustrated by comparison of projected wood volumes in wood fuel feedstock and conventional forest products produced in the United States for the RPA A1B and HFW scenarios, which make the same assumptions regarding future GDP and population growth but have very different projected expansion of U.S. wood energy consumption. Figure 84 shows comparative wood volumes in forest products and wood fuel feedstock for the RPA A1B and HFW scenarios. The wood volumes in forest products include the volume of solidwood products produced plus pulpwood and fiber residue volumes consumed in wood pulp, whereas the volumes in wood fuel feedstock include all roundwood and residues used to produce wood energy. The RPA A1B scenario has much higher wood fuel feedstock production in the United States (and also much higher global wood energy consumption) based on IPCC biomass energy projections, whereas RPA HFW wood energy demands are much lower, based on historical relationships of fuelwood consumption to GDP growth. The two scenarios have similar total volumes of wood use in forest products but different projected volumes of wood use by forest product category.

Two additional charts (figure 85) compare volumes of wood in conventional forest products produced in the United States by major product category for the RPA A1B and HFW scenarios. In the RPA A1B scenario, there is a more significant expansion of U.S. lumber output, boosted by relatively lower roundwood input costs compared with other countries and by strong demands for mill residues with very high global wood energy consumption. U.S. OSB (structural panels) production,

Figure 84. Projected wood volume in wood fuel feedstock and forest products produced in the United States, RPA A1B and HFW scenarios, relative to 2006 levels.

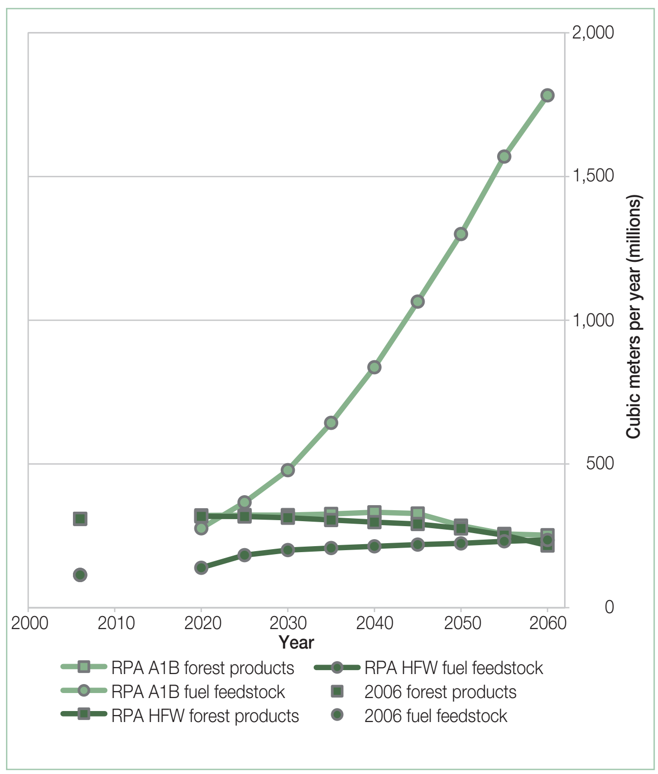
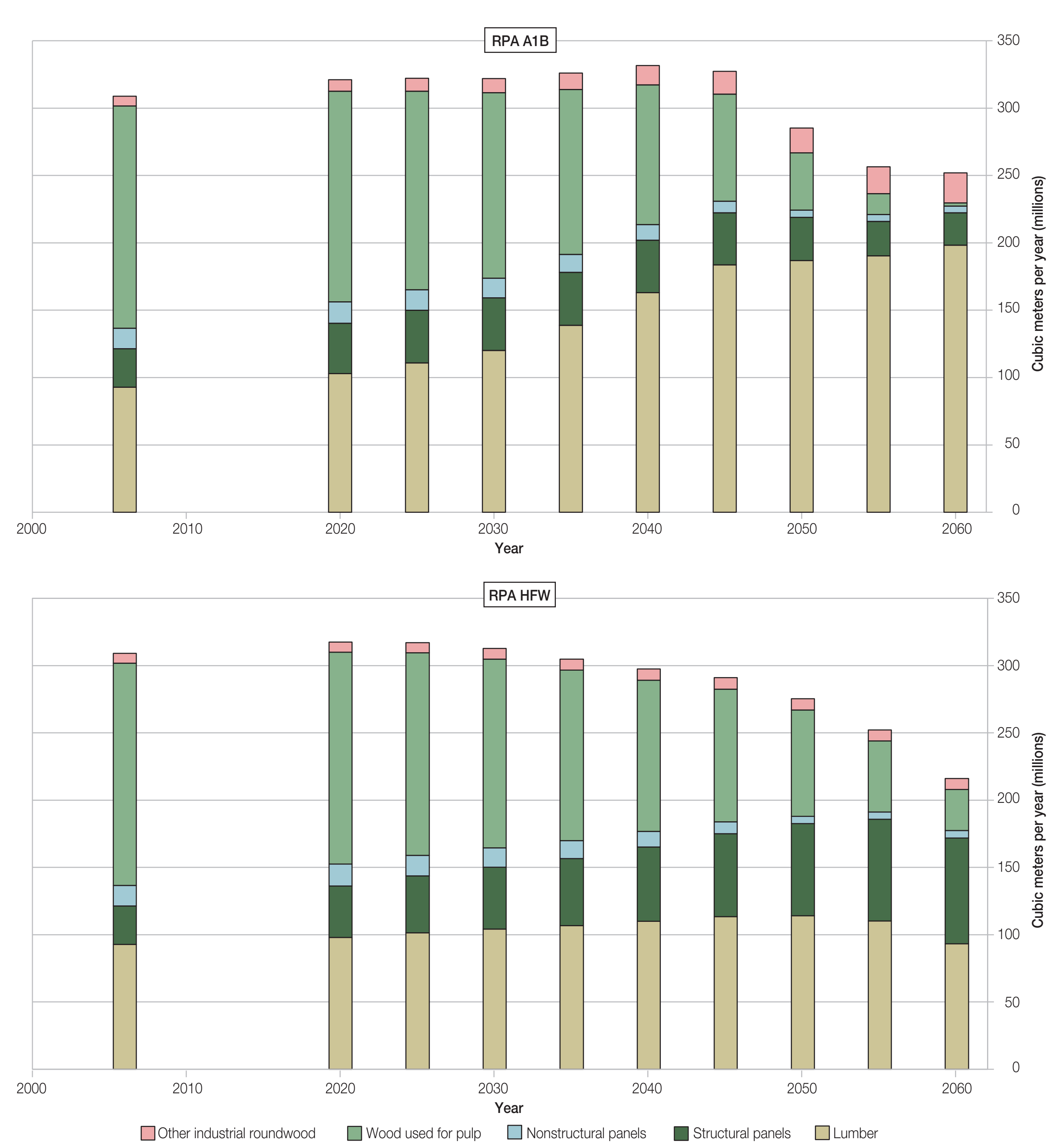


Figure 85. Wood volumes in conventional forest products produced in the United States, 2006, and projections, RPA A1B (top) and HFW (bottom) scenarios, 2020–2060.



however, is crimped in the RPA A1B scenario by competing domestic demands for pulpwood from wood energy. There is less expansion in U.S. lumber production in the RPA HFW scenario, because there is no gain in relative roundwood costs for U.S. versus foreign lumber producers. There is expansion of wood use in OSB in this scenario, however, and less of a decline in wood use in pulp production because of more abundant pulpwood supply and little competition for pulpwood from wood energy. In both scenarios, wood use for pulp production declines in the long run because of limited growth in U.S. paper and paperboard production and projected future gains in paper recycling.

Lastly, the RPA analysis used exogenous projections of global wood energy demands and did not analyze trends in other energy prices, but some comparative results can be computed for wood fuel pellets that are used for space heating in relation to the energy-equivalent price of heating oil. With the 16-fold expansion of U.S. wood energy consumption by 2060 in the RPA A1B scenario, the real price of wood fuel feedstock is projected to reach more than $150 per cubic meter, or several hundred dollars per dry ton (in constant 2006 dollars), which is about six times higher than current wood fuel feedstock prices. At that feedstock price, assuming nonwood production costs remain the same, the corresponding real price of wood fuel pellets in 2060 would be about $410 per ton, or about two-to-three times current wood fuel pellet prices that range from about $140 to $200 per ton (in 2006 dollars). At $410 per ton, the price of wood fuel pellets would be equivalent in gross energy value to a heating oil price of about $3.60 per gallon, or not much higher than recent price levels for heating oil (in 2006 dollars). Wood fuel pellets currently sell at prices that are only about one-half of the price of heating oil in terms of gross energy value, however, and whether wood fuel pellets could sell for two-to-three times as much by 2060 is plausible if global oil production peaks within the next decade, as assumed in the IPCC A1B scenario.

In general, the RPA findings indicate that higher levels of wood energy demand would be associated with higher prices for wood fuel feedstock and wood-based biofuels, because of timber supply price responses to higher demand levels. Price projections suggest that the economic feasibility of using wood biofuels for energy might come into question if wood fuel feedstock consumption were to expand by 15-fold or more by 2060 (as in the RPA A1B scenario). At less than 10-fold expansion (as in the other RPA scenarios), wood-based biofuels would probably remain economical alternatives to conventional energy sources, especially if supplies of conventional energy sources such as oil are limited and energy prices increase in the future. Of course, further expansion in supplies of other substitute energy sources, such as other renewables, natural gas, or nuclear energy, could limit future demand or prices for wood energy.

Conclusions

Historically, the volume of industrial roundwood needed to make wood and paper products consumed in the United States (including product imports) grew at roughly the rate of population growth until recently, when per capita consumption declined with the downturn in housing construction. Net imports and timber prices have varied as influenced by cyclical trends such as housing construction, economic recessions, and the U.S. dollar exchange rate. Annual U.S. timber harvest volumes have gradually declined since the 1980s as both industrial roundwood and fuelwood harvest declined, but harvest could increase in the future with expansion in wood energy consumption, particularly if global oil production peaks within the next decade or two, leading to expansion in consumption of biomass energy.

The range of alternative levels of wood energy consumption across the four RPA scenarios resulted in projected U.S. timber harvest levels and market trends that diverged in varying degrees from recent historical trends, with high levels of projected timber harvest and timber prices in the RPA scenario with the highest projected wood energy consumption.

The relatively flat-to-declining timber price projections in RPA scenarios with modest or historical wood energy demand trends indicate that timber supplies are increasing and that U.S. timber prices are not projected to increase significantly over the long run without substantial increases in wood energy consumption or other new timber demands. Without future growth in timber harvest revenues, there will likely be limited growth in financial resources to support forest management and help sustain forest ecosystem conditions and forest ecosystem services. Thus, enhancing the future market value of wood resources remains a challenge for future forest managers, forest product researchers, and biomass energy developers.

The future expansion rates for U.S. and global wood energy demands strongly influenced U.S. forest product net exports and related domestic production in the RPA analyses. The United States could gain competitive advantages in production of some paper and paperboard products while shrinking the trade deficits in other product categories if global roundwood prices exceed U.S. roundwood prices, even in an RPA scenario in which both the U.S. and global roundwood prices are increasing. On the other hand, U.S. output of pulpwood-based products, such as OSB or wood pulp, could be negatively affected if expanding wood energy demands result in expanded domestic consumption of pulpwood for energy. These analyses did not evaluate potentially offsetting developments such as changes in greenhouse gas emission policies (related to use of biomass for energy), other possible changes in environmental regulations, or the possible development of nonwood-based substitutes for forest products that might be driven by higher wood prices.

Chapter 9. Urban and Community Forests

Urban and community forests are an essential component of America's "green infrastructure," and their benefits extend well beyond the cities and towns where they are located. These forests include all publicly and privately owned trees within an urban or community area, including individual trees along streets and in backyards, and stands of remnant forest (Nowak et al. 2001). Trees play particularly important roles in the functioning of cities and towns and significantly affect ecosystem services and human health in these areas. Trees improve air and water quality, reduce energy use if appropriately placed around buildings, cool air temperatures, reduce ultraviolet radiation, and provide many other environmental, economic, and social benefits (e.g., Kuo and Sullivan 2001; Nowak and Dwyer 2007; Ulrich 1986; Westphal 2003; Wolf 2003). Costs associated with trees can be economic (e.g., planting and maintenance), social (e.g., obstructed views, litter, and storm debris), and environmental (e.g., pollen and volatile organic compound emissions) (Nowak and Dwyer 2007). In addition, there can be transaction costs associated with the necessary institutional arrangements (setting, communicating, and adapting policy) that aid urban and community forest management (Hardy and Koontz 2010; Ostrom 1990).

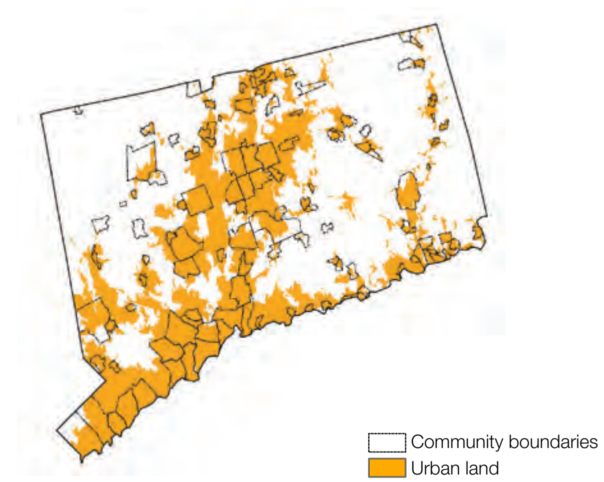
Resource Highlights

- Urban forest area will increase.
- Urban forests will become increasingly important for providing a range of ecosystem services to urban populations.

Urban and Community Land

Urban land is included in the more broadly defined "developed land" category in both the National Resources Inventory (NRI) data and the land use projections. For the purposes of the urban forest assessment, however, we rely on the U.S. Census Bureau data and definitions, which focus on densely populated areas. Both urban and community areas, which overlap, are included in the urban forest assessment. The census defines *urban* as all territory, population, and housing units located within urbanized areas or urban clusters, which are based on population density (USCB 2007).[11] Community lands are places that have geopolitical boundaries (e.g., cities, towns, or unincorporated named places) that may include all, some, or no urban land within their boundaries. As seen in figure 86, there is urban land found outside of community boundaries and areas within communities that are not urban.

Figure 86. Urban and community land in Connecticut, 2000.



Source: U.S. Census Bureau 2007

[11] Urbanized area and urban cluster boundaries encompass densely settled territories, which are described by one of the following: (1) one or more block groups or census blocks with a population density of at least 1,000 people per square mile, (2) surrounding block groups and census blocks with a population density of 500 people per square mile, and (3) less densely settled blocks that form enclaves or indentations, or are used to connect discontinuous areas. More specifically, urbanized areas consist of territory of 50,000 or more people. Urban clusters, a concept new to the 2000 Census, consist of territory with at least 2,500 people but fewer than 50,000 people.

Urban land reveals the more heavily populated areas (population density-based definition) and community land indicates both urban and rural communities that are recognized by their geopolitical boundaries (political definition). Both definitions provide information related to human settlements and the forest resources within those settlements. The combined category of "urban or community" was created to understand forest attributes accumulated by the union of these two definitions.

Urban land in the conterminous United States increased from 2.5 percent of total land area in 1990 to 3.1 percent in 2000, yet this small percentage of land contained 79 percent of the population, or more than 220 million people, in 2000 (USCB 2001). In 2000, the State with the greatest percentage of urban population was California (94 percent) and the State with the least percentage was Vermont (38 percent). Nevada had the greatest percentage urban population growth (1990 to 2000) at 72.3 percent, and Maine had the greatest percentage urban population decrease at 6.4 percent.

The Southeast and Northeast Subregions exhibited the greatest increase in percentage of urban land between 1990 and 2000 (table 12). The most urbanized areas of the United States are the Northeast (9.7 percent) and Southeast (7.5 percent). Between 1990 and 2000, most of the urban expansion across the United States occurred in forest (33.4 percent of the expansion) or agricultural (32.7 percent) land (Nowak et al. 2005).

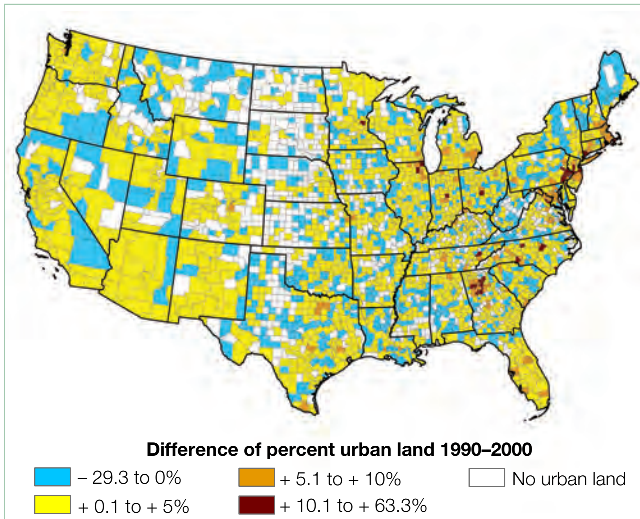
Community land comprised 4.5 percent of the lower 48 States. New Jersey had the greatest proportion of both urban land (38 percent) and community land (27 percent), Wyoming had the least urban land (0.2 percent), and Idaho had the least community land (0.7 percent). Between 1990 and 2000, urban area increased 17 percent and community land increased 23 percent (figures 87 and 88).

Table 12. Urban area and urban growth within the conterminous United States by RPA subregion, 1990–2000.

RPA subregion[a]	Percent urban	Increase in percent urban	Percent increase in urban area	Urban growth (km²)
	2000		*1990–2000*	
Northeast	9.7	1.5	18.8	8,120
Southeast	7.5	1.8	33.0	11,450
Pacific Southwest	5.0	0.7	17.0	2,984
North Central	4.2	0.7	19.0	7,905
South Central	2.8	0.5	23.2	8,412
Pacific Northwest	1.9	0.4	24.2	1,598
Intermountain	0.7	0.2	33.2	3,727
Great Plains	0.5	0.1	17.7	637
U.S. Total	**3.1**	**0.6**	**23.0**	**44,833**

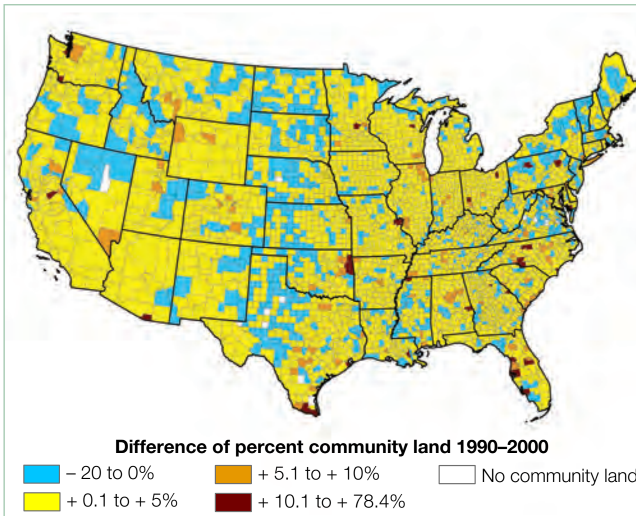
[a] Alaska and Hawaii data are not included in their respective RPA subregions. Ohio is included in the North Central Region in this table instead of the Northeast Region.
Source: Nowak et al. 2005

Figure 87. Change in percent urban land by county in the conterminous United States, 1990–2000.



Source: U.S. Census Bureau 2001

Figure 88. Change in percent community land by county in the conterminous United States, 1990–2000.



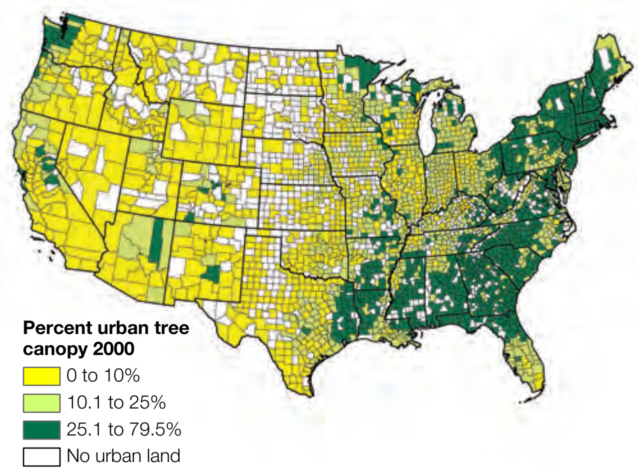
Urban and Community Tree Cover

Tree cover[12] in urban areas (circa 2005) is estimated at 35 percent, tree cover in communities at 34 percent, and tree cover in urban or community lands at 35 percent (Nowak and Greenfield, 2012a). In urban or community areas, percentage tree cover is highest in Connecticut (67 percent) and lowest in Nevada (10 percent). States with the highest proportion of their total tree cover occurring in urban and community areas are New Jersey (39 percent), Connecticut (36 percent), and Massachusetts (36 percent) (Nowak and Greenfield, 2012a).

Urban tree cover tends to be highest in urban areas in forested ecoregions, followed by grasslands and deserts. The percentage of tree cover in urban areas tends to decrease as population density increases and can vary within a city based on the distribution of land use types and ecoregion (e.g., vacant land in forested regions often supports tree cover, but vacant land in deserts is often devoid of trees) (Nowak et al. 1996, 2001). Understanding the factors most associated with urban tree cover can improve projections of future tree cover and inform policies to improve urban canopy cover.

Urban tree cover is on a slight decline nationally (circa 2002 to 2009) with a loss rate equal to about 0.03 percent of urban land per year. In more major cities, the loss rate is higher, with 17 of 20 cities analyzed exhibiting statistically significant declines in tree cover (circa 2004 to 2009), with an average annual loss in tree cover of 0.27 percent per year (Nowak and Greenfield 2012b). Tree canopy cover can serve as an indicator of the extent to which trees and forests are providing crucial ecosystem services to local residents. The percentage of tree cover in urban areas is typically greater in the Eastern United States (figure 89), and tree canopy cover per person is typically greatest in the Southeast and the New England States.

Figure 89. Percent tree cover in urban areas by county in the conterminous United States, 2000.



Source: 2001 National Land Cover Database

Urban Forest Ecosystem Services

Urban trees and forests provide several ecosystem services in the form of provisioning services such as food, water, timber, and fiber; regulating services that affect climate, floods, disease, wastes, and water quality; cultural services that provide recreational, aesthetic, and spiritual benefits; and supporting services such as soil formation, photosynthesis, and nutrient cycling (MEA 2005).

Enhancing urban forest cover generally increases these benefits, but can also potentially increase the costs and risks, such as fire risk, energy costs, and water use (especially if native vegetation is converted). In some cases, particularly in the arid West, water availability could limit increases in canopy cover. In other areas, impervious surfaces, mowing practices, public investments, water scarcity, or seed sources could limit increases in canopy. In addition, tree management and urban development policies can hinder or enhance the expansion of urban forest cover based on the limitations or incentives they establish, affecting individual and collective decisionmaking.

Trees in urban areas provide many benefits and values to society based on their current structure and functions. Urban trees are estimated to remove 783,000 tons of pollutants (ozone, particulate matter, nitrogen dioxide, sulfur dioxide, and carbon monoxide) annually (Nowak et al. 2006). These estimates are based on mid-1990s-to-early-2000s data and are currently being updated with more recent data. Recent carbon estimates based on 2000 Census data and circa 2005 urban tree cover data reveal that U.S. urban trees store about 704 million tons of carbon with a gross carbon sequestration rate of 28 million tons per year. Urban forests in the Northeast, Southeast, and South Central Subregions store and sequester the most carbon (table 13).

Urban Forest Health

Urban forests face a myriad of management challenges from a wide range of human-caused and natural disturbances. Urban forests are severely affected by numerous insects and diseases, many of them invasive species. Some, such as gypsy moth, emerald ash borer, Dutch elm disease, and Asian longhorned beetle, have caused significant tree mortality (USDA National Agricultural Library 2011). Endemic pests such as mountain pine beetle also cause severe damage to urban forests. Invasive plants can modify, and in some cases degrade, urban forests

[12] The amount or percentage of land area that, when viewed from above, is covered by tree canopies.

Table 13. Estimated carbon storage and gross annual sequestration in trees on urban land by RPA subregion in the conterminous United States, circa 2005.

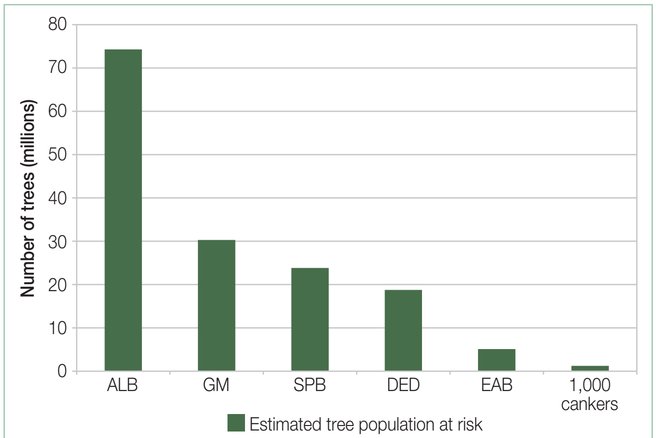
RPA subregion[a]	Carbon storage		Gross sequestration	
	tons	*tons/acre*	*tons/year*	*tons/acre/year*
Northeast	228,490,000	15.1	7,600,000	0.50
Southeast	164,600,000	14.6	7,920,000	0.70
South Central	131,540,000	12.0	5,930,000	0.54
North Central	93,680,000	9.9	3,020,000	0.32
Pacific Southwest	34,630,000	6.8	1,750,000	0.35
Pacific Northwest	24,150,000	12.1	790,000	0.39
Intermountain	18,560,000	5.0	620,000	0.17
Great Plains	8,320,000	8.0	290,000	0.28
U.S. Total	**703,980,000**	**12.0**	**27,930,000**	**0.48**

[a] Alaska and Hawaii data are not included in their respective RPA subregions.
Source: Nowak et al. in prep.

by removing native plants and altering ecosystem structures. In addition, natural events such as ice storms and severe wind can damage urban forests and significantly alter urban forest structure and health.

Monitoring of urban forests will be vital to quantifying changing urban forest health and assessing risks that threaten future forest health. Various State assessments of urban forests reveal the magnitude and potential risks and health issues related to urban forests (Cumming et al. 2008). For example, in the urban forests of the State of Tennessee, the most common damages noted on trees were trunk bark inclusion (8.7 percent), vine in crowns (7.9 percent), dead or dying crowns (3.2 percent), and canker or decay (2.9 percent) (Nowak et al. 2011). Species with the highest percentage of crown dieback were black walnut (16.3 percent), sassafras (7.8 percent), and shagbark hickory (7.1 percent). Based on Tennessee's urban forest composition, some of the greatest potential risks to this resource could come from Asian longhorned beetle, gypsy moth, and southern pine beetle (figure 90).

Figure 90. Estimated number of trees that could potentially be attacked by Asian longhorned beetle (ALB), gypsy moth (GM), southern pine beetle (SPB), Dutch elm disease (DED), emerald ash borer (EAB), and 1,000 cankers disease on Tennessee's urban tree population.



Source: Nowak et al. 2011

There are a myriad of additional risks to urban and community forests. Wildlife can cause substantial damage to trees, particularly in the wildland-urban interface. High population growth and development in these areas tend to increase fire risk and human-caused fire ignitions. Human development can alter forest lands and fragment existing forest stands. In both urban areas and at the wildland-urban interface, air pollution can reduce tree growth and weaken natural resistance to other threats such as pests and drought. In addition, climate change is expected to produce warmer air temperatures and change precipitation patterns, and result in more extreme weather events (IPCC 2007b) that can alter urban forest structure and health. These potential natural and human-caused threats will directly affect urban forests, as well as interact with other threats, potentially creating cumulative and emergent risks yet to be understood.

Urban forests are dynamic systems, heavily influenced by human activities. Urban land area is projected to continue to increase in response to growing populations. Population growth and associated urban expansion will have a considerable effect on the wildland-urban interface because urban expansion is expected to occur as extensions to existing urban centers. Issues such as timber harvesting, fire protection, ecological functions, recreation uses, scenic views, wildlife, invasive species, and forest fragmentation become more contentious as urbanization increases (Nowak et al. 2010).

Conclusions

Urban forests are a significant resource nationally and are likely to increase in significance in the coming decades. Urban growth in the United States is going to have an increasingly important effect on forest management, environmental quality, and human well-being. As urbanization increases, so will the value of urban forests and surrounding rural forests in providing ecosystem services required by urban residents. Significant amounts of U.S. forest land are projected to be transformed by urbanization, particularly in the Northeastern and Southern United States.

In addition, urban growth is projected to increase canopy cover in parts of the United States, particularly in grassland areas. Climate changes are also projected to have varying effects on the local climate that will affect future forest health and composition. Various parts of the country (e.g., various counties in the Pacific Northwest and Eastern United States) are projected to lose tree cover to development and become more arid in the future. Future regional resource planning and management activities need to understand, adapt to, and direct the changing landscape to sustain forest health and productivity, as well human health and well-being in landscapes that are urbanizing and projected to experience changes in climate. An increased understanding of the biophysical, social, and institutional factors affecting urban and community forestry by decisionmakers—from households and neighborhoods to nongovernmental organizations and public agencies—would enhance planning.

Chapter 10. Carbon in Forest Resources and Products

Forests and forest products retain carbon as part of the Earth's larger carbon cycle through the land, water, and atmosphere. Forests in the United States were in approximate carbon balance with the atmosphere from 1600 to 1800. Utilization and land clearing caused a large pulse of forest carbon emissions during the 19th century, followed by regrowth and net forest carbon sequestration in the 20th century. Recent data and general knowledge of the behavior of forests after disturbance suggest that the rate of forest carbon sequestration is gradually declining (Birdsey et al. 2006). Significant regional differences in past and projected carbon storage reflect long-term changes in land use and wood harvesting.

Forest carbon stocks and stock changes (flux) are measured in five pools: aboveground biomass, belowground biomass, dead wood, litter, and soil organic carbon. In addition, changes in two harvested wood pools are estimated: harvested wood products (HWP) in end uses and HWP in solid-waste disposal sites (SWDS). The United States reports changes in forest and HWP carbon stocks and total carbon levels annually for the U.S. Environmental Protection Agency (EPA) inventory of greenhouse gas emissions and sinks. The methods for estimating forest and HWP carbon stock changes are described in detail elsewhere (Heath et al. 2011; Skog 2008; U.S. EPA 2011c).

Resource Highlights

- Carbon stored in forests is projected to peak between 2020 and 2040, then decline.
- Carbon storage projections are highly sensitive to forest land area projections.
- Carbon stored in harvested wood products depends on future timber markets.

Historical Forest Carbon Stocks and Flows

Carbon stocks for U.S. forests are estimated using forest survey data from the Forest Service's Forest Inventory and Analysis (FIA) data. The official U.S. reports include carbon on all forest land in the conterminous United States and coastal Alaska. Net annual change in forest carbon stocks (flux) include effects of growth, mortality, harvesting, and other disturbances, and any changes in total forest land area. Annual estimates of changes in HWP pools are based on additions to and removals from products held in end uses (such as housing and furniture) and products disposed of in landfills. Carbon stored in urban forests is reported in the "settlements" land use category in the official U.S. reports (Heath et al. 2011).

The most recent reporting year for carbon stocks in the United States is 2010, whereas the most recent year reported for flux is 2009 (U.S. EPA 2011c). During 2009, 235 million metric tons of carbon were added to carbon held in forests and in HWP (table 14). The annual additions to HWP carbon stocks declined notably between 2005 and 2009 as a result of the economic recession and associated decreases in timber harvest and wood product production. Total carbon stocks have increased slightly during the historical period, with most of the carbon residing in aboveground biomass and soil organic carbon (table 15).

Future Carbon Stocks and Flows

Forest Carbon

Forests represent a vast reservoir of stored carbon in the United States. Depending on forest management, land use management, and other changes to forest inventories, forests can either sequester or emit atmospheric carbon. Analysis of historical FIA records shows a net gain in forest carbon stocks between 1990 and 2008 of about 2.8 billion metric tons (7 percent), mainly because of an accumulation of biomass in the Nation's forests (Heath et al. 2011). Forests sequestered carbon over this period.

Table 14. Net annual changes in carbon stocks in forest and harvested wood pools, 1990–2009.

Carbon pool	1990	2000	2005	2009
	million metric tons of carbon per year			
Forest—Total	**(149.8)**	**(72.4)**	**(219.9)**	**(220.6)**
Live, aboveground	(98.2)	(78.3)	(122.1)	(122.1)
Live, belowground	(19.3)	(15.7)	(24.1)	(24.1)
Dead wood	(8.6)	(3.5)	(8.4)	(9.1)
Litter	(8.8)	7.5	(11.4)	(11.4)
Soil organic carbon	(14.9)	17.6	(53.8)	(53.8)
Harvested wood products—Total	**(35.9)**	**(30.8)**	**(28.7)**	**(14.8)**
Products in use	(17.7)	(12.8)	(12.4)	1.9
Products in SWDS	(18.3)	(18)	(16.3)	(16.7)
Total annual change (flux)	**(185.7)**	**(103.2)**	**(248.6)**	**(235.4)**

SWDS = solid waste disposal sites.
Source: U.S. Environmental Protection Agency 2011c

Table 15. Carbon stocks in forest and harvested wood pools, 1990–2010.

Carbon pool	1990	2000	2005	2010
	million metric tons of carbon			
Forest—Total	**42,783**	**44,108**	**44,886**	**45,988**
Live, aboveground	15,072	16,024	16,536	17,147
Live, belowground	2,995	3,183	3,285	3,405
Dead wood	2,960	3,031	3,060	3,105
Litter	4,791	4,845	4,862	4,919
Soil organic carbon	16,965	17,025	17,143	17,412
Harvested wood products—Total	**1,859**	**2,187**	**2,325**	**2,449**
Products in use	1,231	1,382	1,436	1,474
Products in SWDS	628	805	890	974
Total carbon stock	**44,643**	**46,296**	**47,211**	**48,437**

SWDS = solid waste disposal sites.
Source: U.S. Environmental Protection Agency 2011c

Forest carbon stocks are a function of area of forest land and carbon per acre. Changes in forest carbon can result from changes in forest land area and changes in carbon per acre. Changes in forest land area transfer a large amount of carbon from one land use to another, rather than release carbon to or store carbon from the atmosphere.

We used the inventory projections presented in chapter 7 as the basis for estimates of future forest carbon pools for the conterminous United States (we do not project forest carbon for coastal Alaska). The forest carbon projections are based on a newly revised carbon accounting framework for the FIA inventory, therefore these projections of forest carbon stocks and fluxes are not directly comparable to the historical estimates in tables 14 and 15.

Forest area and forest inventory are projected to decline between 2010 and 2060 in all Resources Planning Act (RPA) scenarios (chapter 7). The result is an overall decline in the amount of carbon stored in forests by 2060 (table 16 and figure 91).[13]

Forest area is strongly correlated with future soil carbon, and standing biomass is strongly correlated with vegetative carbon pools. Carbon losses are a result of a transfer of forest land to other land uses (especially developed uses), a transfer of carbon in biomass to storage in wood products, and losses to the atmosphere. Following the pattern of inventory projections, forest carbon is projected to peak sometime between 2020 and 2040 at between 41.4 and 41.7 billion metric tons and then to decline (figure 91). Forest carbon stocks in 2060 would be reduced by between 0.8 (RPA B2) and 2.5 (RPA A1B) billion metric tons from 2010 levels.

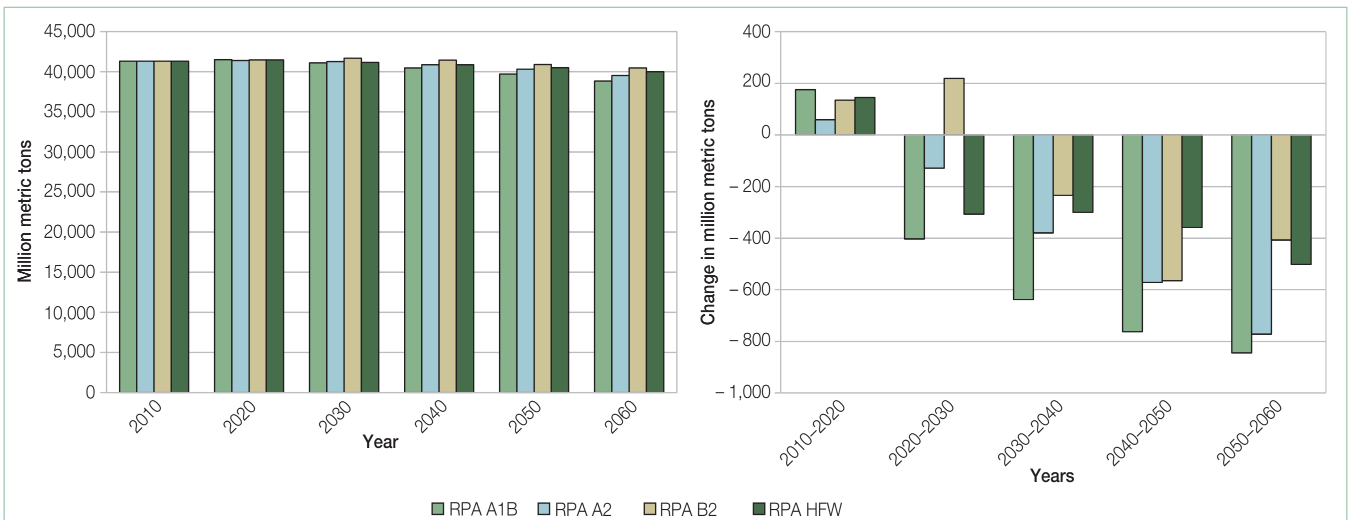
Figure 92 shows the forest carbon projections on a per-forest-acre basis and demonstrates the interplay of forest area changes and forest management in determining carbon outcomes, although the variation by RPA scenario is not large. The RPA historical fuelwood (HFW) scenario has the highest amount of carbon per acre. In this scenario, the combination of the lowest harvest levels and the highest loss of forest area results in fewer

[13] The results shown in this chapter are based on the CGCM3.1 GCM for scenarios RPA A1B, A2, and HFW, and on CGCM2 GCM for RPA B2, as discussed in chapter 7.

Table 16. Projected forest carbon stocks in conterminous U.S. forests by RPA scenario, 2010–2060.

Scenario	2010	2020	2030	2040	2050	2060
	million metric tons of carbon					
RPA A1B						
Forest—Total	**41,325**	**41,500**	**41,097**	**40,459**	**39,696**	**38,851**
Live, aboveground	13,910	14,241	14,080	13,722	13,304	12,822
Live, belowground	2,867	2,938	2,903	2,829	2,748	2,651
Dead wood	2,673	2,690	2,670	2,647	2,598	2,554
Litter	4,896	4,901	4,895	4,866	4,804	4,727
Soil organic carbon	16,978	16,730	16,549	16,394	16,242	16,097
RPA A2						
Forest—Total	**41,325**	**41,384**	**41,256**	**40,875**	**40,304**	**39,532**
Live, aboveground	13,910	14,180	14,234	14,082	13,847	13,455
Live, belowground	2,867	2,922	2,933	2,903	2,856	2,776
Dead wood	2,673	2,692	2,682	2,665	2,637	2,600
Litter	4,896	4,913	4,919	4,901	4,852	4,790
Soil organic carbon	16,978	16,676	16,488	16,325	16,112	15,911
RPA B2						
Forest—Total	**41,325**	**41,460**	**41,679**	**41,445**	**40,880**	**40,473**
Live, aboveground	13,910	14,233	14,486	14,386	14,102	13,911
Live, belowground	2,867	2,935	2,987	2,966	2,905	2,868
Dead wood	2,673	2,693	2,710	2,706	2,670	2,653
Litter	4,896	4,906	4,929	4,927	4,890	4,865
Soil organic carbon	16,978	16,694	16,568	16,460	16,313	16,177
RPA HFW						
Forest—Total	**41,325**	**41,470**	**41,163**	**40,864**	**40,505**	**40,004**
Live, aboveground	13,910	14,269	14,235	14,135	14,053	13,868
Live, belowground	2,867	2,943	2,933	2,912	2,898	2,861
Dead wood	2,673	2,691	2,678	2,669	2,648	2,618
Litter	4,896	4,900	4,897	4,904	4,877	4,833
Soil organic carbon	16,978	16,668	16,420	16,243	16,029	15,825

Figure 91. Total carbon stored in conterminous U.S. forests (left) and changes in carbon stocks by decade (right), by RPA scenario, 2010–2060.



but older forest acres. RPA B2 has a comparable total carbon stock but on a larger forest area (i.e., it results in more but younger forest acres).

Projected carbon losses are greatest in absolute and percentage terms for the North Region (roughly one-half of the total), where inventory declines most strongly, especially for the RPA A1B scenario (figure 93). The Pacific Coast Region also loses carbon across the RPA scenarios, but the Rocky Mountain Region gains a slight amount of carbon. The South Region's forest carbon pool is projected to remain relatively constant or decline only slightly, depending on the RPA scenario. Although these projections indicate a change from sequestration to carbon emissions for forest pools, they are not a full accounting of related carbon dynamics (i.e., they do not account for the ongoing contribution of wood products to carbon sequestration [see next section] and the replacement of fossil fuels by wood energy). Although these projections do not explicitly track emissions from forest fires, projected stocks do account for the net effects of fire consistent with fire histories observed during the past 10 to 20 years.

Historical and projected forest carbon stock by forest carbon pools are shown in table 17 in the four RPA scenarios. The accumulation of forest carbon stocks by pool over time is shown in figure 94 for the RPA A1B and RPA B2 scenarios, demonstrating the peaking of carbon stocks in the early years of the projection period, followed by a slow decline.

Figure 92. Total carbon stored per acre of forest in the conterminous United States, by RPA scenario, 2010–2060.

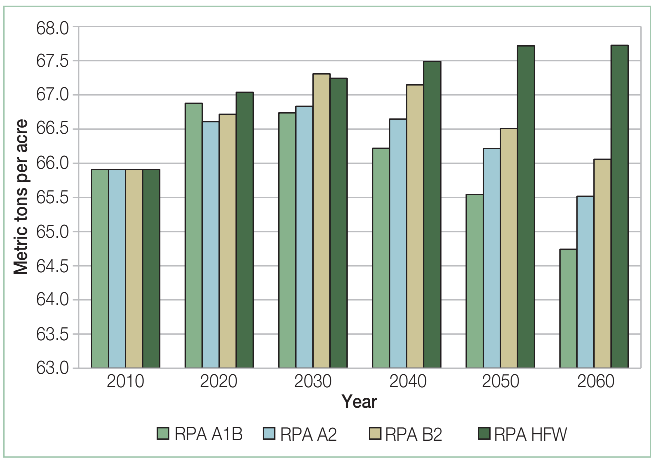


Figure 93. Carbon stored in conterminous U.S. forests, by RPA region, RPA A1B scenario, 2010–2060.

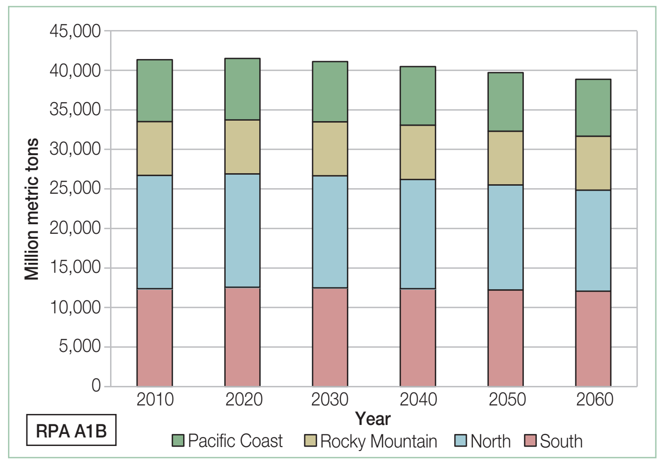


Figure 94. Historical and projected conterminous U.S. forest carbon stocks, RPA A1B (left) and RPA B2 (right), 1990–2060.

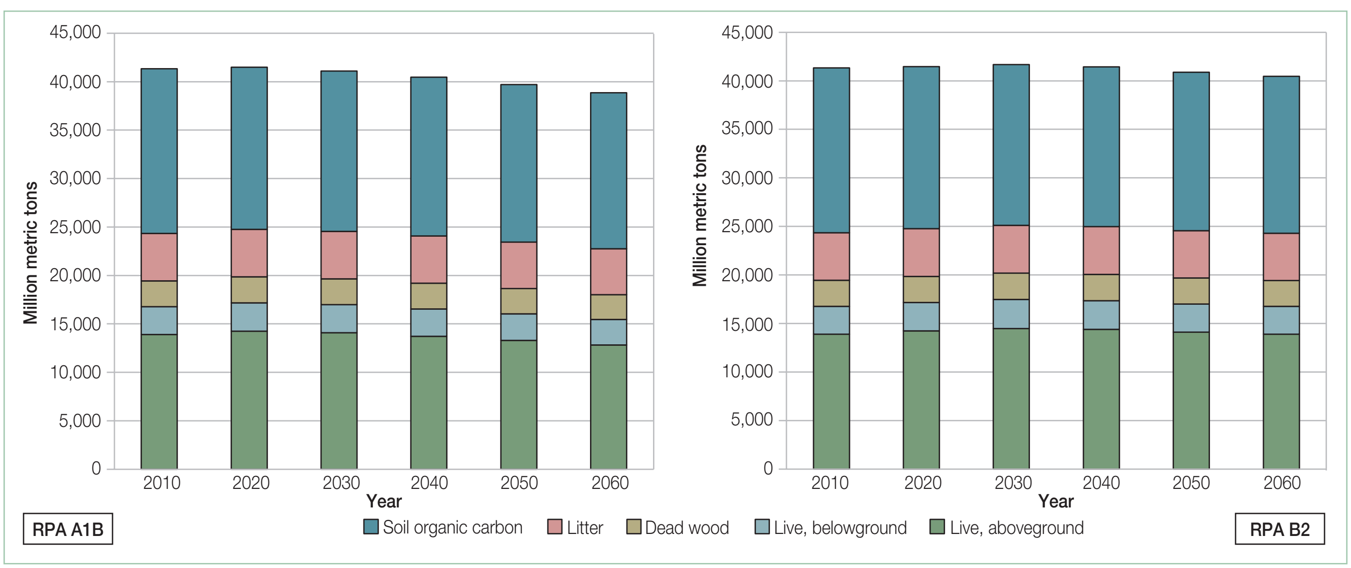


Table 17. Net annual changes in carbon stocks in conterminous U.S. forests and harvested wood product pools, 2010–2060. Negative numbers indicate net additions to stocks.

Scenario	2010–2020	2020–2030	2030–2040	2040–2050	2050–2060
	change in million metric tons of carbon				
RPA A1B					
Forest—Total	(18)	40	64	76	85
Live, aboveground	(33)	16	36	42	48
Live, belowground	(7)	3	7	8	10
Dead wood	(2)	2	2	5	4
Litter	(1)	1	3	6	8
Soil organic carbon	25	18	16	15	15
Harvested wood products—part of total	(35)	(38)	(45)	(53)	(52)
Total	**(53)**	**2**	**19**	**23**	**33**
RPA A2					
Forest—Total	(6)	13	38	57	77
Live, aboveground	(27)	(5)	15	24	39
Live, belowground	(6)	(1)	3	5	8
Dead wood	(2)	1	2	3	4
Litter	(2)	(1)	2	5	6
Soil organic carbon	30	19	16	21	20
Harvested wood products—part of total	(30)	(29)	(28)	(28)	(23)
Total	**(36)**	**(16)**	**10**	**29**	**54**
RPA B2					
Forest—Total	(14)	(22)	23	56	41
Live, aboveground	(32)	(25)	10	28	19
Live, belowground	(7)	(5)	2	6	4
Dead wood	(2)	(2)	0	4	2
Litter	(1)	(2)	0	4	2
Soil organic carbon	28	13	11	15	14
Harvested wood products—part of total	(33)	(33)	(33)	(34)	(36)
Total	**(47)**	**(55)**	**(10)**	**22**	**5**
RPA HFW					
Forest—Total	(15)	31	30	36	50
Live, aboveground	(36)	3	10	8	19
Live, belowground	(8)	1	2	1	4
Dead wood	(2)	1	1	2	3
Litter	0	0	(1)	3	4
Soil organic carbon	31	25	18	21	20
Harvested wood products—part of total	(33)	(36)	(37)	(37)	(33)
Total	**(48)**	**(5)**	**(7)**	**(1)**	**17**

Harvested Wood Products

We estimated the net annual contribution of HWP to the forestry sector carbon sinks and emissions for each RPA scenario using methods provided by the Intergovernmental Panel on Climate Change (IPCC) 2006 guidelines for sinks and emissions reporting (IPCC 2006). Historical estimates are those provided in the EPA greenhouse gas sinks and emissions report (U.S. EPA 2011c) and prepared using the WOODCARB II model (Skog 2008). Estimates of HWP contribution were made using three IPCC accounting approaches (table 18). The United States reports HWP contribution (U.S. EPA 2011c) using the Production Accounting Approach, which tracks carbon from wood leaving harvest sites in the United States and includes estimated carbon stored in products exported to other countries. The projections are made using the assumption that primary wood products produced after 2009 are used in end uses and have the same decay and disposal patterns as for the late-2000s period.

The annual HWP carbon contribution under the Production Accounting Approach (net addition in 2009) is driven primarily by historical and current levels of solidwood product production from U.S. harvest. Annual HWP carbon contribution has decreased in recent years because of a decrease in U.S. timber harvest associated with the economic recession (table 14). Harvest levels are projected to have recovered by 2020, and the HWP contribution is projected to be at or above historical levels (tables 17 and 18). The HWP contribution is greatest for the RPA A1B and B2 scenarios, because they show the highest levels of U.S. production of forest products from U.S. harvested timber—particularly solidwood products, which have a longer use life and longer life in landfills. The HWP

Table 18. Net annual contribution of harvested wood products to U.S. forestry sector carbon sinks and emissions, under three accounting approaches, by RPA scenario, 2010–2060. Negative numbers indicate net additions to stocks or net removals from the atmosphere.

Approach	2010–2020	2020–2030	2030–2040	2040–2050	2050–2060
	Change in million metric tons of carbon				
Production					
RPA A1B	(35)	(38)	(45)	(53)	(52)
RPA A2	(30)	(29)	(28)	(28)	(23)
RPA B2	(33)	(33)	(33)	(34)	(36)
RPA HFW	(33)	(36)	(37)	(37)	(33)
Stock Change					
RPA A1B	(47)	(49)	(53)	(58)	(60)
RPA A2	(46)	(48)	(52)	(58)	(66)
RPA B2	(47)	(44)	(43)	(43)	(47)
RPA HFW	(47)	(49)	(52)	(57)	(61)
Atmospheric Flow					
RPA A1B	(36)	(39)	(45)	(51)	(46)
RPA A2	(28)	(20)	(11)	(4)	9
RPA B2	(34)	(30)	(27)	(28)	(32)
RPA HFW	(35)	(38)	(39)	(40)	(37)

contribution is least for the RPA A2 scenario, because it shows the lowest level of product production from U.S. harvested timber (figure 95).

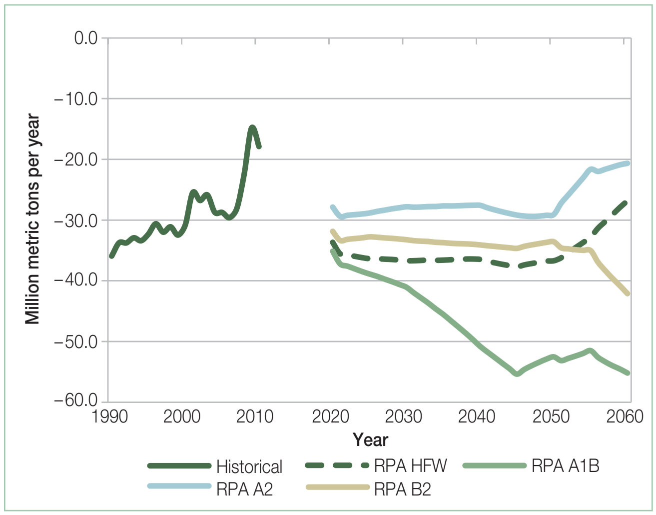
The annual HWP carbon contribution can also be estimated using the Stock-Change and Atmospheric-Flow Approaches, which, respectively, track annual additions to HWP carbon stocks held in the United States and net flux of carbon between HWP held in the United States and the atmosphere. For all RPA scenarios, HWP contributions under the Stock-Change and Atmospheric-Flow Approaches are generally higher and lower, respectively, than under the Production Approach (table 18). The stock-change estimate is higher because the United States remains a net importer of solidwood products, and net imports increase the stock-change estimate, but not the production estimate. The stock-change estimate is high for RPA A1B because of high U.S. production and high for RPA A2 because of high net imports—additions of 60 and 66 million metric tons of carbon per year from 2050 through 2060 (table 18).

The contribution under the Atmospheric-Flow Approach is determined by the degree to which annual carbon emissions from HWP in the United States are lower than annual harvest from U.S. forests. The contribution is high (emissions are less than harvest) with high net exports and emissions from U.S. products occurring in other countries. This contribution by HWP is the least for RPA A2, in which the United States has the highest net imports—a loss of 9 million metric tons of carbon per year from 2050 through 2060—and highest for RPA A1B, in which exports are higher (table 18).

Forest Sector Carbon Flux

Projections of net annual carbon flux for the forest sector include combined contributions from forest carbon and HWP

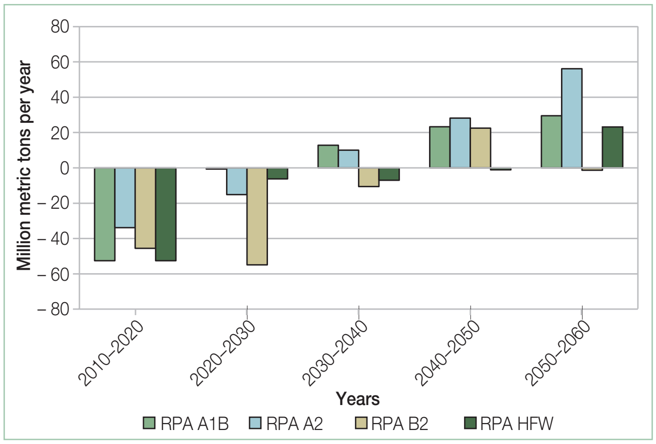
Figure 95. Historical and projected annual HWP carbon contribution to forest sector sinks and emissions using the Production Accounting Approach, by RPA scenario, 1990–2060. Negative indicates addition to HWP carbon stocks.



(Production Approach). The RPA A2, B2, A1B, and HWF scenarios have net annual increases in carbon stocks for the first two decades (table 17 and figure 96). The RPA A1B scenario, with the highest harvest rates, has increases only through 2010 to 2020. The RPA HFW scenario, with the lowest harvest rates, has net increases for the longest period—through 2040 to 2050. The RPA B2 scenario has increases through 2030 to 2040. Figure 97 shows the average annual carbon fluxes for the individual pools for the RPA A1B scenario and the RPA B2 scenario, providing a comparison between the RPA scenarios with the greatest (RPA A1B) and least (RPA B2) changes during the projection period.

Overall change in forest carbon during the projection period can be explained by changes in forest area and carbon per acre

Figure 96. Total carbon flux in U.S. forest sector, by decade, by RPA scenario, 2010–2060.



in each RPA scenario. The contribution of these two changes varies by RPA scenario (figure 92 and table 16). For scenario RPA A1B, with the highest harvest rates, about one-half of the decline is because of decrease in forest area and one-half is because of decline in carbon per acre. For RPA A2, almost all the decline is because of decrease in forest area, with a small portion because of decrease in carbon per acre. For scenarios RPA B2 and HFW, with the lowest harvest rates, the decline is entirely because of decrease in forest area, whereas carbon per acre actually increases. The forest carbon decreases are largest for RPA scenarios A1B and A2, in which both forest area and carbon-per-acre decline.

Overall cumulative carbon stock increases during the projection period, including both forest carbon and HWP carbon (Production Approach), are largest for scenarios RPA HFW and RPA

Figure 97. Projected average annual carbon fluxes for conterminous U.S. forest pools and harvested wood products, by decade, RPA A1B (top) and RPA B2 (bottom), 2010–2060.

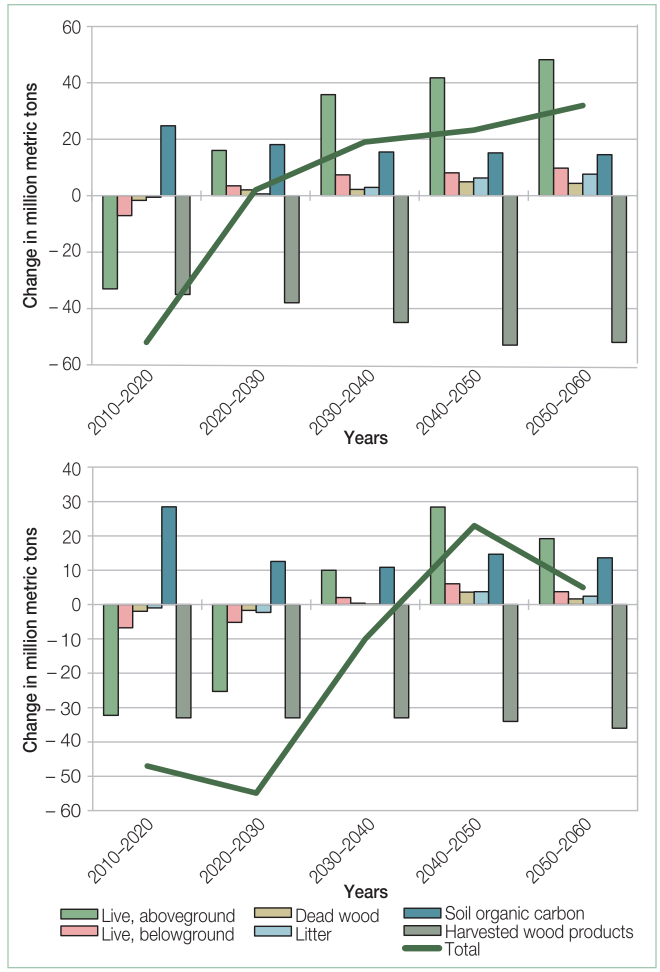


Table 19. Net annual contribution of harvested wood products and U.S. forests to carbon sinks and emissions, under three accounting approaches, by RPA scenario, 2010–2060. Negative numbers indicate net additions to stocks or net removals from the atmosphere.

Approach	2010–2020	2020–2030	2030–2040	2040–2050	2050–2060
	Change in million metric tons of carbon				
Production					
RPA A1B	(53)	2	19	23	33
RPA A2	(36)	(16)	10	29	54
RPA B2	(47)	(55)	(10)	22	5
RPA HFW	(48)	(5)	(7)	(1)	17
Stock Change					
RPA A1B	(65)	(9)	11	18	25
RPA A2	(52)	(35)	(14)	(1)	11
RPA B2	(61)	(66)	(20)	13	(6)
RPA HFW	(62)	(18)	(22)	(21)	(11)
Atmospheric Flow					
RPA A1B	(54)	1	19	25	39
RPA A2	(34)	(7)	27	53	86
RPA B2	(48)	(52)	(4)	28	9
RPA HFW	(50)	(7)	(9)	(4)	13

B2, in which harvest is lowest. For RPA B2, later decades have larger decreases than RPA A1B because of higher harvest (tables 17 and 19). Note that these cumulative carbon stock increases do not account for changes in fossil carbon emissions that occur with varying levels of wood energy use.

Overall cumulative carbon flux changes during the projection period using the Stock-Change and Atmospheric-Flow Approaches for HWP estimates are highest (most carbon emission offset) for RPA B2, very closely followed by RPA HFW (table 19). The estimated cumulative offsets are highest for all RPA scenarios under the Stock-Change Approach.

Wood Substitution Effects on Carbon Stocks and Flows

Estimates of annual changes in forest and forest products carbon stocks are used to monitor carbon fluxes over time. Changes in policy can affect forest investment and management and wood products production and use, which in turn affect carbon fluxes. Areas of particular interest are the potential change in carbon flux over time in response to (1) changes in use of wood as a substitute for materials that emit more carbon in their manufacturing, and (2) changes in wood use for energy.

The 2010 RPA Assessment did not evaluate specific policies or cases in which solidwood product use increases to displace nonwood products, particularly steel and concrete, in construction. We have information, however, that suggests the magnitude of the possible effect of such increases if they were to occur. A recent meta-analysis of studies of wood-based building systems determined that the average displacement factor value was 2:1, meaning that for each ton of carbon in wood products substituted for nonwood products, there is an average greenhouse gas emission reduction of approximately 2 tons of carbon (Sathre and O'Connor 2008, 2010). This reduction corresponds to a 3.9-ton carbon dioxide equivalent emission reduction per ton of oven-dry wood used, or a roughly 1.9-ton carbon dioxide equivalent (or 0.52 tons carbon) emission reduction per cubic meter of wood product.

The difference in net carbon emissions between producing wood products and nonwood products for construction is largely because of two factors. First, wood is assembled using energy from the sun via photosynthesis, whereas other materials are assembled using humanmade energy largely from fossil fuels. Second, wood mill residues are used for energy. The emissions from burning mill residue for energy are offset during some time period by the absorption of carbon in forests. One can view this absorption as occurring after harvest when the forest regrows.

When a policy causes an increase in wood products production and use, and an associated decrease in nonwood products production and use and emissions, three changes occur in carbon flux between the wood product-increase case and the no-increase case. First, there is a reduction in manufacturing emissions. Second, there is a decrease in forest stock from harvest to make the wood product. Third, the harvest of wood for the product can increase (with sustainable management) the long-term carbon accumulation rate of the forest relative to what it would have been without the harvest. This increase is a longer term carbon benefit from producing and using the solidwood product. This third factor would only be additional if it is not included into calculating the first factor—the emission offset factor. The third factor has not been used in most studies that estimate the first factor.

The 2010 RPA Assessment also did not examine different policies that might affect the use of biomass for energy, although the four RPA scenarios varied widely in assumptions about the future use of woody biomass for energy. We will be examining wood energy options and potential effects on forest resources and product markets in the assessment update cycle.

Conclusions

U.S. forests sequester substantial amounts of carbon. During the last few decades, carbon stocks on forest land and in harvest wood products have increased. Carbon storage on forest land is highly dependent on forest area and carbon per acre of forest. The RPA scenarios all project decreasing forest land, although at different scales. Carbon stocks are projected to decrease across all RPA scenarios, primarily or entirely because of declining forest land area, depending on the RPA scenario. Harvest levels that change the age class distribution and carbon per acre on remaining forest land also influence stock change.

Differences in projected carbon storage in HWP (Production Approach) reflect varying levels of forest harvest and resulting solidwood product production and use. The RPA A1B scenario, which projects the highest harvest, stores the most carbon during the projection period. The contribution of HWP to carbon flux is vital to keeping the combined forest and HWP pools as a carbon sink for an additional decade in three of four scenarios. For the RPA HFW scenario, carbon additions to HWP keep the forest sector as a carbon sink for an additional three decades.

Overall cumulative carbon stock increases during the projection period, including both forest and HWP carbon (Production Approach), are largest for scenarios RPA HFW and RPA B2, in which harvest is lowest. In identifying RPA scenarios with the largest carbon increases (emission offsets), however, we have not included the effect of varying levels of wood energy use in changing fossil fuel emissions. An evaluation comparing RPA scenarios that differ only in the level of wood energy use may show greater carbon offsets from the higher wood energy case—over a given time period—to the extent that forest carbon and HWP carbon are expanded because of the increased wood energy use. Policies that result in substitution of wood products for nonwood products in construction could decrease overall carbon emissions, although the RPA scenarios were not set up to evaluate the effect of such policies.

The forest carbon change projections in this chapter are determined by how forest area and forest growth are modified in response to changing harvest for timber products and wood energy. Sources of uncertainty include natural disturbance; forest landowner response in the form of harvest, land conversion, or management change; and forces to convert land to nonforest. HWP carbon change projections are determined primarily by how solidwood products production changes in response to changing U.S. and foreign demand for timber products and wood energy. Sources of uncertainty include the relative increase in foreign versus U.S. product prices, which will determine net trade and factors that determine the lifetime of solidwood products in use and disposal after use.

Chapter 11. Rangeland Resources

Rangelands are found in many ecoregions encompassing a diverse suite of vegetation. This chapter begins with a description of the extent of U.S. rangelands across various ownerships and of the area of rangelands in protected status. Recent trends in rangeland productivity and health are reviewed, as is the role of rangelands in livestock and forage production. The final section reviews current scientific knowledge about the potential effects of climate change on rangelands and their ability to continue to deliver goods and services into the future. Additional details on data sources and methods can be found in Reeves and Mitchell (2012).

Resource Highlights

- Rangelands are projected to continue their slow decline in area.
- Rangeland productivity is stable.
- Rangeland health is difficult to consistently evaluate.
- Rangeland forage supply is sufficient to meet demand.

Extent of U.S. Rangelands

Rangelands are areas where the natural vegetation consists principally of grasses, forbs, grasslike plants, and shrubs that are suitable for browsing or grazing. Rangelands are distinguished from grazing lands, with grazing land identified as any vegetated land that is grazed or has the potential to be grazed (SRM 1998), including rangeland, pastureland, grazed forest land, native and naturalized pasture, hayland, and grazed cropland. Consistent quantification of the extent of the Nation's land resources is crucial to providing a baseline against which repeated measures of land health, carbon sequestration, and forage availability can be compared in the future. Unlike forest lands, a consistent measure of rangelands across all ownerships does not currently exist because different definitions are applied in different inventory processes.

Because of these different definitions, current estimates of U.S. rangeland area vary widely. To better understand the differences in U.S. rangeland estimates, we compared the extent of U.S. rangeland by applying two different rangeland definitions to spatially explicit vegetation data that cover rangeland on all ownerships (Reeves and Mitchell 2011): the rangeland definitions used by the Forest Service in the Forest Inventory and Analysis (FIA) program and the definition used by the Natural Resources Conservation Service (NRCS) in the National Resources Inventory (NRI) (see sidebar, Defining Rangeland Extent in the United States).

Using this geospatial modeling process, the FIA and NRI definitions yielded estimates of 511 and 662 million acres of rangelands in the conterminous United States, respectively (table 20). These estimates do not match the rangeland figures in table 4

Table 20. Estimated rangeland area in the conterminous United States by RPA region, using Forest Inventory and Analysis (FIA) and National Resources Inventory (NRI) definitions of rangeland for all rangelands, National Forest System (NFS) rangelands, and Bureau of Land Management (BLM) rangelands.

RPA region	All range FIA	All range NRI	NFS range FIA	NFS range NRI	BLM range FIA	BLM range NRI
	million acres					
North	3.6	15.2	< 0.1	0.6	NA	NA
South	61.4	121.6	0.7	1.6	< 0.1	< 0.1
Rocky Mountain	386.6	436.4	24.0	34.8	108.6	115.8
Pacific Coast	59.2	89.1	4.0	13.5	21.7	23.6
U.S. Total	**510.8**	**662.3**	**28.7**	**50.5**	**130.3**	**139.4**

NA = not applicable.
Source: Reeves and Mitchell 2011

that are based on the 2007 NRI because both the FIA and NRI definitions were applied to all ownerships, whereas the NRI estimates include only non-Federal lands. Assuming that Alaska contains roughly 173 million acres of rangeland (USDA Forest Service 1989) reveals a national total of 681 million acres (FIA perspective) or 835 million acres (NRI perspective). The biggest discrepancies between these estimates arise from their different treatments of oak, pinyon-juniper, and mesquite woodlands. Another area of discrepancy occurs in the Southeastern United States, particularly in forested flatwoods and longleaf pine sites that were historically lightly treed savannahs.

Non-Federal Rangeland

Unlike total rangeland extent, NRI data can be used directly as a reliable estimator of non-Federal rangeland extent over time. Most rangeland in the United States is privately owned and lies west of the 95th meridian. According to the 2007 NRI, the current area of non-Federal rangeland in the conterminous United States is 409 million acres. There was a net loss of 8.8 million acres of non-Federal rangeland between 1982 and 2007 (USDA NRCS 2009), about 2 percent of the current non-Federal rangeland base. The Rocky Mountain Region contains the greatest amount of non-Federal rangeland and exhibited the greatest loss of all Resources Planning Act (RPA) regions since 1982. Florida exhibited the highest State loss of non-Federal rangeland in the country, 1.75 million acres between 1982 and 2007.

Conservation Reserve Program Lands

Although Conservation Reserve Program (CRP) lands are never considered rangeland in the NRI because the cover is not considered "permanent," CRP lands planted to range vegetation may provide similar ecological functions and act to decrease fragmentation in landscapes dominated by rangeland vegetation. Currently, there are about 34 million acres of lands enrolled in the CRP. These lands have provided benefits from reduced erosion and wildlife viewing and hunting (Sullivan et al. 2004). In addition, CRP lands generally improve ecological condition, and the recent emphasis on biological carbon sequestration from rangelands emphasizes the potential of CRP lands hosting rangeland vegetation to sequester a significant quantity of atmospheric carbon dioxide (Jordan et al. 2007). Participation in the CRP has possibly led to some unintended negative consequences, however (Baker and Higgins 2009; Noss et al. 1995). For example, millions of acres enrolled in the CRP are seeded with nonnative species, such as crested wheatgrass and intermediate wheatgrass.

Federal Rangelands

The Forest Service and Bureau of Land Management (BLM) manage a significant area of rangeland. Using the Reeves and Mitchell (2011) approach described previously, National Forest System (NFS) lands had about 29 million acres (about 15 percent of the total NFS land base) based on the FIA definition and almost 48 million acres (about 25 percent of the total NFS land base) using the NRI definition (table 20). As with all rangeland estimates, the difference reflects the disparate treatment of species common in pinyon-juniper, mesquite, and other woodland environments and the different canopy cover thresholds between definitions. Of the 175 million acres of land administered by the BLM in the conterminous United States, about 131 million acres were estimated to be rangeland from the FIA definition and about 139 million acres from the NRI definition, which means that roughly 75 percent of BLM lands within the conterminous United States are rangeland.

Rangelands in Protected Status

Rangeland accounts for about 195 million acres (45 percent) of the protected areas in the Protected Areas Database of the United States (PAD-US) (table 21). Approximately 82 percent of the protected rangelands are found in just five States: Arizona, California, Idaho, Nevada, and Oregon. Table 21 lists the protected area in States containing more than 1 million acres of rangeland. Rangeland area estimates are provided for both the FIA and NRI definitions, and for the percent of rangeland protected based on the NRI definition.

Outlook for U.S. Rangeland

Mitchell (2000) identified consolidation, subdivision, and urbanization of rangeland as important factors in determining the future of rangeland. The extent of Federal rangeland is not expected to change substantially in the future. Between 1982 and 2007, non-Federal rangeland was lost primarily to cropland and developed land uses (table 4). Rangeland is projected to continue its slow decline under all RPA scenarios (Wear 2011). The largest loss of rangeland is projected to occur under scenario RPA A1B, almost 9 million acres (2 percent) of non-Federal rangeland between 2010 and 2060. The largest percentage decline (6 percent) occurs in the Pacific Coast Region, and the greatest acreage loss (4.5 million acres) occurs in the Rocky Mountain Region.

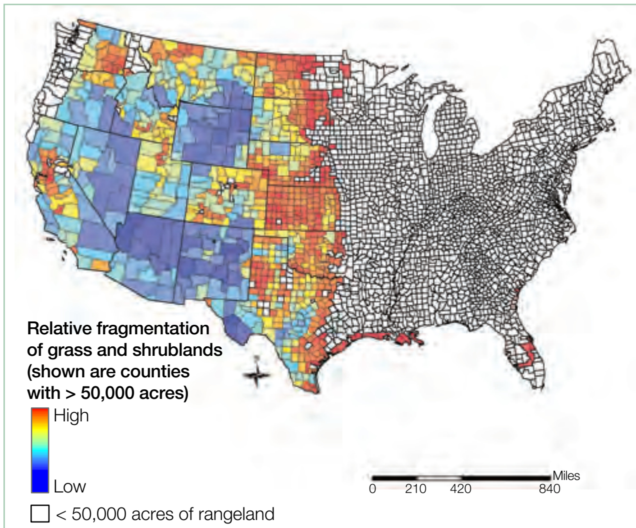
Table 21. Protected area in States with more than 1 million acres of rangeland.

State	Total protected area	Protected rangeland area (FIA definition)	Protected rangeland area (NRI definition)	Percent of protected area that is rangeland (NRI definition)
	thousand acres			
Nevada	97,519	64,361	74,098	76
California	61,381	26,333	36,700	60
Oregon	39,082	16,630	20,848	53
Idaho	34,021	12,656	15,477	45
Arizona	19,728	7,988	13,018	66
Utah	15,656	3,742	5,353	34
New Mexico	12,472	2,692	4,796	38
Wyoming	13,770	3,085	3,582	26
Colorado	17,657	2,587	3,441	19
Montana	21,592	2,562	3,301	15
South Dakota	3,229	1,965	2,361	73
Florida	12,141	461	2,206	18
Texas	5,525	1,607	1,981	36
North Dakota	2,614	1,643	1,978	76
Washington	12,312	1,206	1,498	12

FIA = Forest Inventory and Analysis. NRI = National Resources Inventory.
Source: Conservation Biology Institute 2010

Building from the spatial patterns for grasslands and shrublands described in chapter 6, an index of rangeland fragmentation was developed to provide a relative value indicating the ratio of rangeland vegetation edge to the area of urban and agricultural landscapes. Higher values indicate areas of rangeland vegetation that are relatively more fragmented (figure 98). Fragmentation is detrimental to natural landscapes because of factors such as loss of goods and services, decreased gene pools, and barriers to species depending on rangelands for all or part of their life cycle. Arizona and Nevada are the States with the least fragmented rangeland areas, whereas the most fragmented areas correspond to areas with high agricultural usage. This method does not account for some types of development effects, such as the effects of oil and gas development on rangeland.

Figure 98. Patterns of relative fragmentation of rangeland using the Morphological Spatial Pattern Analysis index, 2001.



Source: Adapted from Riitters 2011

Defining Rangeland Extent in the United States

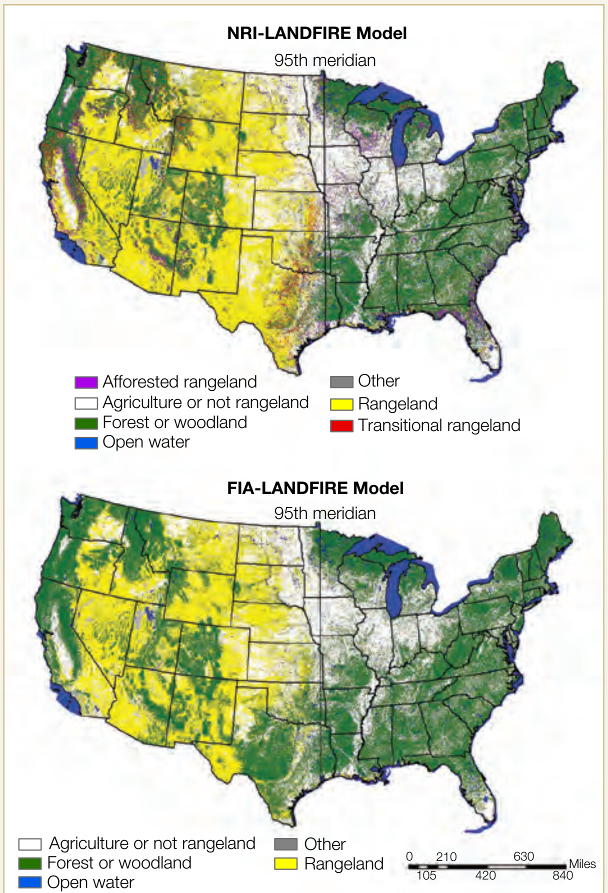
A consistent set of spatially explicit data with appropriate precision to enable mapping of rangeland area, based upon any definition, has been lacking. Definitions of rangeland often include land cover, land use, and potential vegetation or administrative characteristics, with each approach having unique problems (Lund 2007). Not only are different concepts applied to identify rangeland, different tree canopy thresholds are used to determine whether a stand is classified as forest or rangeland. Woodlands are also treated differently, sometimes classified as forests and sometimes as rangeland.

Reeves and Mitchell (2011) accounted for all rangeland in the conterminous United States by applying two different definitions of rangeland from land management agencies to spatially explicit data describing vegetation composition, structure, and historical makeup. Specifically, rangeland extent was characterized using rangeland definitions from the Forest Service's Forest Inventory and Analysis (FIA) Program and from the Natural Resources Conservation Service's National Resources Inventory (NRI) (figure 99). Areas of disagreement generally reflect different tree canopy cover thresholds and treatment of woodland species (such as juniper, oak, and mesquite species) between the FIA and NRI rangeland definitions (figure 100).

The spatially explicit vegetation data, supplied by the LANDFIRE project, included existing vegetation type, existing vegetation height, existing vegetation cover and biophysical settings (Reeves et al. 2009; Rollins 2009; Zhu et al. 2006). The vegetation classification used by LANDFIRE to describe current and pre-Euro-American vegetation was Ecological Systems (Comer et al. 2003; Comer and Schulz 2007). Three classes of rangeland were identified: rangeland, afforested rangeland, and transitory rangeland (Spreitzer 1985). Afforested rangeland represents areas that were historically dominated by herbs and shrubs but currently support a tree canopy cover exceeding the amount allowed by rangeland definitions. The NRI definition identified 47 million acres of afforested rangeland, but a comparable analysis was not possible using the FIA definition. These afforested areas would be considered forest using the FIA definition. Transitory rangeland represents areas that were historically forested, but currently are temporarily dominated by shrub and/or herbaceous vegetation after logging, severe fires, or other disturbances.

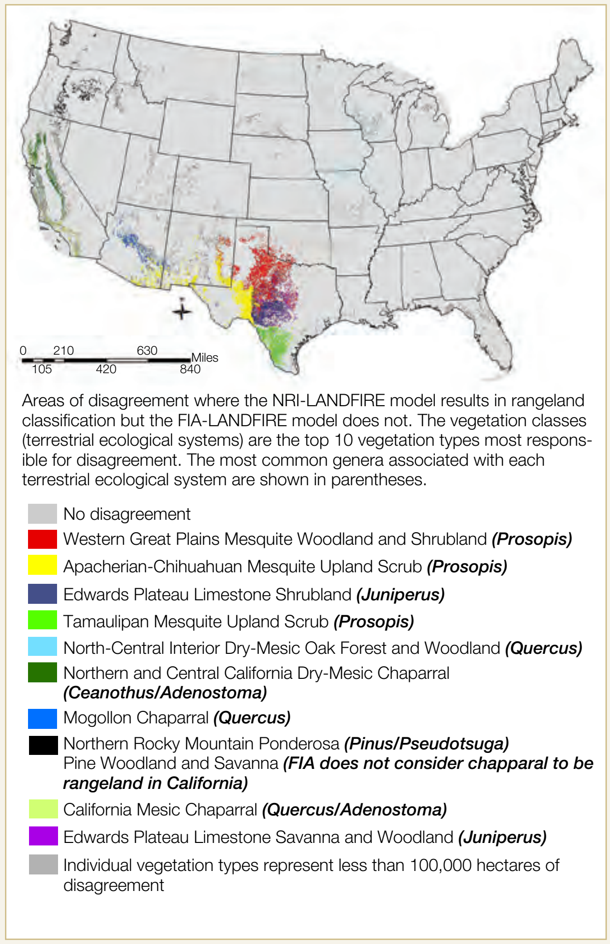
The total rangeland area quantified using the FIA and NRI perspectives from Reeves and Mitchell (2011) in the conterminous United States is 511 and 662 million acres, respectively (table 20).

Figure 99. Comparison of rangeland extent using National Resources Inventory (NRI) and Forest Inventory and Analysis (FIA) definitions, 2001.



Source: Reeves and Mitchell 2011

Figure 100. Areas of disagreement in rangeland extent between the National Resources Inventory (NRI) and Forest Inventory and Analysis (FIA) perspectives, 2001.



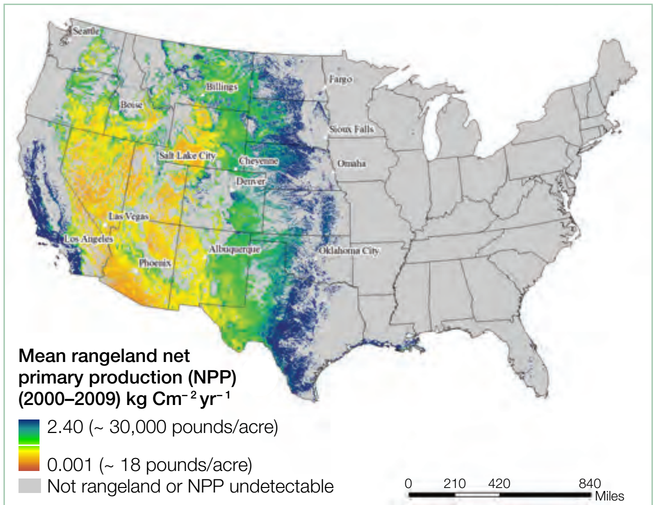
Rangeland Productivity

In its most basic form, rangeland productivity can be described as the rate of change in vegetative biomass accumulation (aboveground and belowground) expressed on an area basis. Vegetation productivity is often measured as net primary productivity (NPP) and because primary production provides the foundation for all herbivory, it is a crucial component to monitor on rangeland. Although rangeland productivity ultimately controls grazing capacity, data are not available for a nationally consistent assessment. To fill this gap, a combination of ecosystem modeling and remote sensing was used to quantify spatial and temporal trends in productivity for rangeland vegetation across large areas. The trend in NPP was estimated annually from 2000 through 2009 using the Moderate Resolution Imaging Spectroradiometer (MODIS) vegetation product suite (Running et al. 2004). This approach estimates landscape-level NPP, but does not provide a framework for quantifying the proportion of aboveground production suitable for grazing. The analysis excludes all areas in the conterminous United States exhibiting tree canopy cover greater than 10 percent.

The most productive systems (using National Vegetation Classification Standard Groups and Macrogroups) occur in coastal California (generally chaparral types), Florida peninsula and scrub vegetation, Eastern North American grassland meadow and shrubland, Western North American warm temperate forest, and Great Plains tallgrass prairie and shrubland. Figure 101 depicts the spatial patterns of rangeland productivity across the conterminous United States. From 2000 to 2009, U.S. rangeland averaged approximately 0.218 kilograms of carbon per square meter per year (about 1,960 pounds per acre). This value includes aboveground and belowground vegetative structures and includes areas with shrubs.[14]

U.S. rangeland with the highest variability in NPP occurred in more xeric regions, such as the Southwestern United States and the southern Great Plains, presumably in response to interannual variability in precipitation (Reeves et al. 2006; Zhao and Running 2010). The vegetation types exhibiting the greatest variation were Great Plains shortgrass prairie and shrubland, North American warm desert scrub and grassland, and Western North American warm temperate scrub woodland and shrubland. Rangeland vegetation exhibiting the highest average productivity tends to have the lowest variability between years, reflecting greater stability (less interannual variation) in precipitation.

Figure 101. Mean annual rangeland net primary production (NPP), 2000–2009. NPP values represent both aboveground and belowground production.[a]



[a] Only patches comprised of rangeland occupying ≥ 198 contiguous acres are shown, thus eliminating about 90 percent of the rangeland areas patches of the Eastern United States.

Source: Based on Moderate Resolution Imaging Spectroradiometer Collection 4.5 data

Overall, from 2000 to 2009, U.S rangelands exhibited a weakly positive, albeit insignificant, trend in productivity. The Rocky Mountain Region, however, exhibited a stronger increasing trend from 2000 to 2009 than other RPA regions, but the cause of the increase is not known.

Rangeland Health

The concept of rangeland health has evolved from comparing current vegetation composition to a climax plant community to judging the degree to which the integrity of soil and the ecological processes of rangeland ecosystems are sustained (Joyce et al. 2000; National Research Council 1994). Rangeland health is currently characterized using a variety of both qualitative and quantitative indicators (Herrick et al. 2010) describing multiple facets of ecosystem integrity such as erosion, percentage bare ground, species composition, and annual production (Pellant et al. 2005). Because no rangeland health monitoring protocol is being consistently used by land management agencies across all rangeland, we report on two separate analyses of BLM lands and non-Federal rangeland, the two largest nationwide rangeland ownership categories.

BLM Lands

The BLM has been monitoring the ecological status of rangeland since 1978, using systems to classify BLM lands into four ecological status categories that are based on the percentage similarity of the current vegetation to the Potential Natural Community (PNC) (Habich 2001). More recently, the BLM created the Standards for Rangeland Health (USDI BLM 2001) that provide standards for ecological processes, water quality, habitat of protected species, and watershed function. Between 2004 and 2009, the condition of all BLM lands was quite stable, a conclusion also reached in the last RPA Rangeland Assessment (Mitchell 2000). Roughly 75 percent of the lands administered by the BLM are in the mid and late seral stages. Approximately 89 percent of all BLM lands are classified as either meeting all land health standards, making significant progress toward meeting the standard, or not meeting all standards or making significant progress toward meeting the standards but appropriate action has been taken (USDI BLM 2001).

[14] The values reported here cannot be reliably compared with herbaceous productivity from most previous studies, because productivity is often only reported for aboveground structures of herbaceous species.

Non-Federal Rangeland

The NRI recently incorporated a rangeland health protocol fashioned after Pellant et al. (2005). Herrick et al. (2010) summarized the results for three attributes based on data collected between 2003 and 2006: soil and site stability, hydrologic function, and biotic integrity. Biotic integrity exhibited the largest departure from reference conditions, followed by hydrological function and site stability. In general, the northern Great Plains appeared more intact in all three attributes than the Southwestern United States (Herrick et al. 2010). Biotic integrity appeared to be most affected by the presence of nonnative species, although invasive native species also contributed to decreased biotic integrity, especially mesquite and juniper species. Nonnative species were present on roughly 50 percent of non-Federal rangeland and represented more than 50 percent of the total plant cover on 5 percent of non-Federal rangeland. Overall, roughly 80 percent of the non-Federal rangeland in the conterminous 48 States is in relatively healthy condition and exhibits no significant soil, hydrologic, or biotic integrity problems.

Woody Encroachment on Non-Federal Rangeland

Woody encroachment is the establishment, development, and spread of tree or shrub species onto rangeland sites that are postulated to have hosted less dense cover by woody species in the past. The densification and encroachment of woody species can induce significant ecological change by transforming grasslands into savannas and savannas into shrublands or woodlands (Hughes et al. 2006), which can alter fire regimes (Ansley and Rasmussen 2005; Chambers et al. 2005; Miller and Rose 1999), nutrient cycling (Rau et al. 2010; Strand et al. 2008), carbon sequestration, biodiversity, and forage yield (Miller et al. 2005). In arid regions, increases in the abundance of shrubs at the expense of grasses are a type of desertification often accompanied by accelerated rates of wind and water erosion. Likewise in semiarid and subhumid areas, encroachment of shrubs and trees into grasslands and savannas may promote primary production but potentially reduce streamflow, groundwater recharge, livestock production, and biological diversity (Archer et al. 2001). Shrub encroachment can also increase soil organic matter, which has the ultimate effect of increasing sequestered carbon. The increased carbon accumulation, however, is dependent on many factors, such as temperature and rainfall, with relatively wetter sites receiving a greater amount of sequestered carbon (Knapp et al. 2001).

Three key genera—juniper, mesquite, and pine—are the primary concerns for woody encroachment. As a whole, approximately 10 percent of U.S. rangeland is currently occupied by invasive juniper species. In general, pinyon and juniper woodlands occupy approximately 74 million acres in the Western United States (Miller et al. 2005), mostly between 2,000 and 6,000 feet in elevation (Gedney et al. 1999). The increased abundance of western juniper is also reducing aspen in some stands (Mitchell 2000) and decreasing the streamflow for watersheds because of increased transpirational demand. Finally, densification of western juniper is also linked to reduced understory biomass and diversity of wildlife and plant species (Wall et al. 2001).

Without disturbance or management, most invaded landscapes will become closed woodlands, resulting in the loss of understory plant species, decline of sagebrush communities, loss of habitat, decline in herbaceous production, decline of landscape heterogeneity, and greater costs for restoration (Miller et al. 2008). Soil erosion resulting from juniper encroachment is a major concern, with grassland communities in the Great Plains being especially vulnerable (Ansley and Rasmussen 2005). Eastern redcedar and Ashe juniper now occupy more than 6 million acres of rangeland and forest land in Oklahoma (approximately 15 percent of the land area), influencing almost 30 percent of the estimated 21.6 million acres in native plant communities (Bidwell et al. 1995).

Eastern redcedar tends to invade more northerly rangeland, especially former tallgrass prairie. The species occurs in nearly every State east of the Rocky Mountains, but appears invasive toward the western edge of its range. Eastern redcedar is the most widely distributed conifer east of the Mississippi River and pioneers aggressively into abandoned fields and grasslands (Schmidt and Leatherberry 1995). Relative to other juniper species, invasions by Eastern redcedar are particularly problematic because they threaten tallgrass prairie, one of the most endangered ecosystems in North America (Briggs et al. 2005).

Whereas altered fire regimes and overgrazing are often cited as inducing invasions by juniper species, overgrazing in general is postulated to drive encroachment by mesquite species, but debate still remains as to the exact causes (Kupfer and Miller 2005). Ecological systems dominated by mesquite occupy a large region of the southwestern area of the conterminous United States, with significant coverage in Arizona, New Mexico, and Texas. Mesquites occupy semiarid and arid landscapes, creating the potential for an increasing area of arid land or desertification. In these landscapes, mesquite can exploit the additional soil moisture that infiltrates under intermittent streambeds and in local areas where water accumulates during runoff (Schlesinger et al. 1990).

Domestically, mesquite species are the dominant woody plant on more than 94 million acres of what has been considered semiarid southwestern grasslands (Van Auken 2000). Such a large distribution and, in some cases, high stem densities create similar ecological consequences as juniper species. In addition to altering nutrient cycles, mesquite invasions greatly reduce herbaceous forage and thus create an economic burden for working ranches.

Invasive Plants Abundance and Distribution

The spread of exotic or nonindigenous plants throughout U.S. rangelands has had harmful effects on overall rangeland health and presents management obstacles (Mitchell 2000). Generally, invasive species result in a loss of income for stock growers and landowners from reduced forage, productivity, increased control costs, and reduced land value. Today, an estimated 3,310 nonnative species occur within the conterminous United States, and 126 million acres are infested by 16 prominent invasive plant species (Duncan et al. 2004). Nonnative species have been shown to degrade natural ecosystem integrity and are now estimated to be present on 50 percent of U.S. rangeland (Herrick et al. 2010). Some of the most problematic species that commonly invade rangeland include cheatgrass, leafy spurge, Dalmatian Toadflax, red brome, knapweeds, and starthistles (DiTomaso et al. 2010).

Cheatgrass is considered one of the most abundant invasive plant species in North America. It is most prominent in the Great Basin and throughout the Western United States, has steadily increased in the last decades, and is expected to continue expanding. It outcompetes native species, changes fire regimes, and alters forage supply. Dalmatian Toadflax is most prominent in the Northwestern United States and southern California. It is estimated to infect almost 400,000 acres in the Western United States (Duncan et al. 2004) and contains a toxic substance that causes a health risk to grazing animals.

Knapweeds are found mostly in the Western United States, particularly in the Southwest and Intermountain regions, and are estimated to infest 5 million acres (Wilson and Randall 2005). Infested areas are often associated with increased runoff and sediment yield and loss of topsoil. Leafy spurge occurs predominantly in the Northwestern United States, especially in eastern Montana and Wyoming. It has invaded approximately 3.7 million acres in Western States and almost 1 million acres in the East (Duncan et al. 2004). Red brome occurs in the Southwestern United States, where it alters fire regimes and threatens the native species.

Livestock and Forage Production

Rangeland is an important forage source for livestock grazing, both on public and private rangeland. Grazed forage includes any vegetated land that is grazed or has the potential to be grazed, so it encompasses rangeland, pasture, grazed woodland, and grazed cropland.

Livestock Numbers

The United States has a large cattle industry, although U.S. cattle production peaked in 1982 at more than 104 million animals (USDA NASS 2009). Cattle numbers fell between 1997 and 2007, but losses were distributed asymmetrically. The North Region lost nearly 26 percent but the Pacific Coast Region gained 10 percent. The South Region has the most cattle, primarily because of Texas and Oklahoma, which together contain 56 percent of the region's cattle population. In the short run, the cattle inventory is projected to expand slightly, from less than 92 million in 2012 to almost 97 million by 2020 (USDA 2011). Sheep numbers have declined by approximately 26 percent since 1997, the continuation of a decades-long decline. A combination of low lamb consumption, decreased dependence on wool, increased competition from imports, and disease and predator losses raising domestic production costs have greatly decreased U.S. sheep populations (Jones 2004).

Horses have increased approximately 33 percent, and goats have increased 96 percent from 1997 to 2007. The trend in domestic goat production follows a global trend of increases. Goats are gaining popularity because they efficiently convert feed and are valuable as vegetation management tools. Bison numbers on private lands are estimated at about 198,000 animals (USDA NASS 2009). Bison numbers are greatest on the northern Great Plains, particularly North Dakota, which accounted for 15,000 bison on private lands. In addition to these commercial livestock groups, the 2007 Census of Agriculture also revealed that there are about 270,000 deer, 68,000 elk, 245,000 alpacas and llamas, and 284,000 mules, burros, and donkeys. The majority of these animals are raised on private land in managed pasture settings and do not significantly affect the forage availability on rangelands.

Demand for red meat strongly influences livestock production. Per capita consumption of beef declined from about 1985 through the mid-1990s, but stabilized until the early years of the 2000s. Total per capita meat consumption fell between 2004 and 2009. Per capita red meat consumption is projected to continue to decline through 2012, then increase slightly through 2020 (USDA 2011).

Forage Supply

Demand for grazeable forage is derived from red meat demand (not including grazing by wild ungulates). Joyce (1989) concluded that expanded contributions from private land could meet the increased demand for grazeable forage from cattle and sheep. For the 2000 RPA Rangeland Assessment, Van Tassell et al. (2001) tested various scenarios to conclude that changes in supply remained tied to land use changes, and that technology was not expected to significantly change the forage supply per unit in most regions. Given the projected declines in rangeland area, declines in forage supply from that source were also expected.

We used remote sensing to estimate total forage supply. Data from the MODIS NPP Collection 4.5 were converted to aboveground biomass, using a series of assumptions regarding root-to-shoot ratios, and amount of carbon in biomass. Average annual forage supply was estimated to be between 1.9 and 2.6 trillion pounds of grazeable pasture, rangeland forage, and forage beneath tree canopies (table 22). This estimate includes forage from rangelands, forested lands, and pasture lands. A per-acre average pasture forage figure of 4,000 pounds was applied to the estimated pasture area, and an average estimate of 215 pounds per acre of forage beneath forested canopies was applied to forest land. At these levels, every 1 million acres of pasture corresponds to 5.1 million animal unit months (AUMs), or approximately 427,000 cattle per year, assuming they are grazed or cropped continuously.

Whereas most pasture land in the Southern United States is used on an annual basis, only a small fraction of grazeable forest land is used (Joyce 1989) and therefore might represent a relatively untapped reservoir of forage. Although the estimates presented here are rough, the total forage supply should support approximately 204 to 280 million animal units per year, or 2.5 to 3.3 billion AUMs at full utilization.

Livestock Grazing on Federal Lands

The Forest Service and BLM administer the largest holdings of Federal grazeable lands. During the 1980s and 1990s, permitted livestock use fluctuated within 10 percent of 10 million AUMs. During the last decade, however, permitted livestock grazing use on BLM lands decreased by 12 percent and was at a decadal low in 2004 (USDI BLM 2001–2010). In comparison, permitted use on NFS lands fluctuated within 19 percent of 7.6 million AUMs between 2000 and 2008 (USDA Forest Service 2000–2008).

Permitted livestock use is the sum of all animals permitted to graze, whereas authorized or actual use is the actual amount of use granted to the permit holder. Authorized or actual use can differ substantially from permitted use for a number of reasons, including drought-induced forage shortage, restrictions because of timber harvest or revegetation, or even ranch-level economics. Quantifying the nonuse of permitted AUMs on NFS lands was discussed in both Joyce (1989) and Mitchell (2000). Compared with the 1980s and 1990s, the most recent decadal data suggested a slight increase in the proportion of nonuse. Between 1977 and 1994, the average nonuse by sheep and cattle were roughly 14 and 20 percent, respectively, but during the period between 2000 and 2008, those numbers both rose to approximately 28 percent, suggesting a slightly increasing trend in nonuse. Many areas in the Southwest and Intermountain regions were in drought between 2000 and 2008, causing a reduction in stocking rates that may partially explain the nonuse trend in those areas.

Livestock Appropriation of Forage

Forage is used by a variety of domestic and wild ungulates. Information regarding numbers and spatial distribution of wildlife and less abundant livestock are scant and difficult to interpret, however. As a result, we focused on forage demand for sheep, goats, and cattle, based on data from the National Agricultural Statistics Service (NASS), and evaluated the estimated amount of NPP allocated to these livestock by comparing forage availability and forage demand on rangeland.

Forage availability was estimated using remote sensing (Running et al. 2004) as described in the section on forage supply. NASS data were used to estimate livestock numbers from 2000 to 2009 at both the State and county levels. Cattle numbers were converted to forage demand from rangeland by subtracting the number of cattle fed in feedlots from the total number of cattle as determined by census in each county. Because feedlot data are not available for goats and sheep, they were assumed to use rangeland forage exclusively, and data are only consistently available at the State level.

Forage availability showed a slightly increasing trend from 2000 to 2009. The spatial pattern of forage availability showed an increasing gradient from west to east, with lower production values in the Southwestern United States and the Great Basin (figure 102). Forage demand follows a similar pattern as forage availability, increasing from east to west and from north to south, with the majority of counties in Arizona, Colorado, New Mexico, Nevada, Utah, and west Texas having a forage demand between 0 to 9 pounds per acre (assuming a typical 6-month grazing period) (figure 102). In most States with significant rangeland area, forage demand declined from 2000 to 2009, resulting in slightly lower forage demand than in 2000.

Table 22. Estimates of total forage in the conterminous United States from rangeland, pastureland, and grazeable forest land.[a]

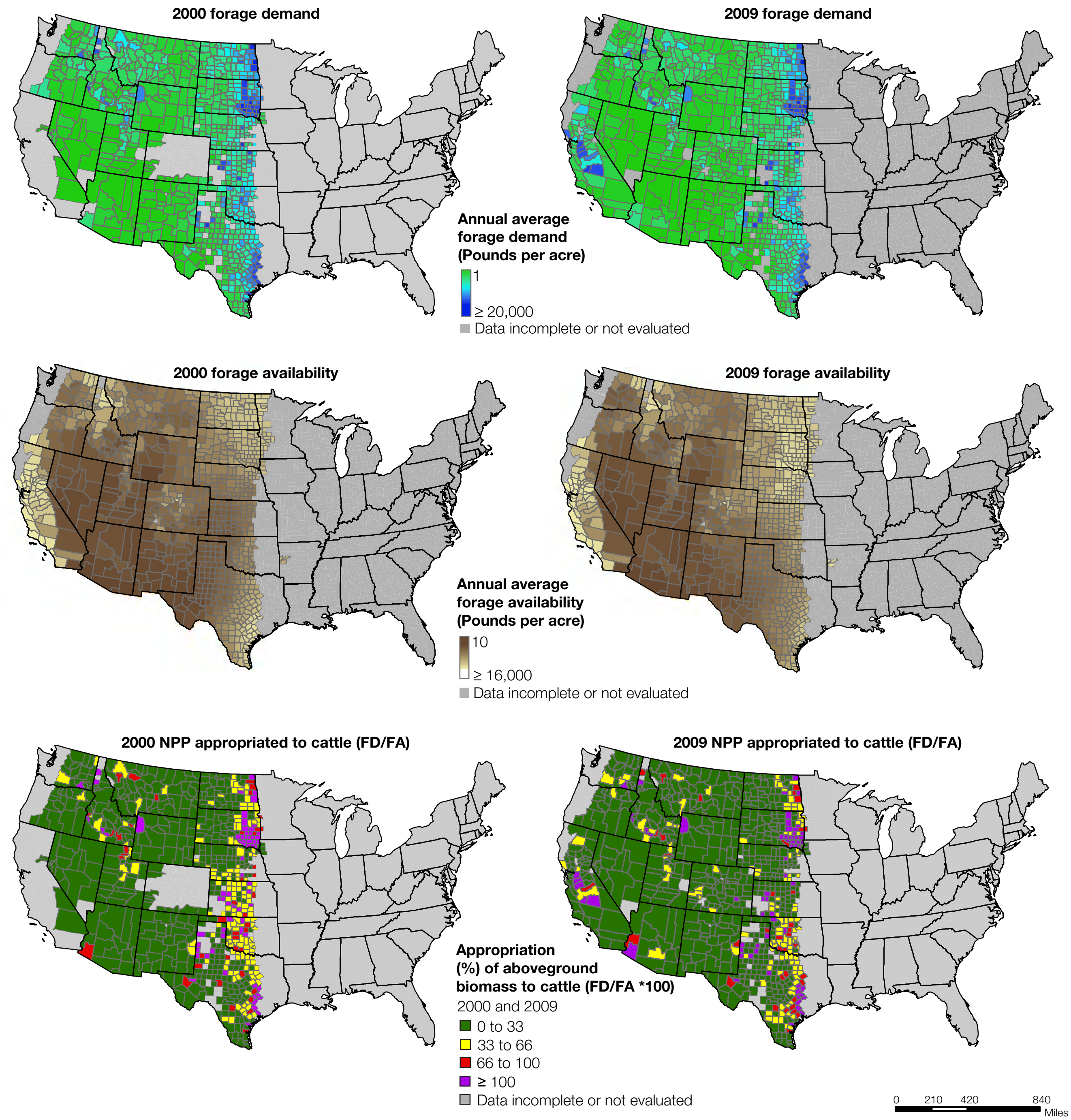
Root:Shoot ratio assumption	Forage from rangelands	Forage from pasturelands	Forage from forest lands	Annual total forage estimate	AUM capacity
	aboveground biomass (billion pounds)				
70:30	1,379	1,103	142	2,624	3,363,707,435
50:50	985	788	142	1,915	2,454,626,153

[a] Estimates do not account for agriculturally derived feedstuffs such as wheat, barley, and sorghum. In addition, estimates do not account for forage present in areas dominated by transitional rangeland. See Reeves and Mitchell 2011 for additional details.

AUM = animal unit month.

Source: Based on Moderate Resolution Imaging Spectroradiometer Collection 4.5 data

Figure 102. Forage availability (FA) and forage demand (FD) on rangeland and aboveground rangeland biomass appropriated to cattle (FA-FD) for 2000 and 2009. Values ≥100 indicate areas where estimated rangeland forage is not sufficient to meet the forage demand, which is estimated at the county level using the U.S. Census of Agriculture. Missing forage demand estimates result from no data found in some States from the Census of Agriculture at the time the data were acquired. Only FD for cattle is shown here because data for sheep and goats are only available at the State level.



Source: Forage availability was estimated from the Moderate Resolution Imaging Spectroradiometer net primary production (NPP), Collection 4.5 data

Table 23 shows the comparison of forage availability (FA) and forage demand (FD) on rangeland using county-level data. The results of the comparison were classified as being "hotspots" if FD exceeded FA or as "cool spots" if FD was less than FA. From 2000 to 2009, approximately 11.2 million acres of rangeland appear to have unsustainable FD (hotspots), whereas 590 million acres show a positive trend (cool spots). New Mexico showed the fewest hotspots and Texas the most.

This national-scale analysis examining the relationship between FD and FA indicates that most regions with significant rangeland area harbor sustainable numbers of livestock and suitable quantities of forage. The analysis, however, does not consider local rangeland conditions or the direct effect of feedlots or pastures on forage availability or forage demand. Nevertheless, feedlots and pastures reduce forage demand from rangelands, to the extent that feedlots and pastures supplant grazing on rangeland.

Climate Change and Rangelands

Climate change will affect U.S. rangelands because changes in temperature and precipitation affect vegetation growth and distribution. Changes in these climate components will be distributed asymmetrically and, therefore, expected effects on rangeland vegetation are difficult to characterize as a result of uncertainty, regional variability, poorly understood vegetation dynamics, and complicated interactions and feedbacks. Research is being conducted to examine the effects of modeled future climates on rangeland vegetation. Although no projections of the effects of climate on rangelands were possible for this assessment, available research enables us to suggest some possible future implications of climate change for U.S. rangelands.

Precipitation and temperature have been reliable predictors of the extent and distribution of plant groups (e.g., cool-season C3 and warm-season C4 species) across the landscape (Epstein et al. 1997; Knapp et al. 2001; Paruelo and Lauenroth 1996). Changes in these drivers have clear and well-understood implications for vegetation. Rising carbon dioxide levels may complicate these relationships in the future, however. For instance, warmer and drier conditions should favor C4 grasses (Knapp et al. 2001; Winslow et al. 2003) so that short and tallgrass prairies may stand to benefit, but rising carbon dioxide should favor C3 species (Morgan et al. 2004, 2007; Polley et al. 2003, 2006; Reich et al. 2001). Further complicating these relationships are changing temperature and precipitation regimes. Increased variation, intensity, and changes in the timing of precipitation can also influence species composition and productivity of U.S. rangelands. For example, as springtime temperatures increase in the Great Basin, the extent and magnitude of cheatgrass infestations may increase.

Most models predict that northern latitudes will warm while maintaining or increasing precipitation. This combination of factors should enhance productivity on northern and high-altitude rangelands through increased growing seasons for some time. If temperatures continue to rise, however, as suggested in all of the RPA climate projections, gains in production related to longer growing seasons and increased precipitation may be offset by decreased moisture availability at some time in the

Table 23. Breakdown of forage appropriated from U.S. rangelands to cattle at the county assessment level. Analysis represents average forage availability (FA) and forage demand (FD), 2000–2009.

State	Area affected through forage appropriated to cattle			
	Hotspots (FD > FA)	Cool spots (FD < FA)	Hotspots (FD > FA)	Cool spots (FD < FA)
	percent		*thousand acres*	
Arizona	1.90	98.10	1,008	52,004
California	6.97	93.03	2,488	33,204
Colorado	1.41	98.59	423	29,536
Idaho	5.67	94.33	1,246	20,715
Kansas	7.22	92.78	954	12,252
Montana	0.49	99.51	239	48,105
Nebraska	1.29	98.71	342	26,238
Nevada	0.01	99.99	6	57,309
New Mexico	0.00	100.00	1	59,617
North Dakota	0.26	99.74	35	13,526
Oklahoma	6.36	93.64	848	12,482
Oregon	0.02	99.98	6	24,823
South Dakota	2.36	97.64	626	25,884
Texas	2.81	97.19	2,651	91,716
Utah	0.49	99.51	143	29,016
Washington	1.19	98.81	96	7,962
Wyoming	0.24	99.76	112	45,659
Total			**11,224**	**590,048**

future. Despite this possibility, recent research suggests that increased temperatures, when coupled with increased carbon dioxide, actually improve plant water relations because of decreased transpirational demand (Morgan et al. 2011). The situation is just the opposite in the Southwestern United States, where projections indicate increases in temperature coupled with decreased precipitation. If this situation unfolds as climate projections suggest, rangeland productivity should decrease and only the most drought-tolerant species, such as desert shrubs and succulents, will prevail. Predicting the future states of species assemblages and plant functional groups is probably more difficult than evaluating the effects of changing climates on productivity, however.

Understanding what changing climates mean for future management strategies is difficult. We can note a few possible effects that are likely to influence management decisions in the future, however. First, although increased carbon dioxide generally increases rangeland productivity, it can decrease leaf nitrogen content, which decreases protein content and therefore nutritional value. This effect implies stocking rates and grazing systems will need to be adjusted accordingly so that animal performance and rangeland health are not adversely affected. Changing species composition may also affect forage quality because higher carbon dioxide seems to favor C3 over C4 plants, and C3 plants often have higher forage digestibility (Wilson and Brown 1983). Recent experimental results, however, confound this generality, finding that relatively less desirable genera belonging to the C3 photosynthetic pathway strongly increased production under increased carbon dioxide scenarios on a shortgrass steppe (Morgan et al. 2004, 2007). Management strategies aimed at adapting to changing species composition could include increased use of alternative livestock, such as goats, that readily use species that are generally unpalatable for cattle. In addition, Federal land managers and landowners may need to consider a more diverse suite of rangeland goods and services that could thrive under a more drought-prone environment. Second, warmer temperatures will likely result in increased fire frequency and intensity, creating more favorable conditions for invasive species such as cheatgrass, which would likely decrease overall forage quality and biodiversity. Thus, management schemes must be flexible and sensitive to changes in species composition resulting from climate change. Changes are likely to manifest in unexpected ways, and effects may be revealed subtly, suggesting that rigorous and comprehensive monitoring strategies could be needed.

Conclusions

Rangelands occupy around 600 million acres in the conterminous United States. Differences in rangeland area estimates reflect inconsistent treatment of woodland species and canopy cover thresholds between Federal agency inventory definitions. The majority of rangelands are privately owned, the area of which has remained relatively constant since 2000. The area of rangeland is expected to slowly decline between 2 and 6 percent by 2060.

The stable rangeland base produces an impressively steady flow of goods and services. Livestock numbers have been relatively constant: cattle have averaged around 96 million animals per year, whereas goats and horses have increased substantially. The trend in goat production is likely to continue as ranches become smaller and more diversified. Livestock numbers are quite sustainable given the current relationship between forage demand and forage production on rangelands. Rangeland productivity has remained relatively constant since 2000, although the Rocky Mountain Region exhibited a slight but significant increasing trend from 2000 to 2009. In fact, our findings suggest that from a national perspective, U.S. rangelands have the potential to support a good deal more grazing from both wild and domestic herbivores. Indeed, only a small proportion of rangelands are chronically overstocked.

The stable rangeland productivity and overall reasonable stocking rates contribute to the overall healthy status of U.S. rangelands. Only 20 percent of privately owned rangelands exhibit notable departure from reference conditions. Exotic and native invasive species contribute most significantly to decreased health of private rangelands, and shrub encroachment continues to decrease rangeland health, particularly in the Great Basin and Southwestern United States. Nonnative species are now present on at least 50 percent of private rangelands. Invasive species arguably represent the biggest threat to rangeland sustainability. The situation is less clear on Federal lands because of a lack of rangeland health information on NFS lands. The BLM rangeland health evaluation protocols reveal, however, that most BLM lands exhibit reasonably healthy characteristics. Our ability to sufficiently inventory and monitor the health of all Federal lands is hampered by a lack of effective and consistent sampling schemes; a situation noted in previous RPA Rangeland Assessments.

Chapter 12. Water Resources

In this chapter, we focus on the vulnerability of U.S. freshwater supplies considering all lands, not just forest and rangelands. We do not assess the condition of those lands or report on how much of our water supply originates on lands of different land covers or ownerships, because earlier Resources Planning Act (RPA) Assessment work addressed these topics. Regarding the source of water supply, we found that forests are the source of more than one-half of the U.S. water supply and of fully two-thirds of the water supply in the West and the South, and that national forests and grasslands alone are the source of one-half of the water supply in the Western States (Brown et al. 2008). Because forests are also generally the source of the highest quality runoff (Brown and Binkley 1994), it is not an exaggeration to say that forests play an extremely important role in the provision of water in the United States. Regarding the current condition of watersheds with National Forest System lands, we found, among other things, that the watersheds in the Interior West are generally at lower risk of impairment than those along the West Coast, which in turn are generally at lower risk than those in the East (Brown and Froemke 2010; Brown and Froemke 2012).

Resource Highlights

- Climate change will increase future water demands.
- Projected water withdrawal varies considerably across regions.
- Future water use depends most importantly on the agricultural sector.
- U.S. water yield is projected to decrease.
- The vulnerability of the U.S. water supply will increase.
- Increases in vulnerability depend both on changes in water yield and on growth in water demand.

Off-stream freshwater use in the United States increased more than 10-fold during the 20th century in response to tremendous population and economic growth. Although aggregate water withdrawal in the United States has leveled off in recent years and water use efficiency has been improving, future population and income growth may place additional demands on raw water supplies. As withdrawals increase, more water is often consumed, leaving less water in lakes, streams, and reservoirs. In addition, climate change is increasing hydrologic uncertainty and may reduce available supplies and increase demands. Taken together, these forces are making careful water management ever more important and call for a broad-scale understanding of the vulnerability of our water supply to shortage.

In assessing vulnerability, we are not attempting to show how water allocation will actually change in response to population growth and climate change. Rather, we aim to show where and to what extent water shortages would occur if populations grew and the climate changed as projected, but water management infrastructure and allocation procedures did not change and past trends in water use rates continued into the future. In other words, we are assessing the vulnerability of water supplies to shortage and showing where and when adaptation to changing circumstances is likely to be most essential.

Many different aspects of water resources could have been covered in this RPA Assessment, including changes in water quality, flooding, dwindling groundwater supplies, and instream flow issues. Our focus on shortages of renewable water supply should not be taken as an indication that other water-related challenges are less important.

Assessing Vulnerability to Water Supply Shortage

Vulnerability has been much discussed recently (e.g., Fowler et al. 2003; Füssel 2007; Gleick 1990; Vörösmarty et al. 2000). Some definitions emphasize not only the likelihood of problems, but also the ability to cope with those problems (Schneider et al. 2007; Wilby and Miller 2009). Given the broad geographic and temporal scope of this assessment, a limited definition of vulnerability was adopted, one that focuses on the consequences of projected trends if adaptation (e.g., additional conservation measures, water trading, and reservoir storage capacity) were not forthcoming. We estimate the vulnerability of renewable freshwater supply to shortage in the conterminous United States from now to 2060 in light of projected socioeconomic and climate changes.

Vulnerability is defined here as the probability of shortage, equal to the probability that the quantity of water demanded exceeds the available supply. "Current" vulnerability is evaluated during the 20-year period from 1986 to 2005. Future vulnerability is estimated for three 20-year periods centered at 2020, 2040, and 2060. For a detailed report on the water supply and demand projections and the assessment of future vulnerability of freshwater supplies to shortage, see Foti et al. (in press).

Vulnerability is estimated for the 98 assessment subregions (ASRs) of the conterminous United States. The ASRs and the water resource regions (WRRs) to which they belong are shown in figure 103. The ASRs are nearly identical to those defined by the U.S. Water Resources Council (1978) for its second national water assessment. Most of the ASRs are part of linked networks. Two or more ASRs are part of the same network when a sequence of water links, either natural (because of upstream-to-downstream flow) or artificial (via water diversions), connects them. The ASR-based water supply system for the United States consists of three multi-ASR networks and 15 single-ASR systems (figure 104). The biggest of the three multi-ASR networks includes 69 ASRs in the Central and Western United States. The other two multi-ASR networks include, respectively, 10 ASRs in the Northeast and 4 ASRs in the Southeast. Of the 15 single-ASR systems, 8 drain to the ocean, 5 drain into Canada, and 2 are closed basins.

A hydrologic network model (Labadie et al. 1984) was used to simulate water management in each water network. The model performs year-by-year linear optimizations of water allocation in a network consisting of a system of nodes connected by links. Each link is subject to capacity constraints and is assigned a priority that reflects the operating rules of the system. Each node is a point of water storage, reservoir evaporation, and/or water diversion. The simulations provide annual values of water flows in any link, storage levels and reservoir evaporation in each ASR, and water assigned to each demand, all of which depend on both climate and the set of priorities.

Ideally, the priorities would represent all of the detailed agreements about water storage and allocation that exist across the country. Lacking information on many of those agreements, we implemented a simple set of priorities in the following order: (1) instream flow requirements, (2) trans-ASR diversions, (3) consumptive water uses, and (4) reservoir storage. These priorities recognize the importance of guaranteeing a minimal amount of water for environmental and ecosystem needs before water is diverted for other uses and enable transbasin diversions to occur before within-basin diversions. For multi-ASR networks, water demands belonging to the same category were assigned the same priority regardless of their position in the

Figure 103. Water resource regions (WRR) (numbered) and assessment subregions (ASR) of the conterminous United States.

1 = New England. 2 = Mid-Atlantic. 3 = South Atlantic-Gulf. 4 = Great Lakes. 5 = Ohio. 6 = Tennessee. 7 = Upper Mississippi. 8 = Lower Mississippi. 9 = Souris-Red-Rainy. 10 = Missouri. 11 = Arkansas-White-Red. 12 = Texas-Gulf. 13 = Rio Grande. 14 = Upper Colorado. 15 = Lower Colorado. 16 = Great Basin. 17 = Pacific Northwest. 18 = California.

Figure 104. Water networks across the United States at the assessment subregion (ASR) level.

Natural links
Artificial links (trans-ASR diversions)
Mexico commitment
Isolated red dots indicate unconnected ASRs

network. Because reservoir storage was assigned the lowest priority level, water is stored in a given year only after all the demands reachable by a reservoir are satisfied. Water stored at the end of 1 year, minus an evaporation loss, is available for use the following year.

Modeling water allocation at the ASR scale makes the aggregate water supply in the ASR available to meet the aggregate water demand in the ASR. It is as if, within an ASR, the water were ideally located to satisfy as much of the total demand as possible, whereas, in fact, it may not be. A more accurate assessment of vulnerabilities could be obtained if the modeling were accomplished at a smaller spatial scale.

To capture in a rough sense the uncertainty about the estimates of vulnerability, water yields and water demands were estimated for each of the RPA scenario-climate combinations discussed previously (table 2), enabling nine separate estimates of vulnerability for each ASR.

Trends in Water Use: Past and Projected

Estimates of water withdrawal across the United States at a fairly fine scale are available at 5-year intervals from the U.S. Geological Survey (USGS) for the period 1985 through 2005 (Hutson et al. 2004; Kenny et al. 2009; Solley et al. 1988, 1993, 1998). Additional USGS water withdrawal data at a larger scale are available for the period 1960 to 1980. These data, along with data on water use drivers and rates of withdrawal per unit of driver, were used to simulate past and current conditions and as a source of information to project future levels of desired water withdrawal (from surface and groundwater combined) by ASR. Consumptive use proportions (the portion of withdrawal that does not return to the stream) from the USGS for years 1985, 1990, and 1995 were then used as the basis for converting estimates of withdrawal to estimates of consumptive use. The resulting estimates of desired consumptive water use, also called demand in this section, were produced for five water use sectors—domestic and public, industrial and commercial, freshwater thermoelectric, agricultural irrigation, and livestock and aquaculture—which were aggregated to a single estimate of demand for modeling vulnerability.

Withdrawal was estimated as number of demand units (e.g., a person for domestic use or an irrigated acre for agricultural use) times the withdrawal rate (withdrawal per demand unit), plus the future withdrawal attributable to climate or other factors that are largely unrelated to past levels of water use. Future levels of withdrawal rates were estimated by extending past trends to show where future water use will go if future supplies are no more constraining to withdrawals than in the recent past. This extension of past trends, of course, provides an unrealistic estimate of actual future water use for some locations, but suits our objective of showing where adaptation will be needed as population and climatic conditions change. At a large spatial scale, water withdrawal rates in most cases have changed gradually, rather than abruptly, presenting an orderly trend. Extrapolation is an accepted approach for projecting future trends when the past trend has been orderly, and in the absence of detailed knowledge of the underlying mechanisms affecting change or adequate data to model those mechanisms (Wilmoth 1998).

For comparison purposes, future water use was first projected with no future climate effects, using the population and income assumptions of the RPA A1B, A2, and B2 scenarios.[15] Climate effects on water use for the nine RPA scenario-climate combinations were then incorporated. The following six subsections describe past and projected withdrawals and consumptive use for the five water use sectors assuming no future climate change, with the projections corresponding to population and income estimates for the RPA A1B scenario. Those projections are then compared with those of the RPA A2 and B2 scenarios, followed by the introduction of effects of climate change on water use. Results are summarized here for the United States as a whole and sometimes also for eastern and western divisions of the United States, where the eastern division consists of WRRs 1 through 9 and the western division consists of WRRs 10 through 18 (see figure 103).

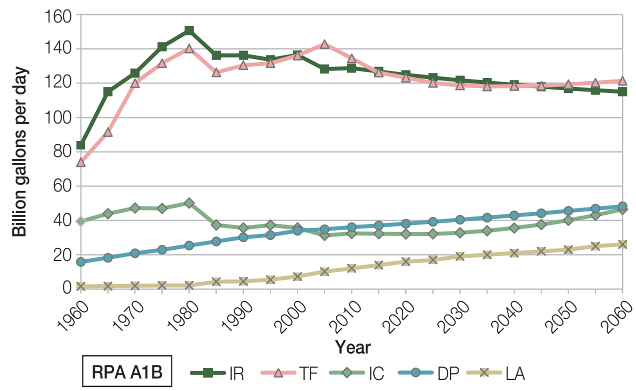
Domestic and Public Withdrawals

From 1960 to 2005, total domestic and public withdrawals in the United States steadily increased, from 16 to 35 billion gallons per day (bgd) (figure 105). The increase in withdrawals reflects the steady growth in population, which rose from 177 to 294 million during that period, and masks an important change in the domestic and public per capita withdrawal rate. Although U.S. per capita domestic and public withdrawals steadily increased from 1960 to 1990, from 90 to 122 gallons per day, since 1990 the nationwide withdrawal rate has leveled off, fluctuating between 118 and 122 gallons per day. The increasing per capita water use from 1960 to 1990 is attributable to a variety of factors, including a decrease in average household size (a certain minimum level of water use per household is largely unrelated to household size), the conversion of older or rural households to complete plumbing, and an increase in use of water-using appliances. These changes are consistent with the increasing real incomes and decreasing real domestic water prices that were experienced in many areas of the United States during the 1960-to-1990 period (Schefter 1990).

The leveling off of the per capita domestic and public withdrawal rate may be the result of conservation programs, the

[15] The RPA HFW scenario does not have any assumptions that vary from the RPA A1B scenerio for the purpose of the water analysis.

Figure 105. Past and projected annual water withdrawals in the United States by water use type, scenario RPA A1B, no future climate effects, 1960–2060.



DP = domestic and public. IC = industrial and commercial. IR = agricultural irrigation. LA = livestock and aquaculture. TF = freshwater thermoelectric.

expansion of water metering to previously unmetered taps, rising water rates, and the use of more efficient plumbing fixtures in newer homes and renovations, plus the completion of the conversion to modern plumbing and tapering off of the drop in household size (Brown 2000). Although the recent trends in the withdrawal rate do not provide a clear indication of future changes, the most recent change, from 2000 to 2005, was a decrease in the rates of both the eastern and western divisions.

Assuming a small but consistent decrease in per capita domestic and public withdrawals from 118 gallons per day in 2005 to 109 in 2060, and a steady increase in total population, from 294 to 444 million per the RPA A1B scenario, results in a projected gradual increase in total domestic and public withdrawals from 35 to 48 bgd (figure 105).

Industrial and Commercial Withdrawals

Industrial and commercial withdrawals in the United States steadily increased from 1960 to 1980, remained at about 36 bgd from 1985 to 2000, then dropped to 31 bgd in 2005 (figure 105). Because of the great variety of outputs of the industrial and commercial sector, the withdrawal rate is measured per dollar of total annual personal income (in year 2006 dollars). The rate declined from 11 gallons per day per $1,000 in 1960 to about 3 gallons in 2005. The drop in withdrawal rate is largely attributable to changes in the type and quantity of industrial and commercial outputs, such as a shift from water-intensive manufacturing and other heavy industrial activity to service-oriented businesses, and to enhanced efficiency of water use. Efficiency improved in response to environmental pollution legislation, which regulated discharges and thereby encouraged reductions in withdrawals, and technological advances facilitating recycling (David 1990). The most recent data show that the rate of decrease in water withdrawal per dollar of income has slackened somewhat.

The reasons for past declines in the industrial and commercial withdrawal rate—loss of heavy manufacturing plants and ever-present environmental concerns—are likely to continue to play a role, suggesting that recent past trends in the withdrawal rate are a good indication of future changes. Assuming a future drop in the industrial and commercial withdrawal rate from 3.0 gallons per $1,000 per day in 2005 to 1.3 in 2060, and a steady increase in total annual income from $11 to $36 trillion, results in a projected increase in total industrial and commercial withdrawals from 31 bgd in 2005 to 46 bgd in 2060 (figure 105).

Electric Energy Withdrawals

Freshwater use in the electric energy sector depends largely on how much electricity is produced at thermoelectric plants. About 90 percent of the electric energy produced in the United States is generated at thermoelectric power plants (USDOE EIA 2009), which require large amounts of water, mostly to cool and condense the steam used to drive the turbines. From 1960 to 2005, there was relatively little growth in production at hydroelectric and other renewable plants, such that production at thermoelectric plants grew at an impressive rate in response to population growth and the increasing per capita electricity use rate. Largely in response to this increasing production of electricity, freshwater withdrawals at U.S. thermoelectric plants rose rapidly from 1960 to 1980 and somewhat more slowly from 1985 to 2005, reaching 143 bgd (figure 105).

This near-complete reliance on thermoelectric power to accommodate expanding demand is now changing. Although aggregate production at hydroelectric plants is projected to remain roughly at its current level into the future, as the modest additions to capacity serve only to replace losses, production at other renewable plants (e.g., wind and solar), which use very little water, has begun to rise and is expected to continue to rise until at least 2035 (USDOE EIA 2010).

The average water withdrawal rate at freshwater thermoelectric plants dropped consistently from 29 gallons per kilowatt hour (kWh) in 1985 to 20 in 2005, as once-through plants—those that use water only once before returning it to the stream (at a higher temperature)—were retired or converted to recycling plants and as new recycling plants were added to the grid. Although withdrawal rates differ markedly between the East and West—in 2005, the rate was 24 gallons per kWh in the East but only 11 in the West, where recycling is more common—rates in all regions have been consistently dropping. The reasons for past declines in withdrawal rate are likely to continue to play a role, suggesting that recent past trends are a good indication of future changes.

Total annual electric energy production at thermoelectric plants is projected to grow from 2.5 trillion gigawatt hours in 2005 to 3.6 trillion in 2060, as the population increases but renewable energy sources provide a growing share of total production. Countering this growth in production at freshwater thermoelectric plants is the change in withdrawal rate, which for the United States as a whole is projected to drop from 20 gallons per kWh in 2005 to 12 in 2060. Combining these projections yields a projected total withdrawal at freshwater thermoelectric plants that drops from 143 bgd in 2005 to 118 bgd in 2035, then rises to 121 bgd by 2060 (figure 105).

Irrigation Withdrawals

Total irrigation withdrawals rose rapidly from 1960 to 1980, were stable at about 136 bgd from 1985 to 2000, then dropped to 128 bgd in 2005 (figure 105). This trend reflects most importantly the trend in irrigated acreage, which grew rapidly from 1960 to 1980 and, since 1980, has fluctuated between 58 and 62 million acres. These national totals, however, obscure an important regional difference. Irrigated acres in the arid and semiarid western division, where the vast majority of irrigation occurs, grew steadily from 1960 to 1980, declined steadily from 1980 to 1995, and in 2005 returned to the 1995 level of about 46 million acres. The drop occurred as farmers sold some land or water to cities, industries, and rural domestic users, and as pumping costs, crop prices, and government incentive programs caused marginal lands to be removed from irrigation. Irrigated acreage in the Eastern States grew continuously from 1960 to 2005, to 15 million acres, as farmers moved to rely more on irrigation water to supplement precipitation during dry times (Moore et al. 1990).

Since 1985, the irrigation withdrawal rate in the East has fluctuated between 1.28 and 1.41 feet per acre, and was 1.33 feet per acre in 2005, whereas in the West the rate fell consistently from 2.95 feet per acre in 1985 to 2.70 feet per acre in 2005. The much lower rate in the East is attributable to the higher precipitation levels in the East and to the prevalence of more efficient (sprinkler, drip) irrigation methods. The drop in the West reflects the gradual switch from flood to more efficient irrigation methods.

Irrigated acreage in the West is projected to continue the downward trend begun in the early 1980s, dropping from 46 million acres in 2005 to 42 million acres in 2060. In the East, irrigated acreage is projected to continue to increase, although at a decreasing rate, from 15 million acres in 2005 to 20 million acres in 2060. Total irrigated acreage is projected to peak in 2040 at 63 million acres and drop to 62 million acres in 2060. In the West, the withdrawal rate is projected to continue falling, reaching 2.4 feet in 2060, whereas eastern rates are projected to drop only slightly, reaching 1.3 feet in 2060. Combining these trends yields a drop in annual western irrigation withdrawal from 110 bgd in 2005 to 91 bgd in 2060, and a rise in eastern withdrawals from 18 bgd in 2005 to 23 bgd in 2060, for a total change from 128 bgd in 2005 to 114 bgd in 2060 (figure 105).

Livestock and Aquaculture Withdrawals

U.S. livestock and aquaculture withdrawals increased gradually from 1960 to 1995, then rose more steeply as the aquaculture sector expanded, reaching 10 bgd in 2005 (figure 105). Livestock withdrawal per capita has been dropping since at least 1990, largely because of changing consumer tastes (Haley 2001). In the West, daily per capita withdrawals dropped more than 35 percent between 1990 and 2005, reaching 12.5 gallons in 2005, whereas in the East the rate dropped 10 percent during the same time period, reaching 4.3 gallons in 2005. By 2060, the withdrawal rates are projected to decline to 8.0 gallons per capita per day in the West and 3.9 in the East.

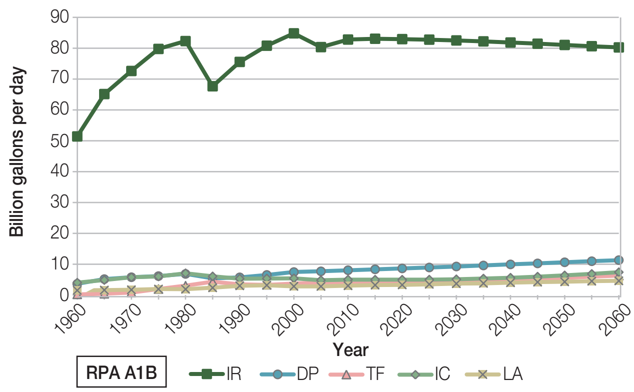
Aquaculture withdrawal per capita per day consistently rose from 1990 to 2005, from 9.9 to 42.7 gallons in the West and from 8.6 to 19.0 gallons in the East. The rate is higher in the West because of the prevalence of coldwater species such as trout, which benefit from a high dissolved oxygen content and are typically farmed using quick once-through withdrawals. Farming of warmwater species, which generally employs more slowly replenished ponds, is more common in the East, especially in the South. The withdrawal rates are projected to reach 72 gallons/capita/day in the West and 39 in the East in 2060. Total livestock and aquaculture withdrawals are projected to increase from 10 bgd in 2005 to 26 bgd in 2060 (figure 105).

Consumptive Water Use

A portion of most water withdrawals returns to the stream and becomes available for additional uses downstream. The quantity that does not return to the stream, called the consumptive use, is the appropriate quantity to compare with available supplies to assess the vulnerability of water supplies to shortages. Consumptive use was computed as a proportion of withdrawals based largely on consumptive use rates estimated from USGS data, as mentioned previously. Minor increases in these proportions are expected in the thermoelectric and irrigation sectors as producers gradually shift to more efficient technologies, and decreases are expected in the livestock and aquaculture sector as aquaculture grows as a percentage of total livestock and aquaculture withdrawal. Consumptive use rates vary widely by water use sector and by region of the country within a sector. The rates tend to be highest in the irrigation and livestock sectors and lowest in the thermoelectric and aquaculture sectors.

Irrigation was estimated to account for 81 percent of total consumptive use in 2005 (figure 106). As irrigation withdrawal lowers and some other withdrawals increase (figure 105), the portion of total consumptive use attributable to irrigation is projected to decrease, to 73 percent in 2060. The domestic and public sector was estimated to account for 8 percent of total consumptive use in 2005, with the other sectors each accounting for less than 5 percent of the total.

Figure 106. Past and projected annual consumptive water use in the United States by water use type, scenario RPA A1B, no future climate effects, 1960–2060.



DP = domestic and public. IC = industrial and commercial. IR = agricultural irrigation. LA = livestock and aquaculture. TF = freshwater thermoelectric.

Other Water Uses

In the effort to decrease our reliance on petroleum, many changes in liquid fuel production are expected in the coming years, most notably a rapid growth of biofuel production. Because processing of liquid fuels from biomass and other nontraditional sources is a relatively new industry, future water use in this sector is not represented in industrial water use projections that are based on past water use, and thus were computed separately.

In production of alternative liquid fuels, water is used for fuel processing and in irrigating some crops used to produce ethanol. Estimates of water use in processing were based on Energy Information Administration projections of future production of corn-based and cellulosic ethanol, biodiesel, and coal-to-liquid fuel needed to meet the renewable fuel standard (RFS) goals of the Energy Independence and Security Act of 2007 (USDOE EIA 2010). Estimates of additional irrigation attributable to ethanol projections were tied to estimates of the effect of ethanol on agricultural acreage (Malcolm et al. 2009). Meeting the RFS goals is estimated to increase total U.S. consumptive water use by 1.3 percent above what would otherwise occur in 2005. This percentage increase diminishes to about 1 percent by 2025 as less water-intensive crops are substituted for corn in ethanol production. Irrigation is projected to account for about 90 percent of the additional consumptive use that is needed in 2010 for production of liquid fuels, a percentage that drops to about 75 by 2060.

Other energy-related water uses involve drilling for oil and gas in shale deposits. The United States has vast oil shale reserves, but U.S. production of oil shale is in its infancy. Extraction of natural gas using newly employed hydraulic fracturing technology is developing as a major new energy source, however. Exploitation of these deposits could use significant quantities of water, but because of the great uncertainty about future production levels and water needs, we did not attempt to include exploitation of shale deposits as a projected water use.

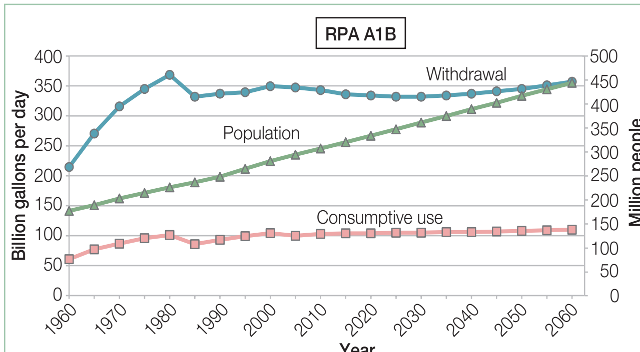
Projected Total Water Use Assuming No Future Climate Effects

Based on past trends, and in the absence of future climate change, water withdrawal rates were projected to decrease in all sectors but livestock and aquaculture. Changes in most drivers of water use—population, per capita income, per capita electricity consumption—are expected to increase pressure on water supplies; the projected decrease in irrigated acreage in the West, however, is an exception to this general trend. Combining these factors, in the absence of future climate change, aggregate U.S. withdrawal is projected to increase by only 3 percent from 2005 to 2060 despite a 51-percent increase in population under the RPA A1B scenario, whereas consumptive use increases by 10 percent (figure 107).

As would be expected given the relative levels of population among the three RPA scenarios, the projected withdrawals and consumptive use of the RPA A1B scenario fall in between the levels of the RPA A2 (higher population) and RPA B2 (lower population) scenarios. With no future climate effects, withdrawals actually decline for many years with the RPA B2 scenario, although they begin to increase slightly after 2050. Withdrawals are slightly greater under RPA A2 than RPA A1B, reflecting greater population growth under RPA A2, but also higher projected income levels under RPA A1B (figure 108).

Projected changes in water withdrawal vary widely among the ASRs. From 2005 to 2060, for the RPA A1B scenario (figure 109), withdrawals are projected to drop in 42 of the 98 ASRs, increase by less than 25 percent in 38 ASRs, and increase by more than 25 percent in the remaining 18 ASRs. The ASRs where withdrawals are projected to drop are rather evenly divided between the East and West, as are the ASRs expecting increases above 25 percent.

Figure 107. Past and projected annual water use and population in the United States, scenario RPA A1B, no future climate effects, 1960–2060.



Projected Water Use Under a Changing Climate

We now add in the future climate change effects to compute projected future water use for the nine RPA scenario-climate combinations. The effects of climate change on water withdrawals were estimated for irrigation use based on changes in precipitation and potential evapotranspiration, for domestic and public use based on changes in precipitation and potential evapotranspiration, and for thermoelectric use based on temperature changes. Whereas temperature is projected to increase everywhere (although more in some areas than others), precipitation is projected to increase in some areas and decrease in others. The precipitation projections of the different general circulation models (GCMs) differ considerably, yielding a range of resulting changes in water withdrawal. The primary climate change effect is that of potential evapotranspiration changes on plant water demand, most importantly in irrigated agriculture and secondarily in domestic and public landscape maintenance. In the thermoelectric sector, the primary effect is expected to be temperature increases on space cooling, which almost always relies on electricity.

Climate change is projected to increase water use substantially. For example, under the RPA A1B scenario, and averaging results from the three associated GCMs, U.S. withdrawals are projected to increase from 2005 to 2060 by 26 percent as compared with only 3 percent without future climate change. Of the 23-percent difference, 76 percent is due to increases in agricultural irrigation, 10 percent to increases in landscape irrigation, and 14 percent to increases in withdrawals at thermoelectric plants to handle the increase in space cooling demand. There is great variation across the RPA scenario-climate combinations in both projected withdrawals (figure 110) and consumptive use. Projections for 2060 vary from 354 bgd with the RPA B2-CSIRO-Mk3.5 future to 493 bgd with the RPA A2-MIROC3.2 future. Given the 2005 withdrawal level of 347 bgd, these projections for 2060 represent increases of 2 and 42 percent, respectively. The MIROC3.2 model projects the highest temperatures and lowest precipitation levels of the four GCMs for 2060.

Similar to the results under the assumption of no future climate change (figure 109), there is wide spatial variation in projections of future water withdrawals under a changing climate (figure 111). From 2005 to 2060, based on a GCM multimodel average, withdrawals under the RPA A1B scenario are projected to drop in 11 ASRs and increase by less than 25 percent in

Figure 108. Past and projected water withdrawals in the conterminous United States, by RPA scenario, no future climate effects, 1985–2060.

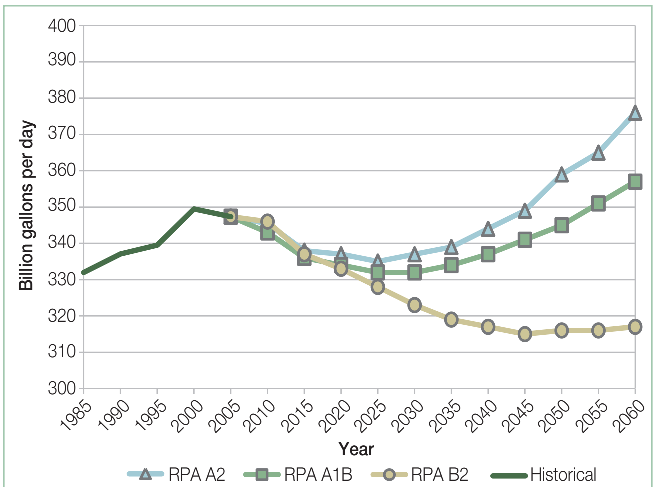


Figure 109. Percent change in projected water withdrawal, by assessment subregion (ASR), RPA A1B scenario, no future climate effects, 2005–2060.

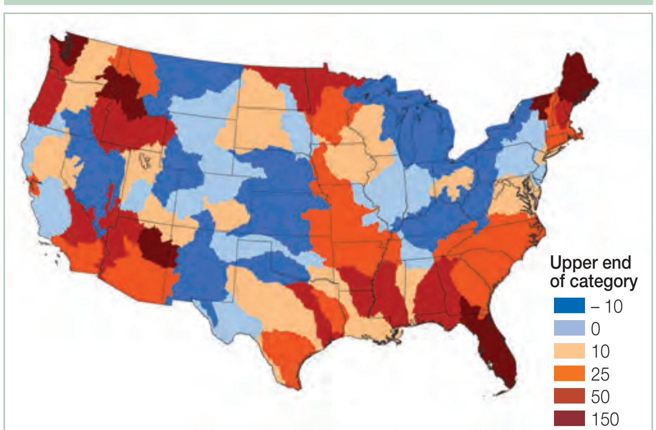


Figure 110. Past and projected water withdrawal for the conterminous United States for nine RPA scenario-climate combinations and RPA A1B with no future climate effects, 1985–2060. Future years are multiyear averages.

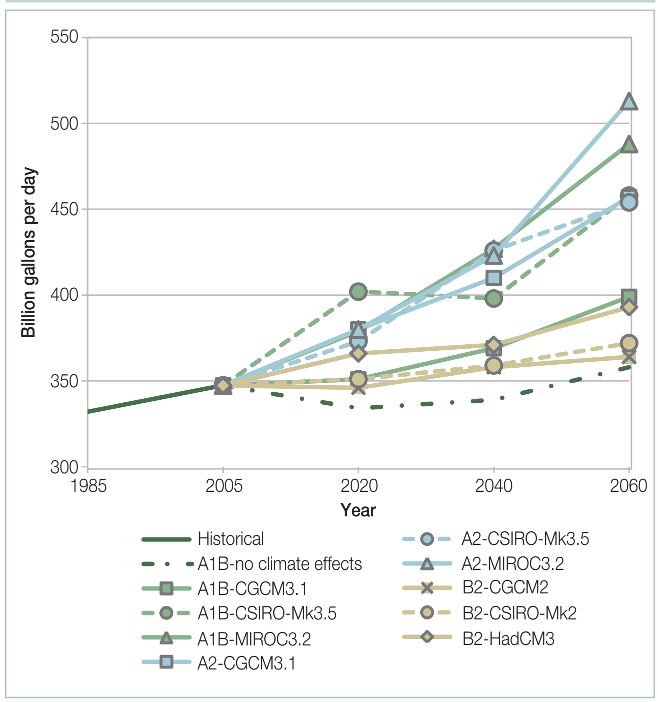
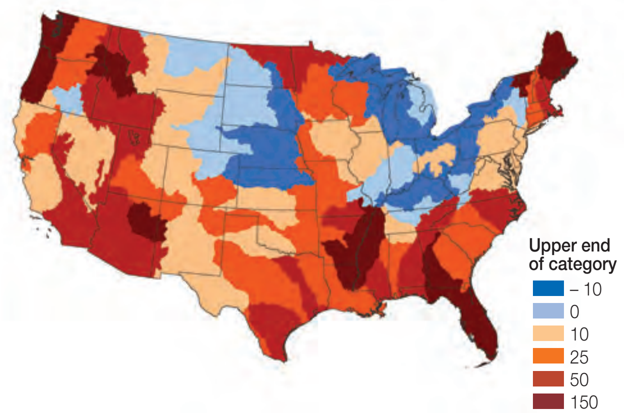


Figure 111. Percent change in projected water withdrawal, by assessment subregion (ASR), RPA A1B scenario, with climate effects (multimodel average), 2005–2060.



37 ASRs, by from 25 to 50 percent in 35 ASRs, and by more than 50 percent in the remaining 15 ASRs. The ASRs where withdrawals are projected to drop are mostly in the East, but ASRs where withdrawals are projected to increase by more than 50 percent are scattered across the country.

Projected increases in consumptive use remain much less than 50 percent throughout much of the West regardless of RPA scenario or climate projection, whereas projected increases in the East often reach well above 50 percent, especially for scenario RPA A2. This regional difference reflects principally the projected changes in irrigated acres in these two broad regions of the United States, with decreases in the West and increases in the East.

These projections, and the GCM models on which the projected effects of climate change rely, are educated guesses. The wide ranges highlight the uncertainty about the effects of increases in greenhouse gases on temperature and precipitation across the United States. Although we cannot be sure that the ranges reported here span the full extent of the future possibilities, it is notable that with all nine RPA scenario-climate combinations the long-term effects of climate change are always to increase aggregate water demands. Further, the principal effect is that of increasing temperature on vegetative water demand (for agricultural irrigation and landscape maintenance), not that of increasing temperature on electricity demand or of changing precipitation. Increasing precipitation in some locations ameliorates the effect of temperature increases, but precipitation increases, where they occur, are insufficient to balance out the temperature effect.

Aside from the projections of climate variables, perhaps the most crucial assumption made for projecting future water demand is that about future irrigated area, because irrigation accounts for the bulk of consumptive use and because irrigation requirements are more sensitive than the other water use categories to climate changes. Although recent trends in irrigated area provide some basis for extrapolation, unexpected changes in world markets for agricultural products could easily alter the trajectory.

Future Water Supply

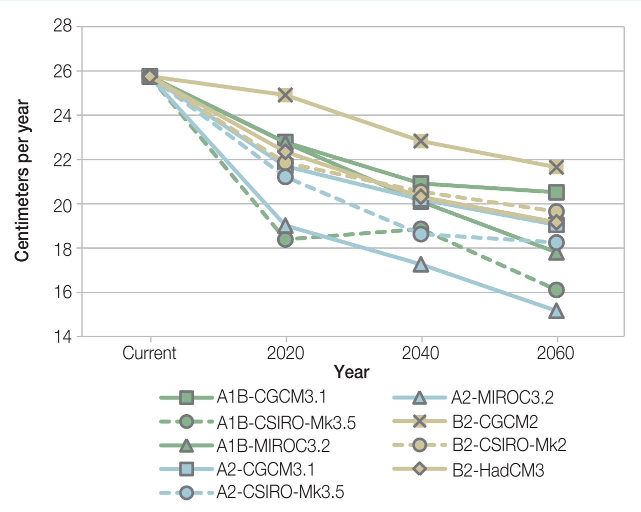
The water supply of an ASR is its water yield as modified (either amplified or diminished) by water redistribution (via natural flow and artificial diversions) and storage, as explained previously. Water yield, the sum of surface and subsurface runoff, was estimated as precipitation minus evapotranspiration using Eagleson's (1978) annual water balance model. The water yield model was implemented on a 5x5-kilometer grid for the United States and calibrated using three different streamflow datasets of measured or reconstructed natural flows.

In light of the lack of comprehensive information on the direct effects of elevated atmospheric carbon dioxide on plant water use across the various ecological conditions (e.g., mature forest, young forest of various species, agricultural crops) (Tubiello et al. 2007), these estimates assume no regional-scale direct effect of increasing carbon dioxide on plant water use per unit area. The major cause of the decrease in future water yield is the general increase in potential evapotranspiration that all GCMs project. Further, the water yield estimates do not reflect the effect of changing vegetation as the climate and land uses change over time.

Using annual temperature, precipitation, and potential evapotranspiration estimates from downscaled global climate model output, the water yield model was used to estimate future yield, and yield estimates were then aggregated to the ASR scale. For the United States as a whole, water yield is projected to decrease throughout the 21st century (figure 112). Considerable uncertainty surrounds the overall level of decrease, however. Projections differ by RPA scenario and by climate projection for a given scenario. Using the results from the CGCM3.1 and CGCM2 GCM models, for example, average annual yield decreases of 16, 22, and 17 percent are projected by 2060 under the RPA A1B, A2, and B2 scenarios, respectively. Taking the RPA A1B scenario as an example, average annual yield decreases of 22, 16, and 18 percent are projected by 2060 with the CGCM3.1, CSIRO-Mk3.5, and MIROC3.2 models. The variation in projected yield is primarily the result of differences among the models in estimates of temperature and precipitation.

Decreases in yield are projected for most but not all ASRs, as indicated in figure 113, which shows changes in yields for three RPA scenario-climate combinations. In general, the magnitude of the decrease is larger in humid areas (the Eastern United States and along the northwestern coast). Increases are projected for a few arid basins, most often in the Southwest (figure 113). The unexpected increases in average annual yield occur,

Figure 112. Mean annual water yield in the conterminous United States, by RPA scenario-climate combination for four 20-year periods. "Current" yield is evaluated over the 20-year period, 1986–2005. Future yield is estimated for three 20-year periods centered at 2020, 2040, and 2060.



despite increasing potential evapotranspiration and sometimes decreasing precipitation, because of increases in the *variance* of projected precipitation and potential evapotranspiration; an increasing variance produces higher flows in wet times, whereas flows during dry times can only drop to zero. Increases in average yield are more likely in arid climates because of their highly skewed distributions of precipitation and water yield. Note that the increases in average yield are very small in absolute terms.

As mentioned, supply depends not only on water yield but also on storage capacity, transbasin diversions, and instream flow requirements. Reservoir storage capacity for each ASR was determined by aggregating the normal storage capacities of natural and humanmade impoundments for the 1,196 reservoirs with a normal surface area of at least 5 square kilometers based on the U.S. Army Corps of Engineers National Inventory of Dams (USACE 2009). Storage capacities of the ASRs range to more than 40 million acre-feet for an ASR along the Missouri River (figure 114). Thirteen ASRs have at least 10 million acre-feet of storage. Reservoir evaporation was estimated from storage-to-surface area relationships and estimates of potential evaporation.

Information on trans-ASR diversions—water diverted from one ASR to another, usually as a result of legal agreements between jurisdictions—is scattered and difficult to gather. We relied on summaries by the USGS (Mooty and Jeffcoat 1986; Petsch 1985), supplemented by more recent information when available (California Department of Water Resources 1998; Colorado Water Conservation Board 1998, 2010; Litke and Appel 1989).

Figure 113. Change from current conditions to 2060 in assessment subregion (ASR) mean water yield (centimeters per year), based on comparing 20-year periods centered at 1996 and 2060, for a sample of RPA scenario-climate combinations: (a) RPA A1B-CGCM3.1; (b) RPA A2-CSIRO-Mk3.5; and (c) RPA B2-HadCM3.

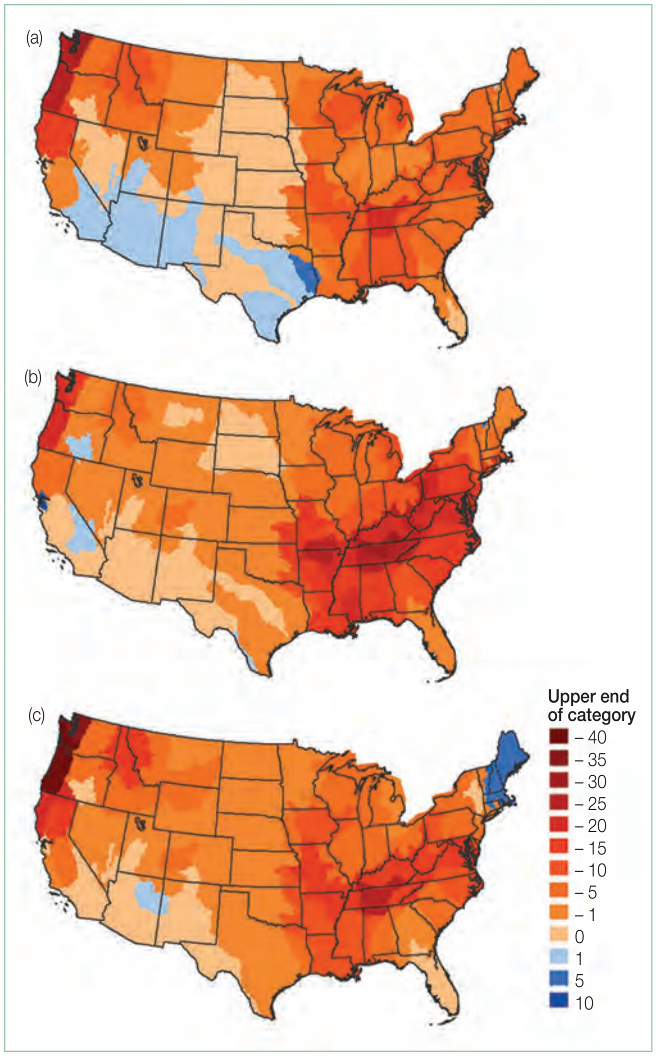
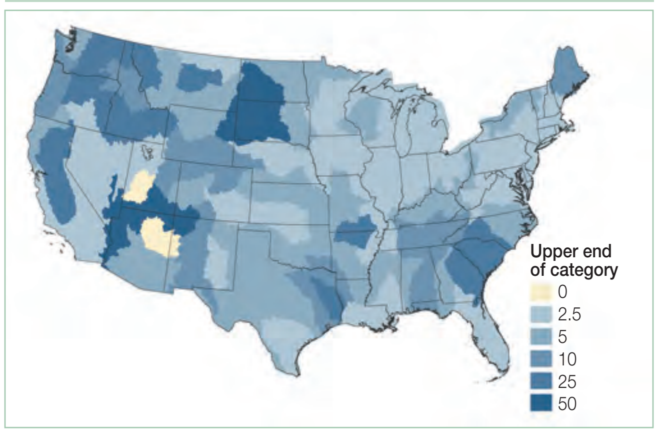
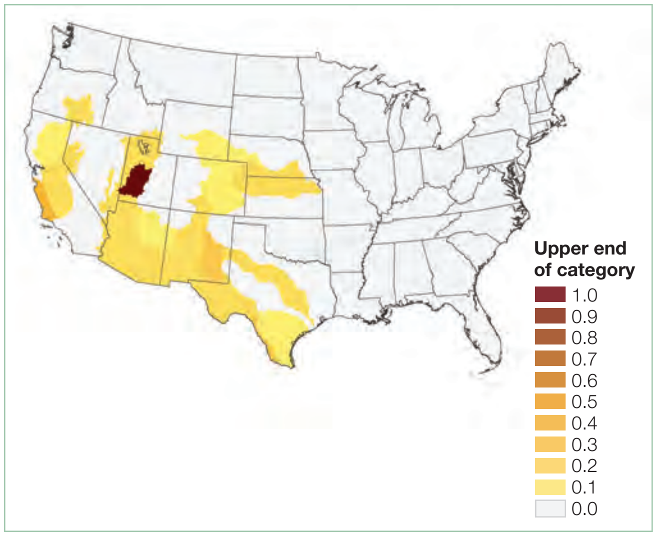


Figure 114. Assessment subregion (ASR) water storage capacity (million acre-feet).



Instream flow requirements are meant to ensure adequate supply for downstream users, including ecosystems, recreation, and hydropower. Determination of instream flow requirements involves a complicated mix of socioeconomic, biological, and environmental factors, which is not practical at the ASR scale. Because instream flow requirements cannot be ignored, we adopt the general guideline of Tennant (1976) and set the instream flow requirement of each ASR for both current and future conditions at 10 percent of average historical streamflow, computed from data for the period 1953 through 1985.

Figure 115. Current probability of annual water shortage.



Vulnerability of U.S. Water Supply

Vulnerability, the probability that supply is less than demand, was computed for each of the 98 ASRs in the United States for current conditions and for future conditions of each of the 9 RPA scenario-climate combinations. Each estimate of vulnerability was based on 20 years of simulation, which were used to estimate distributions of vulnerability and other key variables (Foti et al., in press). Supply of an ASR in a given year was computed as water yield within the ASR plus inflow from upstream and net transbasin diversion into the ASR minus releases to downstream ASRs, with movements of water into and out of an ASR determined by the network model given the priorities imposed and storage capacities available.

Current Vulnerability

The climate of the period 1986 through 2005 was taken as the *current* climate. The water supply systems of four-fifths of the western ASRs and about one-third of the eastern ASRs are vulnerable under current hydroclimatic and socioeconomic conditions, although in most ASRs the probability of shortage is less than 0.1 (figure 115). The most vulnerable ASRs tend to rely heavily on groundwater mining, a nonrenewable source of water that was not included in water supply as estimated for this analysis. This constraint should not detract from the principal focus of the RPA Assessment, which is the change in vulnerability from the current situation to the future. Some localized, within-ASR areas that are known to have faced shortages in the past are not revealed as areas of shortage at the ASR scale. This situation is most likely for areas located in the upper reaches of an ASR, which places them upstream of the bulk of the available water supply in the ASR, as in the case of Atlanta (Feldman 2009).

Future Vulnerability

Traces of future water yield for the period 2006 through 2060 and beyond were obtained by applying the water balance model using the climatic estimates of the nine RPA scenario-climate combinations. Each simulation used a distinct sequence of water demands that also reflect the climatic projections. The physical structure of the water network (links and nodes configuration), operating rules, storage capacities, and transbasin diversions were left unchanged for all simulations.

Vulnerability was assessed for years 2020, 2040, and 2060, each estimate representing 20-year periods centered at those years. Increases in vulnerability are projected to occur mainly in arid and semiarid areas of the United States where the current conditions are already precarious (figures 116 to 119). Most of the Eastern United States, on the other hand, is currently characterized by water abundance, and no eastern ASRs exhibit a probability of shortage greater than 0.1.

Vulnerability tends to increase over time as the effects of climate change become larger (figure 116). For a given RPA scenario, projected levels of vulnerability differ considerably across the climate models used (figures 117, 118, and 119). Compared with the RPA A1B scenario (figure 117), vulnerability is generally greater with the RPA A2 scenario (figure 118) and generally less with the RPA B2 scenario (figure 119). These differences are expected, given the higher population and temperatures in the RPA A2 scenario and lower levels of those variables in the RPA B2 scenario, especially later in the century. Notably, in all cases, the increases in vulnerability largely occur in the southwestern part of the country (California, the Southwest, the Great Basin, and the central and southern Great Plains).

The increasing vulnerability, evident by comparing figure 115 with figures 116 through 119, results mainly from the decreasing water supply and increasing water demand caused by the changing climate. Increase in population and economic activity alone are comparatively minor sources of the increasing vulnerability. Although decreasing precipitation (where it occurs) and

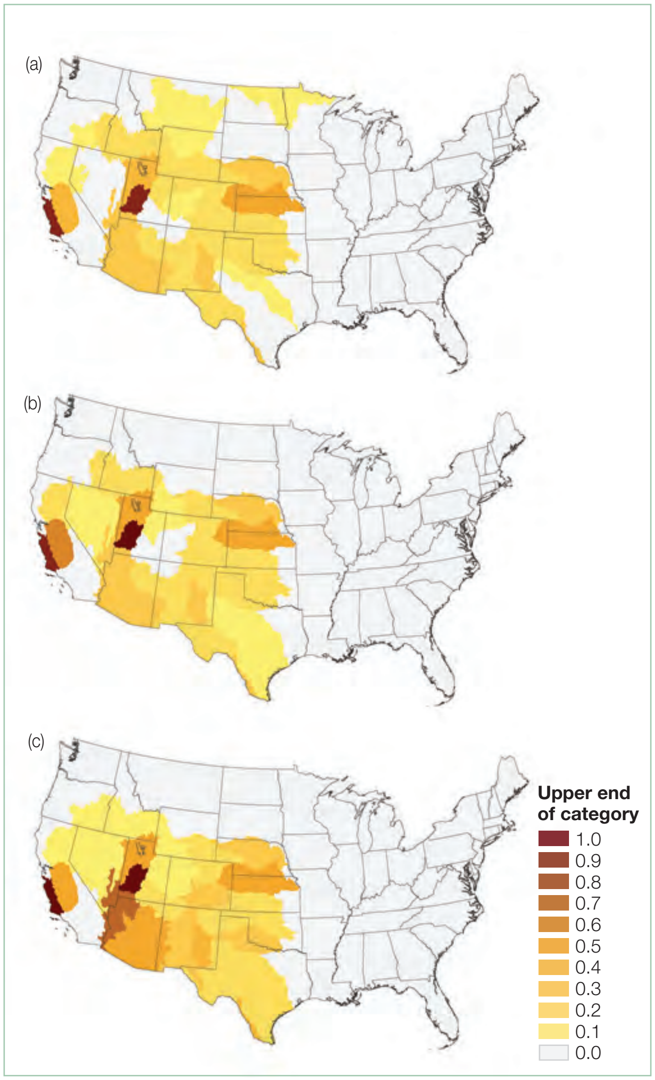


Figure 116. Vulnerability (probability of shortage) for RPA A1B-CGCM3.1, in the year (a) 2020, (b) 2040, and (c) 2060.

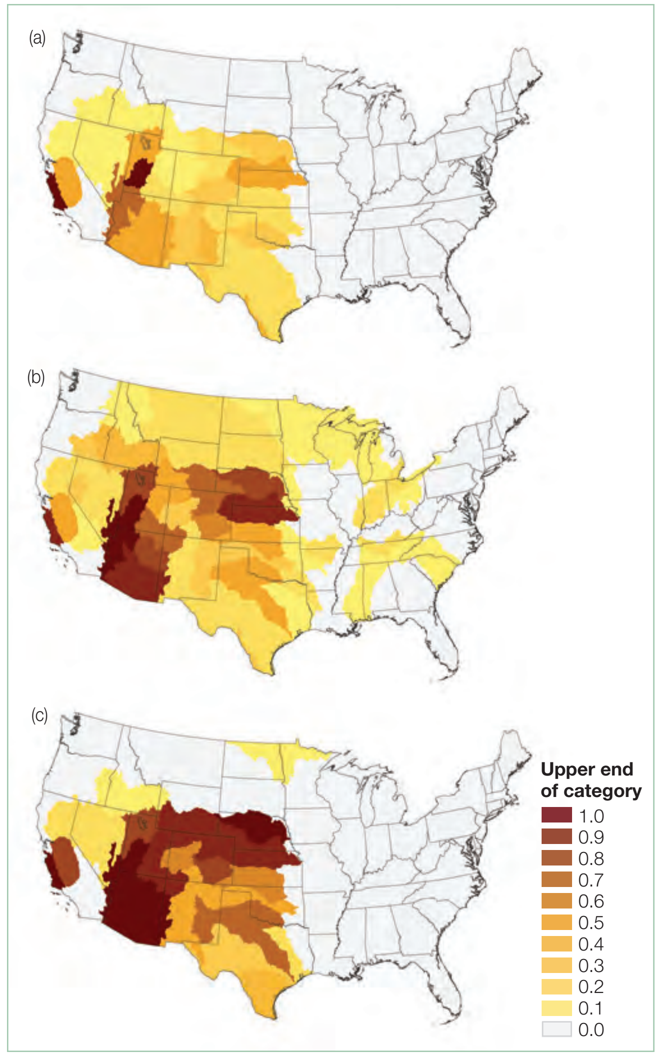


Figure 117. Vulnerability (probability of shortage) for the RPA A1B scenario in 2060 using the following climate models: (a) CGCM3.1, (b) CSIRO-Mk3.5, and (c) MIROC3.2.

increasing potential evapotranspiration both lead to decreases in water supply, the major effect comes from increases in evapotranspiration.

Furthermore, we find that in roughly half of the ASRs, future increases in the vulnerability of the water supply to shortage will depend more on decreases in water yield than on growth in water demand; in the remaining ASRs, the reverse is true. Total water use in the United States has leveled off in recent years, as irrigated area in the West has diminished and the efficiency of water withdrawals in nearly all sectors has improved. Although climate change will increase water demand, future water use efficiency improvements will mitigate that effect so that overall increases in desired water use in many ASRs are expected to be modest in comparison with the climate-induced decreases in water yield and thus in water supply.

These results assume no modifications to the physical structure of U.S. water networks. In addition, instream flow requirements and trans-ASR diversions were set constant, thereby ignoring possible future changes in surface water redistribution. Indeed, it is the purpose of this analysis to point to those locations where adaptation (e.g., larger transbasin diversion capacity or within-basin water transfers and enhanced water conservation) will be most needed. The simulations project a persistent decline in reservoir storage for many of the ASRs of the larger Southwest, with storage reaching zero and never returning to capacity in 10 of those ASRs, most notably in the ASRs along the Colorado River that contain Lakes Powell and Mead. This projected decline indicates that water scarcity there occurs primarily because of supply-demand imbalance rather than insufficient storage capacity, suggesting that increasing storage capacity there is probably not a successful adaptation strategy.

Figure 118. Vulnerability (probability of shortage) for the RPA A2 scenario in 2060 using the following climate models: (a) CGCM3.1, (b) CSIRO-Mk3.5, and (c) MIROC3.2.

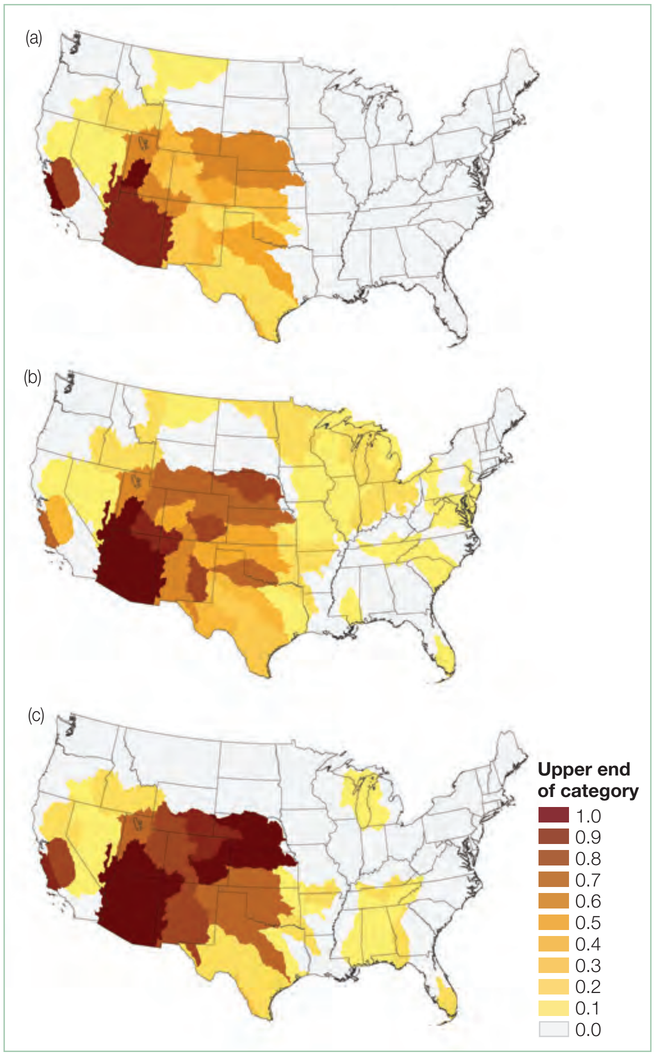
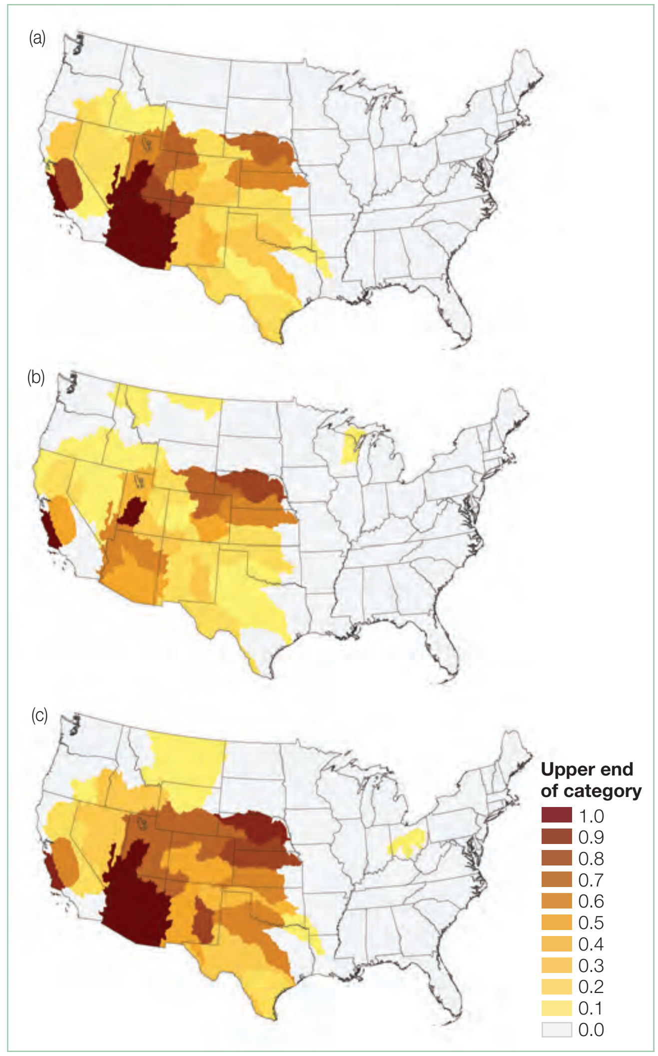


Figure 119. Vulnerability (probability of shortage) for the RPA B2 scenario in 2060 using the following climate models: (a) CGCM2, (b) CSIRO-Mk2, (c) HadCM3.



The simulations do show that some other ASRs of the larger Southwest might benefit from additional storage capacity, however. In addition, note that these results apply to aggregate ASR storage, and thus do not preclude the possibility of useful additions to storage in selected upstream locations.

As figures 117 to 119 make clear, there is much uncertainty about the precise levels of vulnerability projected for the ASRs of the United States. The utility of this assessment is not in its exact estimates of vulnerability but rather in the general pattern of changes in vulnerability that emerges—indicating that ASRs of the larger Southwest are likely to face substantial adaptation challenges—and in the finding that, except in a few ASRs or in selected, generally upland, locations, major additions to reservoir storage capacity would probably not be helpful.

Conclusions

Estimates of future conditions are inherently uncertain. This uncertainty is highlighted by the variation in projected vulnerability among the nine RPA scenario-climate combinations. Additional uncertainty arises because the water yield, water use, and downscaling models used with all of those combinations rely on numerous assumptions and judgment calls. That said, this RPA Assessment represents a concerted effort to realistically project future water demand and supply.

Assuming a stable climate, aggregate water withdrawal in the United States is projected to rise by 2060 by only 3 percent under the RPA A1B scenario. This low level of increase is projected to occur because expected future improvements in the efficiency of water use largely balance out the effects of population and income growth. Correspondingly, consumptive use is projected to increase by 10 percent. Climate change has the potential to greatly increase water demands, however, especially in the agricultural and domestic sectors because plant water demands increase as the ambient temperature rises, all else equal. Again assuming the RPA A1B scenario, aggregate water withdrawal is projected to increase by from 12 to 41 percent depending on which climate model is used. Corresponding increases in aggregate consumptive use with the RPA A1B scenario range from 26 to 86 percent. Projections are higher for the RPA A2 scenario and lower for the RPA B2 scenario. With all RPA scenarios and climate projections, decreases in water demand are projected for some ASRs, especially in the eastern portion of the country, but most ASRs would face increased demands.

Aggregate water yield is projected to decrease with all RPA scenario-climate combinations. For example, with the RPA A1B scenario water yield is projected by 2060 to decrease by from 16 to 22 percent depending on which GCM is used. Greater decreases are projected for the RPA A2 scenario. Decreases are projected for nearly all ASRs, and any increases are very small in absolute terms.

When assessed at the ASR scale, the larger Southwest—including parts of California, the southern Rocky Mountain States, and the central and southern Great Plains—is projected to face significant water shortages. Most scenario-climate combinations show the probability of shortage in any one year reaching above the 0.5 level in several basins. The highest vulnerability levels occur with the RPA A2 scenario. The CSIRO model yields the most widespread positive vulnerability, but the MIROC model tends to yield the most ASRs with vulnerability levels above 0.5.

These projections of vulnerability are of course not a prediction of future conditions. Clearly they are based on unsustainable levels of water use. Rather, the projections show the portions of the country that, based on current evidence, are likely to face the challenge of bringing water demand more in balance with water supply. Achieving such a balance would certainly include lowering water demand but may also include some efforts to increase supply. Note also that the projections are for renewable water resources (they do not allow for water mining) and assume that a minimum level of instream flow is maintained. The projected levels of vulnerability suggest that drier areas of the United States will continue to experience pressures to mine groundwater and deplete streamflow.

Chapter 13. Wildlife, Fish, and Aquatic Resources

The ecosystems occurring in the United States support a rich diversity of terrestrial and aquatic species (Ricketts et al. 1999). During the last one-half century, scientists and managers have learned much about how this diversity contributes to the well-being of humans (MEA 2005). The societal benefits attributed to wildlife and fish resources are many and include the provisioning of food, recreational opportunities, spiritual enlightenment, intellectual stimulation, and the maintenance of important ecosystem functions (Daily 1997). Increasing human populations, land use conversion, and intensive use of natural resources may compromise the ability of ecosystems to provide these services (Balmford and Bond 2005). For this reason, it is important to document changes in wildlife and fish resources as a gauge against which to judge whether notable shifts in resource status might prompt shifts in resource management policies. To that end, we report on recent historical trends in populations, harvests, and users of wildlife, fish, and aquatic resources; future projections of selected wildlife resources in response to land use and climate change; and recent trends and patterns of geographic concentration among species considered to be imperiled. We focus on species that would likely be affected by forest and rangeland management, but in many cases the data we have pertain to aggregate nationwide trends for species with diverse habitat affinities.

Resource Highlights

- Wildlife populations and harvests have mixed trends.
- Projected land use changes are expected to reduce the variety of forest bird species.
- Climate change will differentially stress terrestrial wildlife habitats across the country.
- Freshwater habitat conditions vary widely across the United States.
- Some commercially and recreationally important fish populations are in decline.
- Biodiversity in the United States continues to erode.
- Concentrations of at-risk species vary geographically.

Wildlife Resources: Status and Trends

This section describes the status and trends of wildlife species that are commonly harvested for recreation, subsistence, or commercial use and trends in breeding birds. Because management of resident wildlife is the responsibility of the States, population and harvest data on big game, small game, and furbearers were largely compiled from cooperating State wildlife agencies as coordinated through the Association of Fish and Wildlife Agencies. Management of migratory species largely rests with the Federal Government, and much of the population and harvest data for migratory game birds were obtained from U.S. Fish and Wildlife Service reports. Breeding bird trends were based on the North American Breeding Bird Survey (BBS), an annual survey that provides trends in relative abundance of more than 400 bird species nationwide (Robbins et al. 1986). Details on data sources and methods are reviewed in Flather et al. (in press a).

Big Game

Big game species were important in stimulating public concern for wildlife conservation (Organ et al. 2010). Big game includes large mammal species and wild turkey hunted for sport or subsistence. State data on big game populations and harvest were sufficient to document trends in black bear, white-tailed deer, mule deer, elk, pronghorn, and wild turkey, all of which are species affected in some way by forest or rangeland management activities.

Trends in big game populations have shown a general pattern of increase since the mid-1970s (figure 120). The most substantial increases nationally were observed among wild turkey, which grew at an annual rate of 4.8 percent. American black bear has also shown robust population growth at a 3.5-percent annual rate. White-tailed deer, pronghorn, and elk showed

Figure 120. Population trends in selected big game species for the Nation and RPA regions, 1975–2008. The number of States providing population estimates is given by "n =". Species and regions lacking a graph indicate that no State within that region provided population data.

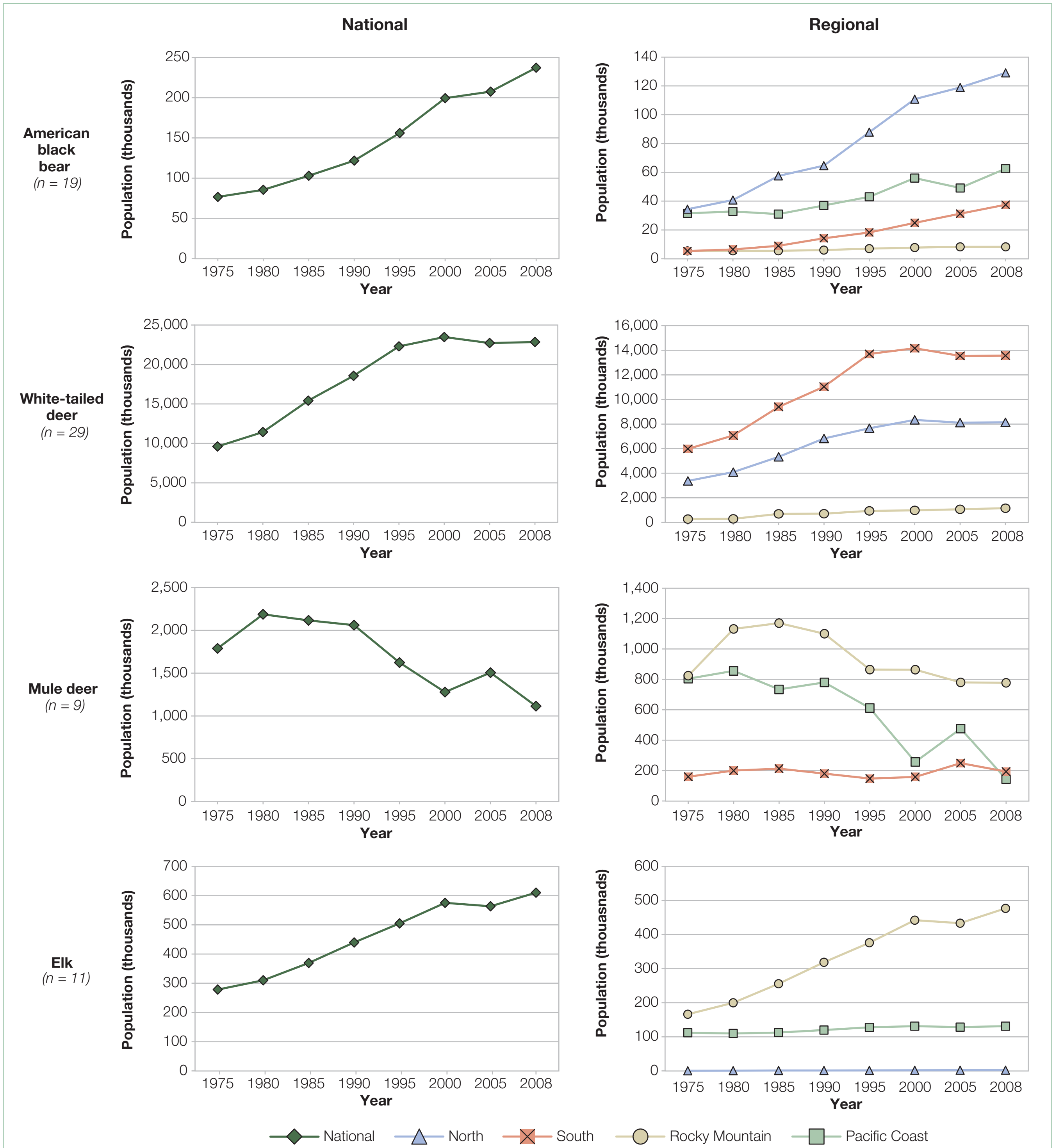
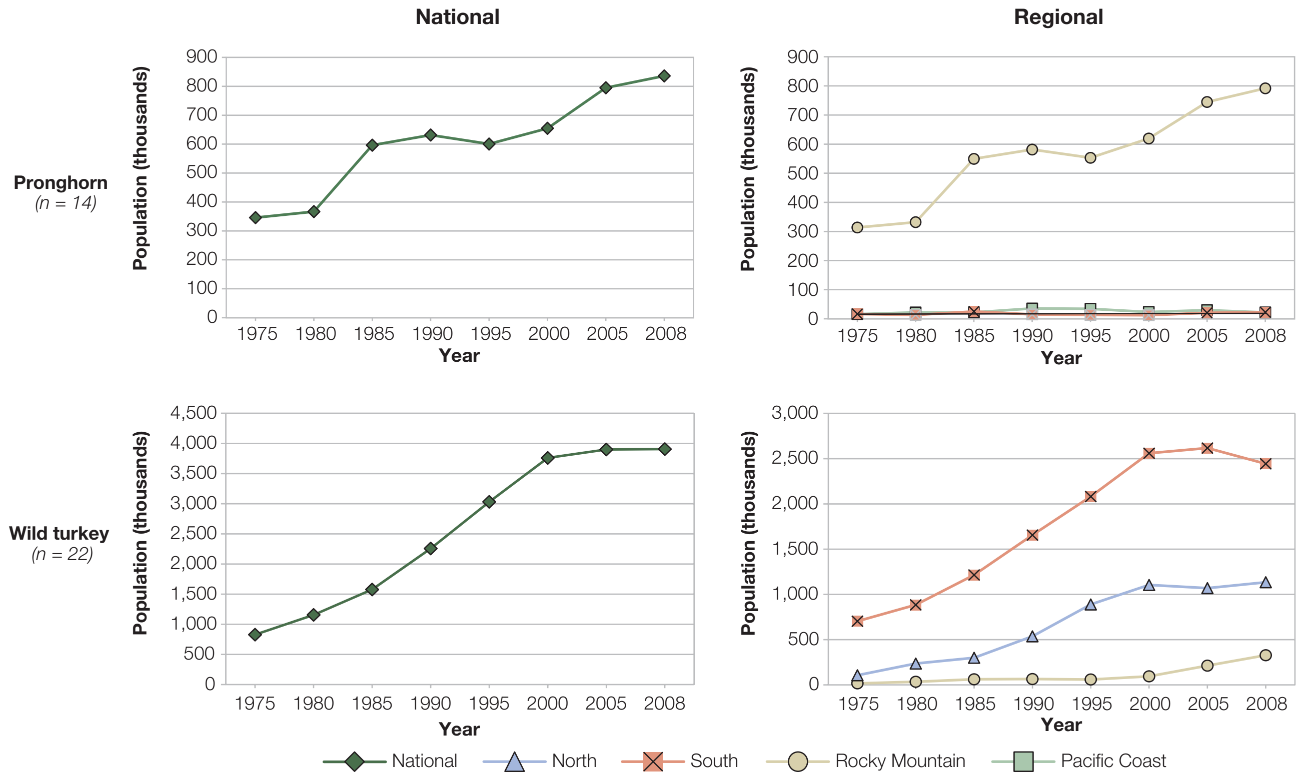


Figure 120 (continued). Population trends in selected big game species for the Nation and RPA regions,1975–2008. The number of States providing population estimates is given by "n =". Species and regions lacking a graph indicate that no State within that region provided population data.



Source: State wildlife agency data request coordinated by the Association of Fish and Wildlife Agencies; data on file with Michael S. Knowles, Rocky Mountain Research Station, Fort Collins, CO

more modest, but still strong, positive annual growth near 2.5 percent. Although white-tailed deer numbers have increased in the long term, there is some evidence in the North and South Regions that such population increases may not be sustainable, because populations have remained relatively constant since 2000. Unlike the other big game species reviewed, mule deer population estimates have generally declined. Since 1980, mule deer populations have declined annually by 2 percent. The causes of this decline are not fully understood owing to a complex set of interacting factors, including weather, urban and residential development, oil and gas development, habitat loss and degradation, predation, and competitive interactions with other big game species (Hurley et al. 2011; Mule Deer Working Group 2004; Unsworth et al. 1999).

Harvests generally tracked population trends among big game species in States where both harvest and population estimates were available. Growth in wild turkey harvests (4.8 percent) and elk harvest (2.4 percent) was nearly identical to population growth. Harvest growth among pronghorn lagged population growth rates by nearly 2 percent. Much of the habitat occupied by pronghorn occurs either on private lands or where private landowners control access to public habitat. Therefore, inadequate hunter access may account for the failure of harvest to keep pace with population growth (O'Gara and Morrison 2004). Harvest growth rates have also lagged population growth for black bear—a pattern that may be related to declining hunter participation (Mockrin et al., in press). Harvest growth rates among white-tailed and mule deer exceeded population growth rates by about 1 percent. In the case of white-tailed deer, this situation may reflect intentional liberalization of the harvest in an attempt to control what have become overabundant populations throughout much of their range (Côté et al. 2004).

Small Game

Small game species are small-bodied resident mammals and birds that can be native or desired nonnative species that were intentionally introduced to provide hunting opportunities. Few States are able to estimate small game populations over time, so we relied on the BBS to provide estimates of abundance trends among resident upland game bird species, most of which are affiliated with forest, shrubland, or grassland habitats.

Small game populations are highly variable, and several species show cyclical patterns that make it difficult to detect population trends. For example, of the 88 long- (1966 to 2008) and short-term (1997 to 2008) population trend estimates depicted in figure 121, more than one-half (57 percent) showed no evidence of a trend. Northern bobwhite has shown the most substantial and geographically consistent population declines among all species. Annual population declines have averaged 3.8 percent in the long term and 4.2 percent in the short term—declines that have been attributed to urban development, intensive agriculture, and habitat fragmentation (Williams et al. 2004). California quail was the only species of upland game bird that showed evidence of both long- (1.0 percent per year) and short-term (2.4 percent per year) population increases at the national level. Ring-necked pheasant have shown mixed population trends, with long-term declines in the North (2.0 percent per year) and Pacific Coast (2.3 percent per year) Regions, but increases in the South Region (2.1 percent per year).

The general pattern of small game harvests is one of declining trends at both the national and regional levels (Flather et al., in press a). The substantial decline in the number of hunters pursuing small game (Mockrin et al., in press) has undoubtedly played a role in these harvest declines. The greatest harvest decline was observed among hares with an average annual decline of 7.2 percent since 1975. Quail harvests dropped by more than 20 million birds from 1975 to 2008, an average annual loss of 5.2 percent. Cottontail harvests declined by a similar magnitude, averaging reductions of 4.5 percent annually since 1975. More modest declines were observed for squirrel (2.9 percent per year), forest grouse (2.9 percent per year), and prairie grouse (2.7 percent per year) harvests. The only species deviating from this pattern of broad decline was pheasant in the South and Rocky Mountain Regions, where harvest estimates indicate a general increase in the number of birds bagged since the mid-1980s.

Figure 121. Long- (1966–2008) and short- (1997–2008) term population trends in selected upland game birds for the Nation and RPA regions from the North American Breeding Bird Survey. Bolded arrows indicate the direction of significant ($P \leq 0.05$) trends; minus (-) and plus (+) indicate a trend that was not determined to be significantly different from stable. Missing value entries (•) occur when there was an insufficient sample (≤14 routes) to estimate a trend.

Species	Long term 1966–2008					Short term 1997–2008				
	National	North	South	Rocky Mountain	Pacific Coast	National	North	South	Rocky Mountain	Pacific Coast
Native										
Northern bobwhite	↘	↘	↘	↘	•	↘	↘	↘	↘	•
Mountain quail	–	•	•	•	–	–	•	•	•	–
Scaled quail	↘	•	↘	–	•	↘	•	–	↘	•
California quail	↗	•	•	↗	↗	↗	•	•	+	↗
Gambel's quail	+	•	•	+	+	+	•	•	+	+
Blue grouse	+	•	•	↗	–	↗	•	•	↗	+
Ruffed grouse	+	–	–	+	–	+	+	–	+	+
Greater prairie-chicken	+	+	•	↗	•	↗	+	•	↗	•
Sharp-tailed grouse	+	↗	•	+	•	+	↗	•	+	•
Sage grouse	↘	•	•	↘	–	–	•	•	–	+
Nonnative										
Gray partridge	–	+	•	–	↘	+	+	•	–	–
Chukar	+	•	•	+	–	+	•	•	↗	–
Ring-necked pheasant	–	↘	↗	+	↘	↗	↘	↗	↗	↘

Source: J.R. Sauer, personal communication

Migratory Game Birds

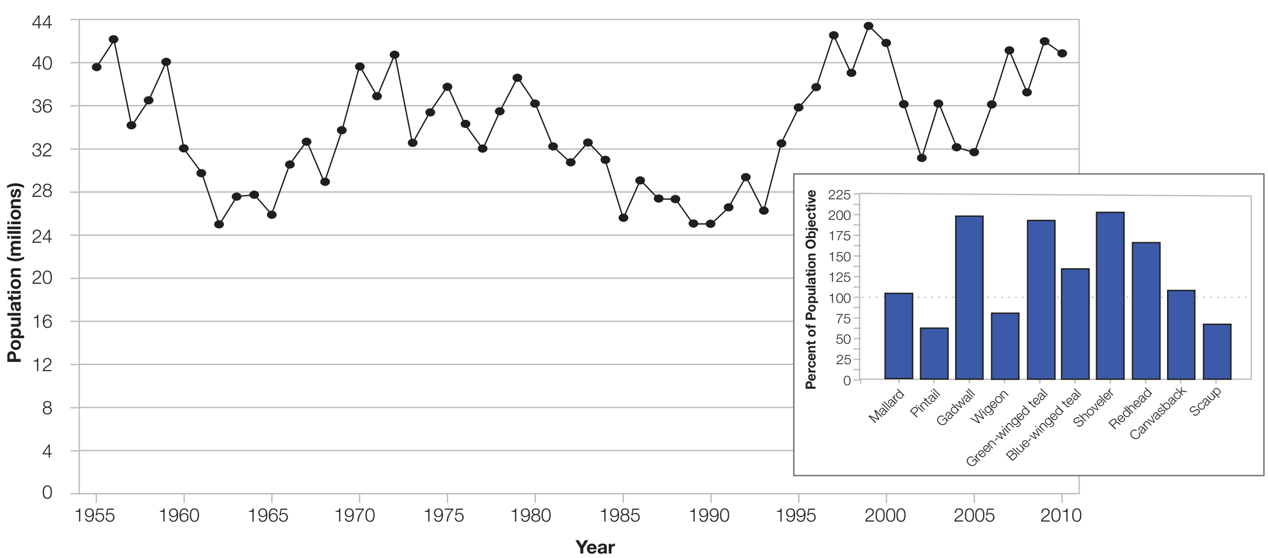
Migratory game birds collectively refer to waterfowl (ducks, geese, and swans) and the so-called "webless" migratory species that include mourning dove and woodcock. This species group has a rigorous management history that is traceable to a series of international agreements signed at the turn of the 20th century to protect and conserve this important biological resource. This focused management has led to the development of what many consider to be the leading monitoring system for continentally distributed species (Nichols et al. 1995). Many of the species in this group will occupy habitat or aquatic ecosystems that are within or in proximity to forests and rangelands.

Waterfowl

Breeding duck population estimates in 2010 were 21 percent higher than the long-term (1955 to 2009) average (figure 122). After reaching record lows in 1990 (25 million birds), duck populations increased nearly 63 percent, to 41 million birds by 2010. Breeding population trends among the 10 most common duck species have been variable. Seven of the 10 most common species have 2010 breeding populations that exceed their long-term means, with green-winged teal, shoveler, gadwall, and redhead exceeding those averages by more than 60 percent. Mallard, the most abundant duck (8.4 million), exceeded its long-term average by 12 percent. Three duck species remain less abundant than their long-term average breeding population: scaup (16 percent), northern pintail (13 percent), and American widgeon (7 percent). These same three species also remain less abundant than the population objectives specified in the North American Waterfowl Management Plan (1994) (figure 122 [inset]). Given that harvests of ducks are established adaptively, with population monitoring data feeding harvest regulation decisions (Nichols et al. 2007), it is not surprising that harvest trends mirror breeding population trends (Flather et al., in press a).

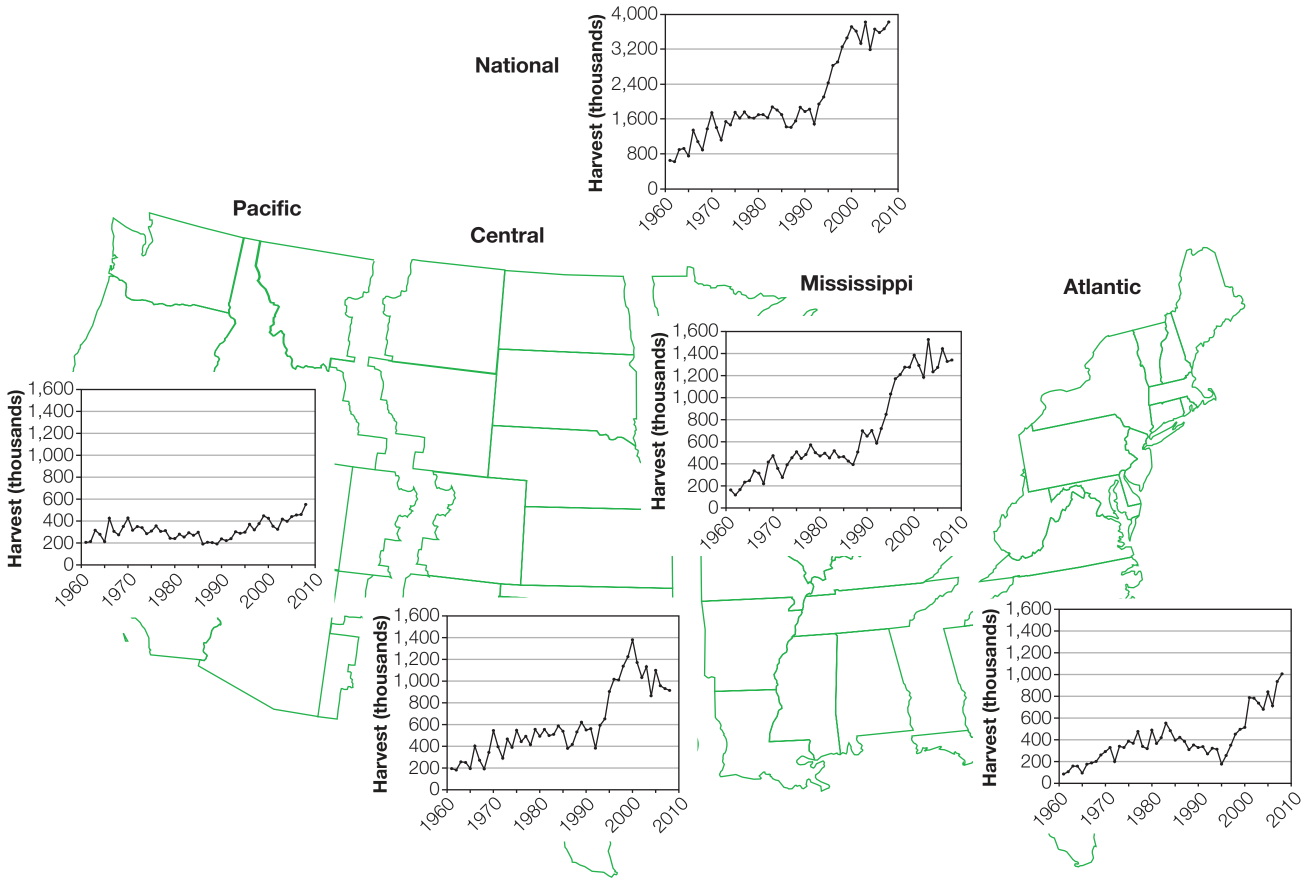
Populations of geese and swans (including Canada geese, brant, snow geese, Ross' geese, emperor geese, white-fronted geese, and tundra swans) are monitored by surveying 30 separate population segments. A total of 11 populations showed at least marginal evidence of increases during the 2001-to-2010 period, and 16 populations showed no evidence of a trend. Therefore, 90 percent of goose and swan populations were determined to be stable or increasing since 2000. Two populations (Atlantic Flyway resident populations of Canada geese and Dusky Canada geese) showed at least marginal evidence of population declines. The general increasing trend in goose populations is reflected in goose harvest trends. Since the early 1990s, there has been a steady and substantial increase in the goose harvests nationally and across all flyways (figure 123). The one flyway showing deviations from this pattern is the Central Flyway—after reaching peak harvests in 2000, the number of geese taken by hunters has declined by nearly 34 percent. Swan harvest estimates, like their populations, have been variable, with little evidence of a trend (Flather et al., in press a).

Figure 122. Trends in duck populations, 1955–2010, and the relation between 2010 population estimates for 10 principal duck species and population objectives specified in the North American Waterfowl Management Plan, measured as percent of objective (inset).



Sources: U.S. Department of the Interior, U.S. Fish and Wildlife Service 2010; Environment Canada Canadian Wildlife Service, and Secretario de Desarrollo Social Mexico, 1994.

Figure 123. Trends in goose harvest, 1961–2008, nationally and by flyway.



Sources: P. Padding, personal communication; R. Raftovich, personal communication

Webless Migratory

Woodcock populations continue to show a long-term pattern of population decline at an annual rate of nearly 1 percent compared with the 1968-to-2010 period. Regional population trends in the eastern and central management areas[16] generally mirror the national counts, suggesting that the causes for the declines are widespread. The population trend estimates are consistent with BBS trends—the latter showing an average annual decline of 2.5 percent from 1966 to 2008. Recent harvest estimates for woodcock have also declined by more than 50 percent since 1999 in both management areas.

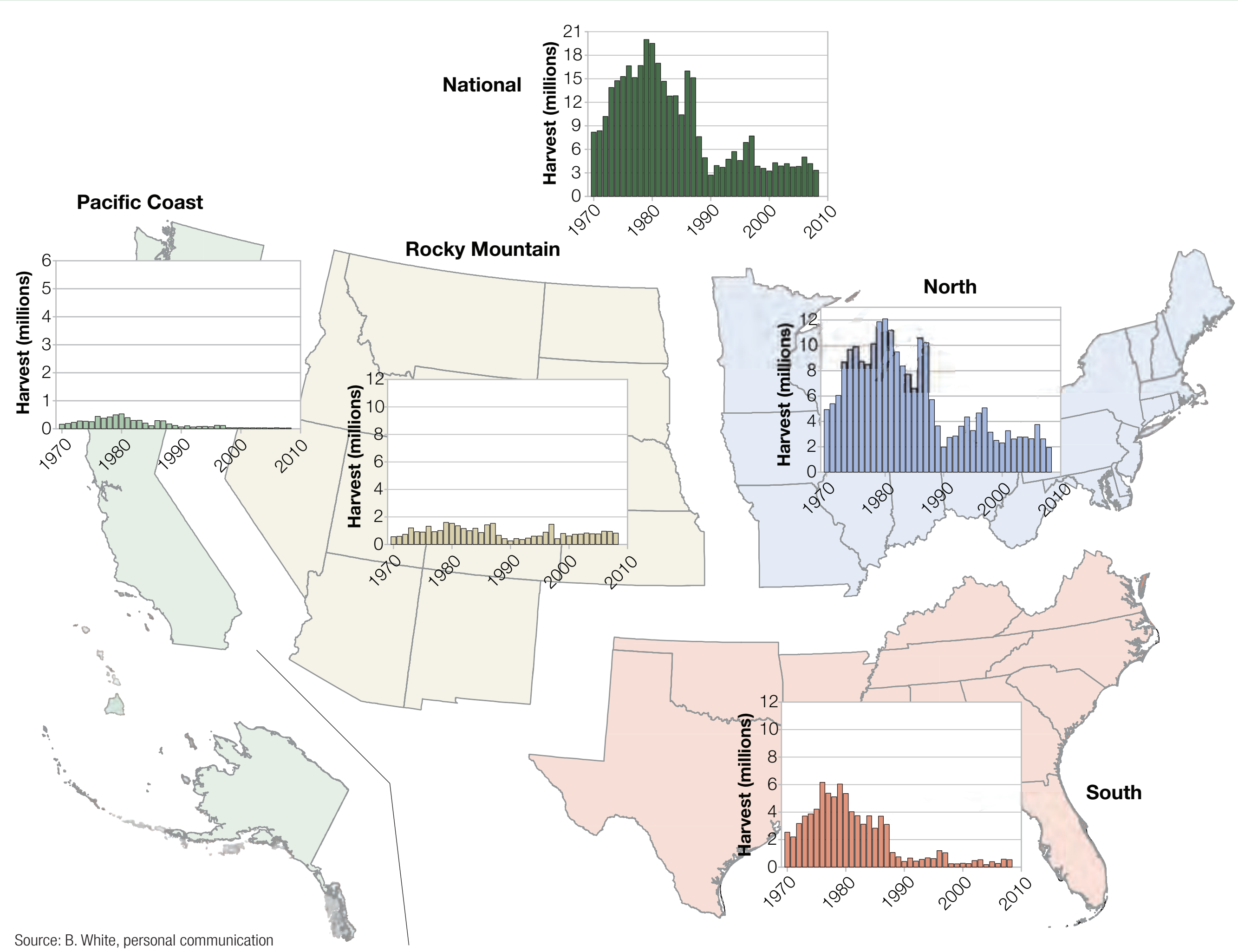
Although they are adapted to urban and rural landscapes, mourning doves declined in abundance across all three management areas since the mid-1960s. Unlike woodcock, regional call-counts indicated variable population declines, with the greatest decline occurring in the western management area (1.3 percent per year) and the least in the eastern management area (0.3 percent per year). Cumulative declines in call counts were 45, 22, and 12 percent for the western, central, and eastern management areas, respectively. The population trend estimates are consistent with BBS trends, the latter showing an average annual decline of 0.4 percent from 1966 to 2008. Harvests have declined since 1999, with the greatest drop occurring in the central management area (34 percent). Harvests in the western management area have actually increased slightly (5.6 percent) since 1999.

Furbearers

Furbearers are a group of mammals, many of which are forest dwellers that have traditionally been harvested for the commercial value of their fur (Organ et al. 2001). The nocturnal and secretive nature of many furbearers makes it difficult to evaluate the population status of most of these species, so we relied on harvest statistics as the only quantitative measure of status and trends for this species group. We did not expect harvest trends to closely track population trends because variation in furbearer harvests is a complex interaction between population size, trapping effort, pelt prices, and the susceptibility of species to harvest (DeVink et al. 2011) and because the former are strongly influenced by pelt prices (Flather et al. 1999).

[16] Management areas for webless migratory species (eastern, central, and western) are defined by the U.S. Fish and Wildlife Service.

Figure 124. National and RPA regional trends in total fur harvest among 28 species, 1970–2008.



National trends in fur harvests show three distinct periods: a period of rapidly increasing harvest during the 1970s, a period of rapidly declining harvest during the 1980s, and a relatively stable harvest level since 1990 (figure 124). After reaching a peak of 20 million pelts in 1979, harvests declined to 2.7 million pelts in 1990. The previous Resources Planning Act (RPA) Assessment documented the strong influence of pelt prices on harvest (Flather et al. 1999), with peak prices during the late 1970s and mid-1980s associated with peaks in harvest (figure 124). Prices during the 1990s were about 60 percent less than peak levels.

Fur harvest trends vary regionally. The North Region has always dominated fur harvests and, since 1995, nearly 70 percent of all pelts came from the region (figure 124). Fur harvests in the Pacific Coast Region have always contributed the least to the national total, accounting for about 1 percent of the total harvest during the same period.

Although prices that trappers receive for their pelts are a strong determinant of harvest, other factors likely have also played a role in fur harvest trends. The number of people choosing to trap has declined in recent years (Organ et al. 2001). Furthermore, furbearer management remains controversial and there have been efforts by some segments of society to prohibit trapping (Andelt et al. 1999; Conover 2001). Recent research has shown that negative opinions about trapping are on the decline (Duda et al. 2010), however, and this shift in opinion may be traced back to the increasing incidence of wildlife damage to personal property and concern for human health (Conover 2001; Organ et al. 2001; Southwick et al. 2005). In the absence of economic incentives (increasing pelt prices), the public will bear an increasing proportion of the costs associated with the control of furbearer populations.

Breeding Birds

Birds have long been thought to be good indicators of landscape change, because changes in habitat affect the abundance and diversity of bird species that occupy a particular region (Flather and Sauer 1996; Pidgeon et al. 2007). We used the BBS to evaluate the status and trends among commonly occurring species throughout the United States, grouping bird species by life-history characteristics to provide a more detailed accounting of how birds have responded to changes in their environments. We examined three broad bird groups, defined by nest type and location, migration status, and breeding habitat type. The number of species with increasing, decreasing, and stable trends was estimated for each of the life-history groups and was based on a hierarchical modeling approach (Sauer and Link 2002).

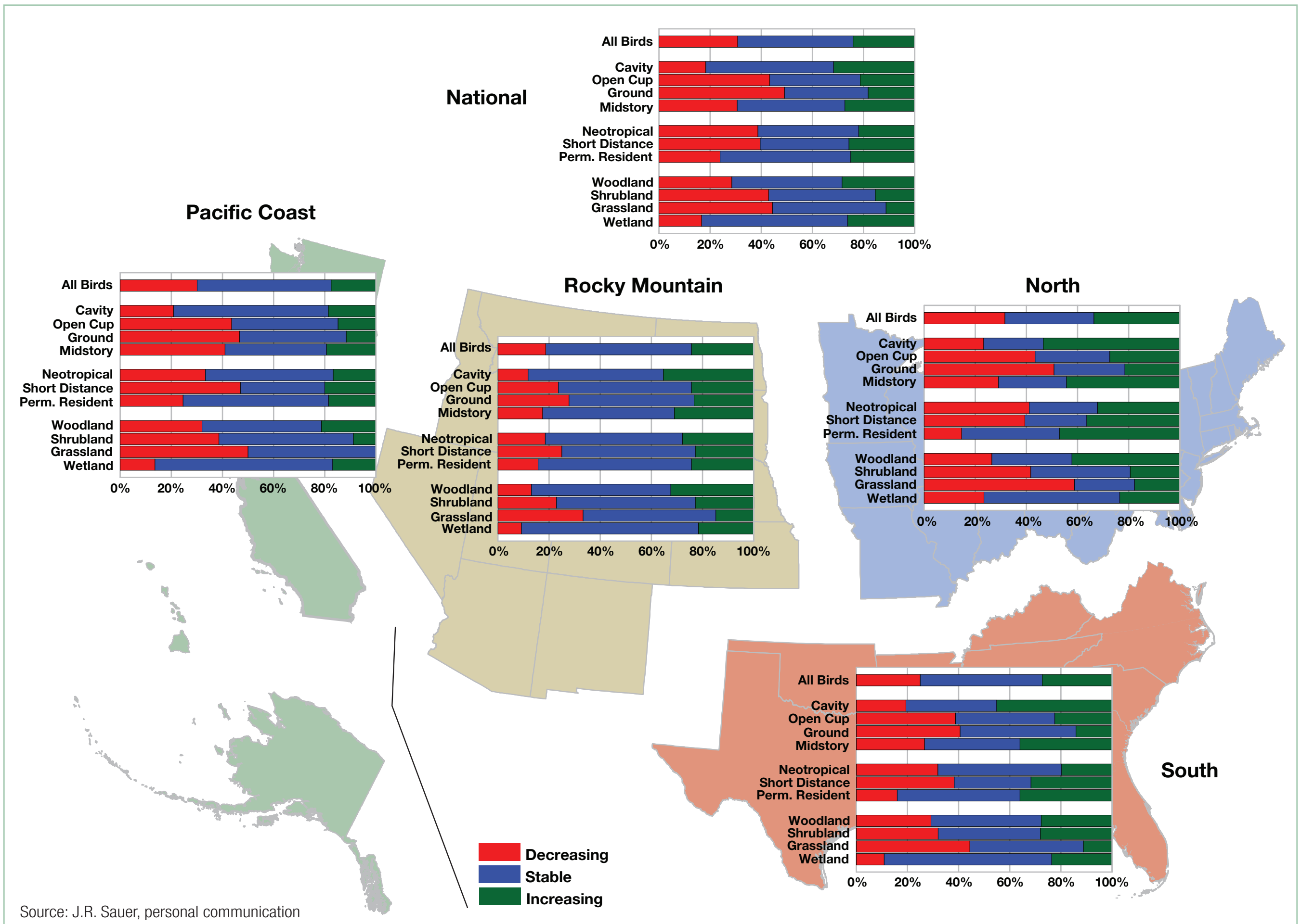
We documented long-term (1966 through 2008) abundance trends to establish the broad geographic pattern of species with increasing, decreasing, and stable trends. Second, we documented abundance trends since 1996 to assess the degree to which these trends have changed from the previous RPA Assessment (Flather et al. 1999).

Long-Term Abundance Trends (1966 through 2008)

For the 426 species of birds with sufficient data to estimate nationwide trends, 45 percent had stable abundance during the 42-year period. A higher percentage of species had declining trends (31 percent) than increasing trends (24 percent). The North Region had the greatest percentage of species with declining trends (32 percent), followed by the Pacific Coast (30 percent), South (25 percent), and Rocky Mountain (19 percent) Regions (figure 125). The majority of species in the Rocky Mountain and Pacific Coast Regions had stable abundance trends (57 and 52 percent, respectively).

Among the bird groups examined (figure 125), species that breed in and around human settlement (62 percent), nest on or near the ground (49 percent), or nest in grassland habitats

Figure 125. The percent of bird species (by broad life-history groupings) with decreasing, increasing, and stable trends, 1966–2008, for the Nation and by RPA region. Species were counted as increasing or decreasing if the trend was different from 0 at P ≤ 0.05.



Source: J.R. Sauer, personal communication

(44 percent) had the greatest proportions of declining species. Given that urban land has been increasing (Wear 2011), the high number of species with declining abundance that breed in and around human settlement is surprising and may be a result of relocation of BBS routes away from urbanizing areas, where traffic noise makes it more difficult to detect species (USDI USGS 2007). Unlike the findings from the previous RPA Assessment (Flather et al. 1999), we did find different responses across migratory strategies. Nearly 40 percent of neotropical and short-distance migrants showed significant declining abundances compared with only 24 percent of those species that are permanent residents. Regional patterns of abundance trends among bird groups did indicate that regions already characterized by prominent human effects tended to have higher proportions of declining species. Weighted mean percentages across bird groups indicated that the North Region had the highest percentage declining species on average (40 percent); followed closely by the Pacific Coast (39 percent) Region. The South Region had an average decline among bird groups of 34 percent. The Rocky Mountain Region had the lowest mean percentage of declining species (22 percent) and was the only region where the mean percentage of increasing species (27 percent) exceeded the percentage of declining species.

Abundance Trends Since the Last RPA Assessment (1997 through 2008)

The last RPA Assessment (Flather et al. 1999) reported on bird abundance trends through 1996. Estimation of trends from 1997 to 2008 gave us an opportunity to see if recent trends were consistent with long-term trends. Because the trend is being estimated over a shorter time period, detection of significant trends is statistically more difficult. For this reason, it is not surprising that all bird groups showed a much greater percentage of species with stable abundance trends than were observed during the longer term (table 24). Compared with the long-term trends, there was a higher percentage of species with increasing trends (28 percent) relative to decreasing trends (18 percent). Among the 12 bird groups, there were 6 cases in which the percentage of species with increasing trends exceeded the percentage with decreasing trends in the short term—compared with only 2 cases in the longer term. These results suggest that in the shorter term, bird abundance trends have been dominated by species with stable-to-increasing trends since 1997. It is noteworthy that species associated with grassland habitats, and those that nest on or near the ground showed abundance trends that were consistent with the long-term patterns, however, which is strong evidence that these species groups have continued to decline in the near term (table 24).

Conclusions

The recent historical trends in wildlife resources show varied responses depending on the species considered—a fact that by itself suggests variations in resource conditions by region or habitat type. This variation in response is no doubt caused by a complex interaction involving land use changes that can convert or create habitats for different sets of species, shifts in the intensity with which humans manage lands that can differentially affect species habitat, shifts in public demands and preferences for goods and services provided by wildlife, and interactions among wildlife species themselves.

A general pattern of increasing population or harvest trends was observed among big game and waterfowl species. When considered in a historical context, the observed trends in these two groups of species are often considered wildlife management success stories (Organ et al. 2010). Population gains are not immune to negative resource consequences, however. Habitats have limited capacity to sustainably support

Table 24. Percentage of breeding bird species with increasing, decreasing, and stable trends, 1997–2008.

Species group	Total species	Increasing	Decreasing	Stable
			percent	
All species	426	27.9	18.1	54.0
Nest type/location				
Cavity	60	36.7	8.3	55.0
Open cup	178	24.7	27.5	47.8
Ground/low	110	19.1	30.9	50.0
Midstory/canopy	121	32.2	19.0	48.8
Migration status				
Neotropical	137	33.6	19.7	46.7
Short distance	101	26.7	29.7	43.6
Permanent resident	88	23.9	12.5	63.6
Breeding habitat				
Woodland	130	34.6	16.2	49.2
Shrubland	84	20.2	21.4	58.3
Grassland	27	25.9	29.6	44.4
Wetland/open water	84	23.8	8.3	67.9

Source: J.R. Sauer, personal communication

individuals, and there is growing evidence that some species may be exceeding those limits. White-tailed deer and several species of geese are commonly referred to as "overabundant," and these population excesses are being blamed for widespread habitat degradation (Ankney 1996; Côté et al. 2004). Because there remains a strong interest in maintaining harvestable surpluses of these species, efforts to reduce populations are often met with public resistance. Therefore, the long-term population increases observed among these species represent an emerging unfavorable and controversial resource management issue that is deserving of closer scientific and management scrutiny from the ecological, biological, and social perspectives (Levy 2006; Menu et al. 2002).

For many small game species, webless migratory game birds, and birds that generally choose to breed on or near the ground, or in grassland and shrubland habitats, population and harvest trends (for game species) have shown notable declines. Particularly prominent declines were observed for northern bobwhite. A common attribute shared by many of these species is their association with grassland, farmland, and early successional habitat. These species show very little sign of recovery from the declines noted in the 1989 and 2000 RPA Assessments (Flather and Hoekstra 1989; Flather et al. 1999). Although there is local evidence that small game species can respond favorably to geographically extensive land use policies that provide suitable habitat (Brennan and Kuvlesky 2005), these local benefits have not yet translated into population and harvest benefits at regional and national scales. Furthermore, early successional forest habitats that were once maintained by natural disturbance regimes now require active management to perpetuate their occurrence across the landscape in more densely populated regions (Litvaitis 2003). For these reasons, the trends in these species remain an important management issue of concern.

Furbearers are a special case, because the data we reviewed focus solely on harvest. Fur harvests can change for a number of reasons that are independent of population levels, including changes in pelt prices, the number of trappers and their effort in pursuing furbearers, and changes in the accessibility of land for trapping. The notable declines in fur harvest since the last assessment are in large part driven by substantial declines in pelt prices. Wildlife damage complaints associated with furbearers are likely to become a more prominent management issue in the absence of any economic incentives to increase harvests.

Wildlife Resources in the Future

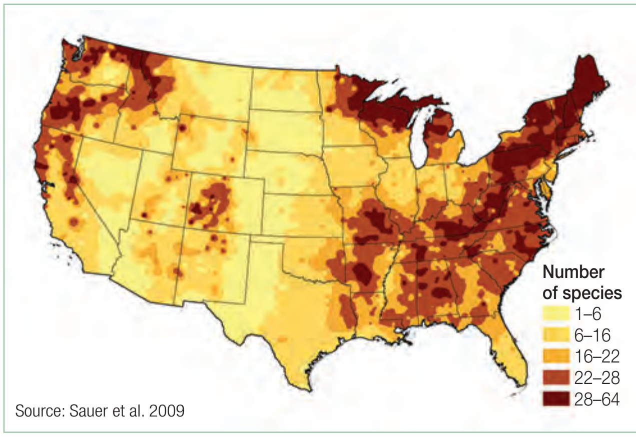
Land Use Change Effects on Forest Bird Species Richness

As human populations grow, more and more of a landscape's native habitats are lost to agriculture, road construction, or urbanization. One of the more general signs that such land conversions may be stressing ecosystems is a reduction in the variety of organisms inhabiting a given place (Rapport et al. 1985). We combined BBS data on bird richness in ecoregions supporting forest vegetation, land use cover data from the National Land Cover Database (NLCD) (Vogelmann et al. 2001), and housing data from the U.S. Census Bureau (USCB 2001) to relate the current pattern of forest bird richness to land use and housing variables (Pidgeon et al. 2007). The results were used to assess bird diversity response to projected changes in land use and housing under three RPA scenarios.[17] These scenarios are useful for determining the sensitivity of bird communities to alternative futures.

Forest bird richness tends to be highest in areas characterized by high topographic relief (figure 126). Notable concentrations of high forest bird richness occur along the Appalachian Mountains, major mountain ranges of the Pacific coast, northern Rocky Mountains, and the Ozark and Ouachita highlands of Arkansas and Missouri. The mixed deciduous-coniferous forests of the Great Lakes also support high numbers of forest breeding birds because of increased habitat diversity associated with this boreal-hardwood transition.

Bird groups are defined by broad life-history characteristics and include forest birds (species that regularly breed in forest ecosystems), neotropical migrants (forest birds that winter south of the United States-Mexico border), ground nesting

Figure 126. Mean forest bird richness observed on a survey route, 2007–2009, using the North American Breeding Bird Survey.

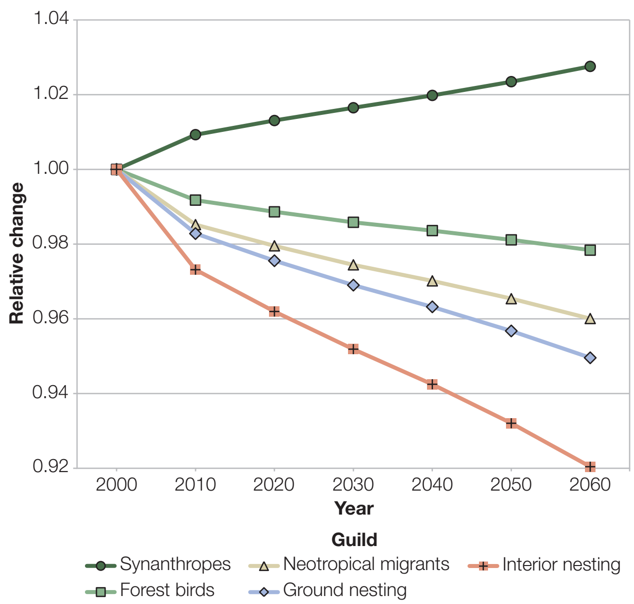


Source: Sauer et al. 2009

[17] The RPA HFW scenario was not analyzed because the land use projections for RPA HFW were not available until after this analysis was completed.

(forest birds that build their nest on or near the ground), interior nesting (forest birds that prefer to nest away from the edge of forest habitats), and synanthropes (forest birds that tolerate and thrive in habitats associated with human settlement).

Figure 127. Changes in forest bird richness, by guild, based on land use and housing density changes projected to 2060, scenario RPA A1B.

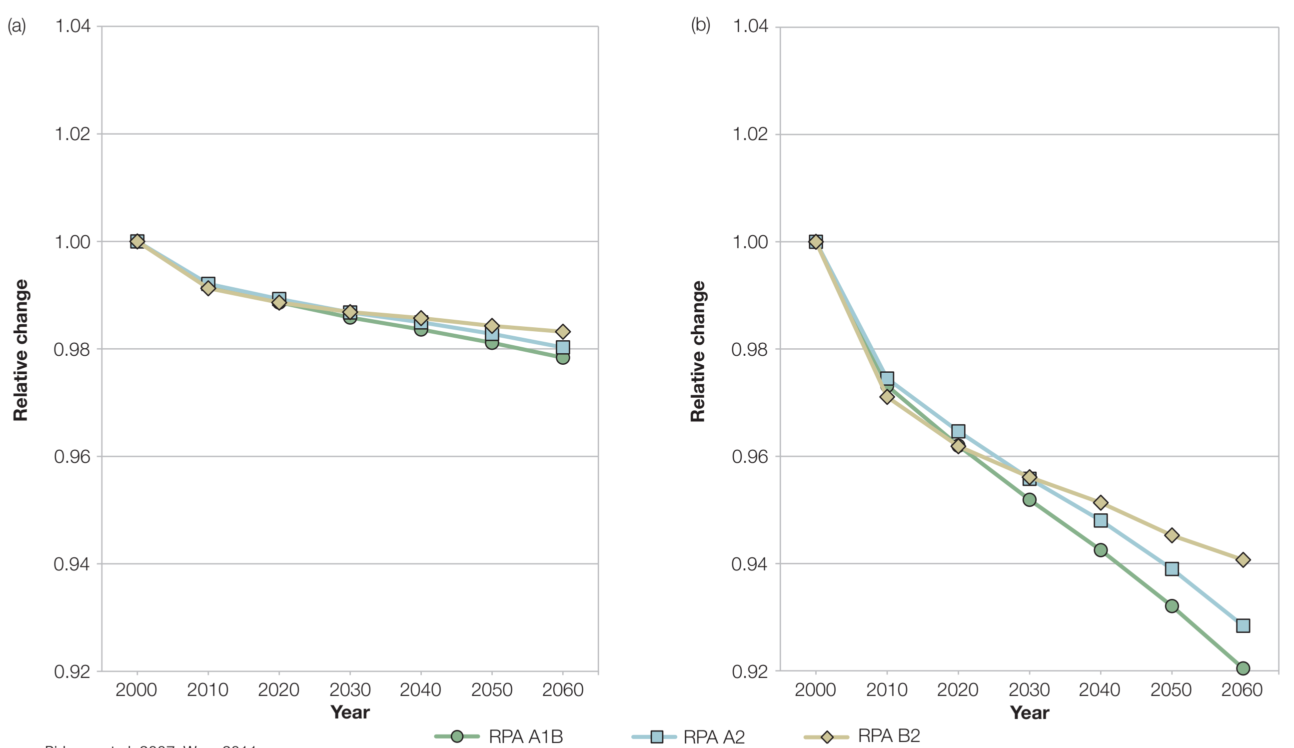


Sources: Pidgeon et al. 2007; Wear 2011

The RPA land use change projections (Wear 2011) and separate housing projections (Radeloff et al. 2010) indicate that intensive land uses and housing development are expected to have a greater footprint on forested landscapes. In response to these changes in land use and housing, most forest bird communities are expected to support a lower variety of species, particularly among those forest species that prefer intact interior habitats (8 percent decline) or nest on or near the ground (5 percent decline) (figure 127). Synanthropes are the one species group that show moderate increases (about 3 percent)—a pattern expected given their tolerance for the land uses associated with human settlements.

Forest bird communities were relatively insensitive to the alternative futures as specified by land use changes in the RPA scenarios examined (figure 128a). The least effect on forest bird richness was observed under scenario RPA B2—a future with lower population growth and intermediate economic growth. The greatest decline in forest richness was observed under scenario RPA A1B—a future characterized by the greatest loss of forest land. Forest birds that prefer to nest in interior habitats away from forest edges showed greater sensitivity among RPA scenarios (figure 128b). Again, the least effect was associated with scenario RPA B2 and the greatest effect was observed with scenario RPA A1B. The difference between these two responses spanned 2 percentage points. Deviation in predicted forest bird richness among RPA scenarios should be interpreted

Figure 128. Changes in bird richness for (a) species that breed in forest habitats and (b) species that prefer to breed in interior forest conditions, by RPA scenario.



Sources: Pidgeon et al. 2007; Wear 2011

with caution, however, because such differences did not become evident for several decades into the future (about 2040). On the other hand, these results may be conservative, because they take into account only gross change in broad land cover and use categories (for example, forest, agriculture, and urban) and housing density. They do not take into account the direct effects of climate change, nor the effects of projected shifts in forest management, such as the expansion of forest plantation area or declines in forest inventory projected in the RPA A1B scenario as compared with other RPA scenarios (because of higher biomass energy demands).

Habitat and Climate Change

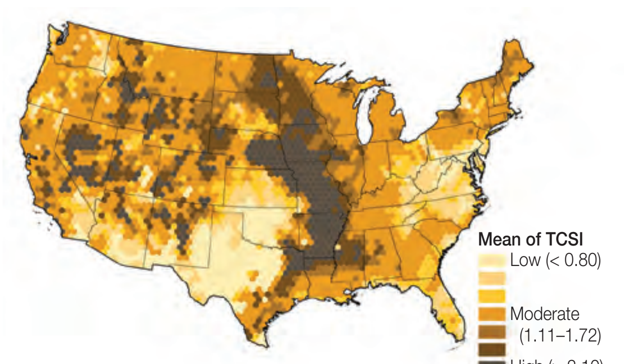
A great deal of uncertainty remains about how climate change will affect biological systems (Parmesan and Yohe 2003). The complex feedbacks between climate, land use, land cover, and biodiversity (Hansen et al. 2001) make it difficult to predict how wildlife may respond to some future climate. Wildlife will be affected by habitat changes in response to climate-driven shifts in land use and natural disturbances (Dale 1997; Hansen et al. 2001). Given that land use and cover are recognized as the most important drivers of biodiversity change (Sala and Jackson 2006), habitat alterations serve as leading indicators of biodiversity response to climate change (Ibáñez et al. 2006; Inkley et al. 2004). In this analysis, we assumed that projected shifts in habitat under alternative future climates provide information for evaluating potential wildlife resource responses and biodiversity risks attributable to climate change across a systematic grid.

We ranked each grid cell's habitat stress from climate change across the conterminous United States (Joyce et al. 2008) based on its (1) historical baseline climate, (2) future climate from global circulation models, and (3) climate-induced changes in productivity and distribution of broad vegetation types, as projected by a dynamic vegetation model (Bachelet et al. 2001).[18] This information was combined into a single index of habitat stress that quantified the degree of change between the recent history and the projected climate and vegetation. We defined the Terrestrial Climate Stress Index (TCSI) as the sum of three separate terms that reflect changes in the climate regime (shifts in temperature and precipitation), habitat quality (change in productivity), and habitat area (distribution shifts in broad vegetation types). We estimated a mean TCSI score for each grid cell across a set of different scenarios, climate models, and assumptions about the effect of carbon dioxide on plant growth. The mean TCSI thus represents the average across a suite of alternative futures.

The terrestrial areas most sensitive to climate change in the conterminous United States were associated with transitions between major biomes and areas of high topographic relief. The areas most exposed to habitat stress occurred along the grassland-forest land transition throughout the central portion of the country and the steep elevation gradients in the Intermountain West (figure 129). The areas least sensitive to climate induced habitat stress were located in the southern portions of the Great Plains, the Middle Atlantic States from North Carolina to southern Pennsylvania, and the eastern coast of Florida. The States with the highest TCSI scores tended to be located inland and include Iowa and Missouri, whereas coastal States like Delaware and Maryland tended to have relatively low average TCSI scores. Interestingly, the variability in TCSI scores among alternative futures was generally low in high-stress areas and high in low-stress areas. This pattern of scenario uncertainty (Joyce et al. 2011) indicated that there was relatively greater agreement among alternative futures in identifying those regions of high stress and less agreement in identifying those regions of relatively low stress (Joyce et al. 2008).

Additional uncertainty in the climate stress rankings can be traced to factors not included in our definition of stress. The TCSI captured the projected shifts in natural vegetation in response to climate change, but did not incorporate land use as a factor affecting the area of habitat available to species. Moreover, we have likely underestimated the effects of climate change on terrestrial wildlife habitats in coastal areas, because

Figure 129. Mean Terrestrial Climate Stress Index (TCSI) based on the average across alternative futures.



Source: Joyce et al. 2008

[18] The climate projections used to estimate terrestrial climate stress were based on IPCC scenarios A2 and B2, described in Chapter 5. The GCMs used here differed from those used in other RPA analyses in the following ways: the GCMs associated with the A2 scenario were earlier model versions of the same GCMs used in RPA A2 (the B2 models were the same); the downscaling methods were similar, but the geographic resolution was restricted to one-half-degree units of latitude and longitude. See Joyce et al. (2008) and Vulnerability and Impacts of North American Forests to Climate: Ecosystem Responses and Adaptation (2011).

we did not account for effects attributable to sea level rise. The 2010 State of the Birds report (North American Bird Conservation Initiative, U.S. Committee 2010) indicated that the potential effects of sea level rise on wildlife resources may be considerable, based on findings that showed substantially higher proportions of vulnerable species associated with island and coastal habitats when compared with relatively low proportion of vulnerable species associated with forest, grassland, or arid land habitats.

In addition to quantifying future climate stress with TCSI (figure 129), we also quantified two current conservation issues that could affect how State wildlife agencies plan and manage wildlife resources in the face of climate change. These current conservation issues include the prevalence of at-risk species and the dispersal resistance that current land use activities may have on the ability of species to move across the landscape in response to climate change. The prevalence of at-risk species was estimated as the count of terrestrial vertebrate species considered to be at risk of extinction according to NatureServe's Conservation Ranks (see Imperiled Species section). Dispersal resistance was estimated as the proportion of the terrestrial land base under intensive human use (agriculture and developed land) from the NLCD (Homer et al. 2007). Generally, the locations where current conservation issues were most pronounced (figure 130) tended not to overlap with the location of high future stress associated with climate change (figure 129), potentially complicating the efforts of managers to prioritize wildlife conservation actions (Joyce et al. 2008).

The mean TCSI was used to identify areas of relatively high and low habitat stress across the conterminous United States. Such information can provide managers and planners with information on the potential for climate-induced stress to wildlife habitats within regions and States. Spatially explicit information on habitat stress attributed to climate change can be integrated with the location of current conservation issues (e.g., areas supporting high numbers of at-risk species; concentrations of intensive land uses that could affect wildlife movements) to evaluate the coincidence of future climate change threats with important wildlife conservation issues. Furthermore, using several alternative futures enabled us to assess the implications of scenario uncertainty on our conclusions. Agreement was more consistent in areas of high stress, implying greater confidence, than it was for areas of low stress.

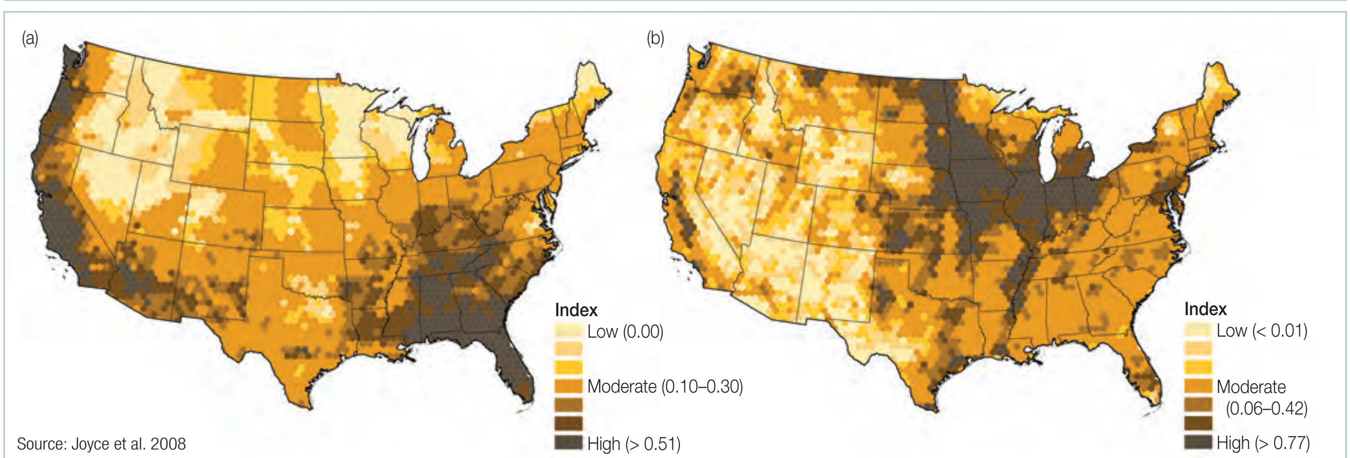
Although the analysis reviewed here provides a repeatable process by which climate stress can be evaluated, its use needs to acknowledge the limitations associated with its focus on terrestrial habitats. Extension of this analysis to include aquatic systems and issues associated with sea level rise, as is being considered by other vulnerability assessment efforts both within and outside of the Forest Service, would broaden its applicability (Glick et al. 2011; Tomosy et al. 2011).

Fish and Aquatic Resources

Aquatic ecosystems provide a variety of ecosystem services and economic benefits to society. These services and benefits range from products as fundamental as safe drinking water to healthy and abundant fish populations that provide food for consumers and sustain leisure opportunities for recreational anglers.

The ecological condition of these resources is driven by many factors. Aquatic systems are the recipients of the byproducts from activities in the surrounding landscape and are also affected by inputs that can originate from well outside the local ecosystem. Nonpoint pollution delivery is affected by land cover, forest and rangeland management, and agricultural

Figure 130. Current conservation issues associated with wildlife resources, including (a) the count of terrestrial species considered to be at risk of extinction according to NatureServe's conservation ranks, and (b) the proportion of the land base that is intensively used by humans (agriculture and developed land) as an indication of resistance to species movement (dispersal resistance), in response to climate change. Both indices have been normalized to vary between 0 (least concern) and 1 (most concern).



activities within watersheds (Allan et al. 1997), and freshwater ecosystems are particularly affected by the introduction of exotic species originating from intercontinental exchanges (Rahel 2002). Furthermore, aquatic systems are often sinks for elements from atmospheric deposition. As such, the biotic communities in these systems are heavily influenced by forces external to their immediate surroundings (Kennen et al. 2005).

This section focuses on the general condition of aquatic habitats, species, and usage trends as reflected in existing surveys and data collection efforts from multiple sources. Details on data sources and methods are reviewed in Loftus and Flather (2012).

Freshwater Habitats

There are more than 3.5 million miles of freshwater rivers and streams and 40 million acres of lakes and reservoirs (excluding the Great Lakes) in the United States (U.S. EPA 2006, 2009). These aquatic systems play a vital role in the economic, social, and ecological framework of the country. Freshwater lakes and reservoirs provide 70 percent of the Nation's drinking water, hydropower for industry, irrigation for agriculture, and transportation corridors for shipping, among other uses (U.S. EPA 2011a). Ecologically, freshwater resources provide vital habitat that supports freshwater and estuarine fisheries, aquatic species of conservation concern, and other aquatic resources, which in turn support commercial and recreational fishing activities.

Inland lakes

In 2007, the U.S. Environmental Protection Agency (EPA) completed the National Lakes Assessment evaluating the condition of freshwater lakes, ponds, and reservoirs of greater than 10 acres, excluding the Great Lakes, in the conterminous United States (table 25). Overall, 22 percent of the lakes were rated in "poor" condition, 56 percent were rated in "good" condition, and 21 percent were rated "fair." In general, natural lakes were in better condition than manmade lakes. The upper Midwest had by far the greatest percentage of lakes rated in good biological condition, whereas the northern plains ecoregion had the greatest number of lakes rated in poor biological condition. A comparison of these results to comparable studies in the 1970s revealed that 75 percent of the 800 lakes sampled in the 1970s showed either improvements or no change in phosphorus levels in the 2007 study (U.S. EPA 2009). There is some evidence that reservoirs may facilitate the spread of exotic aquatic organisms throughout a landscape (Havel et al. 2005).

Wadeable Streams

The EPA conducted an assessment of the biological attributes of 1,392 "wadeable" stream locations in the United States in 2004 and 2005. Wadeable streams constitute 90 percent of the stream and river miles in the conterminous United States. Overall, 42 percent of wadeable streams were rated in poor condition and 28 percent were rated as being in good condition; 25 percent were fair. Streams in the western mountains ecoregion, where only 25 percent of stream lengths sampled were determined to be in poor condition, were in the best biological condition. The southern Appalachians, southern plains, and northern plains ecoregions had 50 percent or more of their stream lengths sampled in poor condition (figure 131).

Great Lakes

The Great Lakes is the largest system of surface freshwater on Earth. The five Great Lakes and connecting waters contain approximately 20 percent of the Earth's freshwater and 90 percent of the surface freshwater in the United States (U.S. EPA 2011b). There is no single assessment of water quality or habitat condition that can characterize the state of the lakes. We were able to use the compilation of assessments from extensive collaboration between jurisdictions to summarize conditions in the Great Lakes, however.

Human settlement within the watersheds of the lakes ranges from relatively sparse areas of the northern regions of Lake

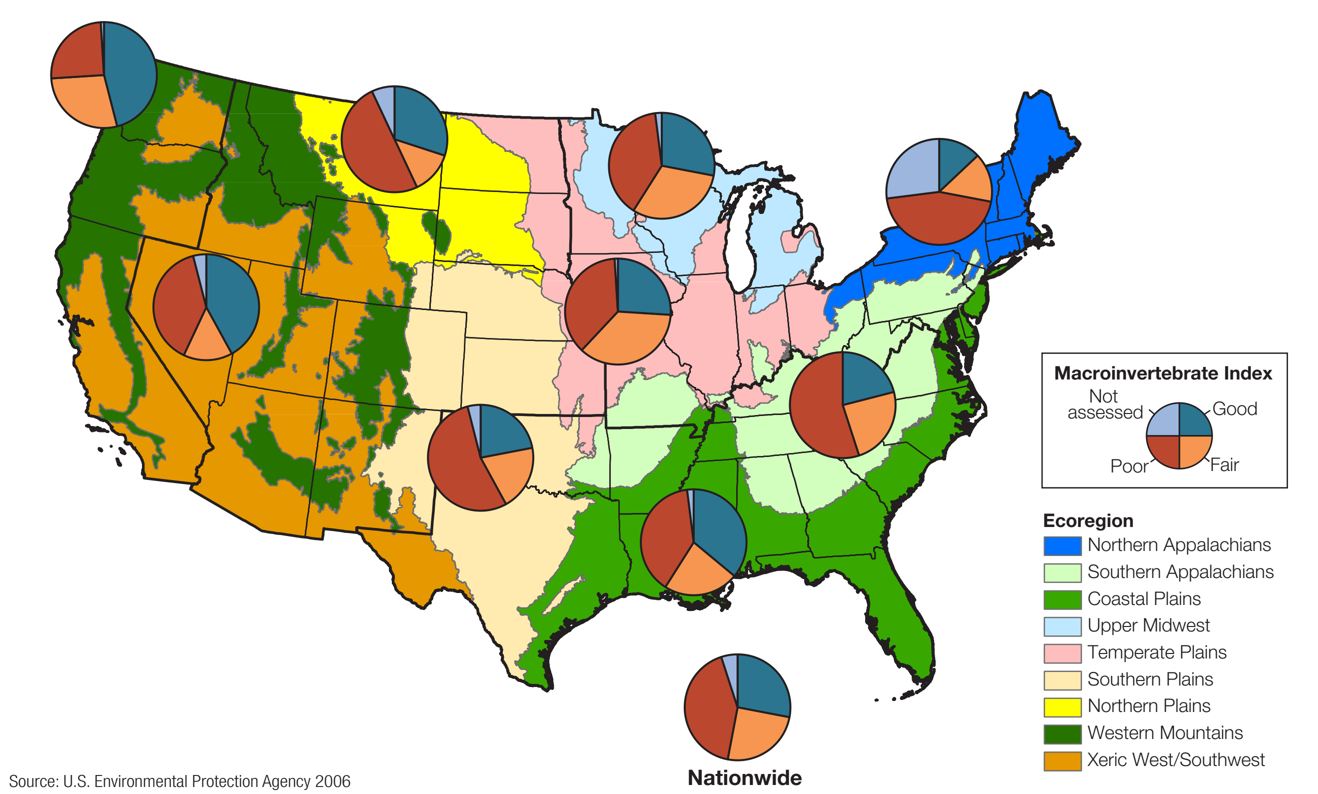
Table 25. Status of the biological condition of lakes larger than 10 acres in the conterminous United States[a], by ecoregion, based on planktonic index.

Ecoregion	Number of lakes	Good condition	Fair condition	Poor condition
		percent		
Northern Appalachian	5,226	55	30	15
Southern Appalachian	4,690	42	27	31
Coastal Plains	7,009	47	25	27
Upper Midwest	15,562	91	5	4
Temperate Plains	6,327	24	40	35
Southern Plains	3,148	34	36	29
Northern Plains	2,660	1	6	90
Western Mountains	4,122	58	31	11
Xeric West/Southwest	802	35	14	49
Nationwide		**56**	**21**	**22**

[a] Excludes the Great Lakes.

Source: U.S. Environmental Protection Agency 2009

Figure 131. Stream habitat condition as measured by macroinvertebrate index of biological condition as compared to least-disturbed reference sites, nationally and by ecoregion.



Source: U.S. Environmental Protection Agency 2006

Superior to some of the most densely populated urban centers, including Chicago, Detroit, Buffalo, Cleveland, and other areas of the southern parts of the region. To varying degrees, all areas face major stresses of toxic and nutrient pollution, invasive species, and habitat degradation (U.S. EPA 2011b). Pollution sources include sedimentation and agricultural pollutants, industrial discharges, runoff and wastewater discharges from urban areas, and pollutants from atmospheric deposition.

Overall, the Great Lakes coastal condition is rated as fair to poor in the lakes and connecting waterways (U.S. EPA 2008) (table 26), although some indicators are improving. Invasive nonnative species (e.g., zebra mussel, quagga mussel, and round gobies) continue to be an important management challenge in all five lakes. In the lower Great Lakes (Lakes Erie and Ontario and connecting waterways), the establishment of invasive zebra and quagga mussels has eliminated more than 99 percent of the native freshwater mussel population. Levels of contaminants in colonial waterbirds and fish have been improving across all lakes, although organic compounds (e.g., Polychlorinated Biphenyls) and mercury continue to persist in the food web. The status of biotic communities varies from lake to lake, with Lake Superior having a more positive status than the other lakes. Lake Superior is the only lake where natural reproduction of lake trout has been maintained. The proportion of forest land in the landscapes improves water quality, and there is a gradient of increasing forest cover from the lower to

Table 26. Great Lakes coastal condition based on five quality indices.

Index	Rating
Water quality (eutrophic condition, water clarity, dissolved oxygen levels, and phosphorus concentrations)	Fair
Fish tissue contaminants (concentrations of PCBs, mercury, chlordane, dioxin, and toxaphene)	Fair
Sediment quality (toxic contamination)	Poor
Coastal habitat (amphibian and wetland-dependent bird abundance and diversity, extent of coastal wetlands)	Poor
Benthic community	Poor

PCB = Polychlorinated Biphenyls.
Source: U.S. Environmental Protection Agency 2008

more northern Great Lakes. The proportion of land converted to agriculture is higher in the landscapes surrounding Lake Ontario and Lake Erie, where nuisance algal blooms and invasive mussels have affected recreation, utility operations, and water quality management. The effects of climate change on the physical and biotic condition of the Great Lakes are a growing concern (U.S. EPA and Environment Canada 2009).

Water Quality

Sections 305(b) and 303(d) of the Clean Water Act require States to report attainment of water quality goals for their State water bodies. According to the most recent data available

(U.S. EPA 2011d), just less than 50 percent of river and stream miles assessed were designated as "good," nearly 50 percent as "impaired," and 1 percent as "threatened." For lakes, reservoirs, and ponds, nearly 34 percent of the acres assessed were rated as good, 66 percent as impaired, and less than 1 percent as threatened.

At the national level, the most widespread probable sources contributing to these impairments include agricultural activities and atmospheric deposition. The combined effects of activities associated with urbanization (e.g., urban runoff, municipal discharge, industrial activities, and construction) are also significant causative factors behind the water quality impairments. Although all of these activities affect aquatic ecosystem health, urbanization is known to dramatically affect the condition of fish communities, primarily resulting from the effects related to increasing impervious surface and road building in these areas.

Fish Population and Harvest Trends

Responsibility for managing freshwater and near-shore marine fisheries generally resides with States and, in some cases, Native American tribal governments (exceptions exist for Federal trust species). Individual States conduct most analyses of the status and trends of freshwater fisheries. This system of management works well for State fisheries management, but does not lend itself to conducting regional or national analyses of the status and trends of freshwater aquatic populations (Mac et al. 1998). As a result, data for a national assessment are quite limited. Little has changed since the findings of previous RPA Assessments (Flather et al. 1999; Loftus and Flather 2000). Information is still substantially lacking, particularly in the freshwater environment, to conduct a comprehensive status and trends analysis. For this reason, we summarized the population and harvest status of commercial stocks and highlight recent efforts to standardize across-State agency data to assess the status and trends of important species.

Commercial Populations

A series of interstate fisheries commissions covering U.S. coastal waters has improved coordination among the States for management and stock assessment of species that migrate through multiple jurisdictions. Fisheries occurring predominately in the Exclusive Economic Zone are managed by the Federal Government acting through a series of regional management councils and, in some cases, international agreement. Data collection has tended to focus on those species of high economic or social importance (USDC NMFS 2009a, 2009b).

Twenty-three percent of 253 marine fish stocks were deemed to be overfished and 15 percent subject to overfishing (USDC NMFS 2009b). These results are similar to those found in 2008, when 23 percent of assessed fish stocks were overfished and 16 percent of the stocks were subject to overfishing. Four stocks of fish have been rebuilt.

Pacific salmon have declined throughout much of their range, although stocks native to Alaska tributaries are much more robust than those in the Pacific Northwest (Loftus and Flather 2000, 2012; Piccolo et al. 2009). Factors contributing to this decline are generally related to the human-induced changes to salmon spawning and rearing habitat (Buck and Upton 2010; Loftus and Flather 2000). Among the factors presenting challenges to successful reproduction of Pacific salmon are excessive siltation caused by landscape changes (grazing in the riparian areas and watershed, other agricultural activities removing vegetation, urbanization, and impervious surfaces in the watershed, etc.); water removals for irrigation, consumption, and industrial uses; obstructions preventing salmon from reaching spawning habitats (hydroelectric facilities, road culverts, etc.); and direct physical changes to their spawning and rearing habitats (Buck and Upton 2010).

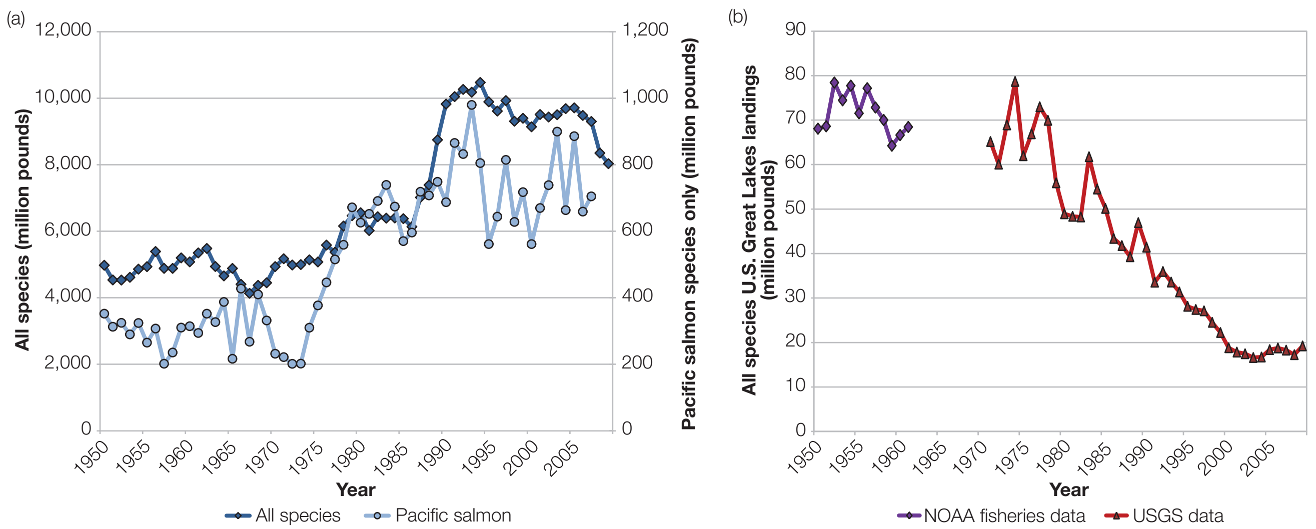
Of the 52 distinct populations of salmon and steelhead in the Pacific Northwest, 28 are currently listed under the Endangered Species Act (ESA) (Buck and Upton 2010). All but two of these species are considered "stable or increasing." Trends in abundance alone may not indicate the true potential for recovery, however. Risk factors such as low levels of abundance, lack of access to historical spawning habitats, extirpation of component populations, and the lack of spatial connectivity among extant component populations are significant factors in determining recovery status (USDC NMFS 2010). Of 32 Northwest Pacific salmon populations assessed, 8 populations were classified in the most severe category ("danger of extinction") and 19 were classified as "likely to become endangered in the foreseeable future." None were classified as "not likely to become endangered" (Good et al. 2005).

Commercial Harvest

Landings data alone are not indicative of population change because management restrictions (e.g., harvest controls) and changes in fishing effort will influence landings. The landings data are an indication of human use of aquatic resources. The total harvest (edible and industrial) of commercial species by U.S. fishermen at U.S. ports in 2008 was 8.3 billion pounds, valued at $4.4 billion. This harvest value is a decrease of 11 percent from the previous year, continuing a trend of the past 3 years (figure 132a), but it was an increase of 5 percent in ex-vessel value compared with the previous year. Finfish accounted for 87 percent of these landings but only 51 percent of the value.

Trends in commercial harvest landed in U.S. Great Lakes ports continued their decline (figure 132b). There is now evidence

Figure 132. Commercial landings of (a) all marine species and Pacific salmon species in U.S. ports and (b) all species from U.S. Great Lakes.[a]



[a] Great Lakes data from l962–1970 are unavailable.

Sources: U.S. Department of Commerce, National Oceanic and Atmospheric Administration 2010; U.S. Department of the Interior, U.S. Geological Survey 2010

that nonnative fishes like Asian carps can have ecosystem-scale effects on the condition of native fish species (Irons et al. 2007). Given that more than 180 nonnative species have already been detected in the Great Lakes (including sea lamprey, zebra mussel, round goby, spiny water flea, and Eurasian watermilfoil), there are mounting concerns that colonization of the Great Lakes by Asian carp species will further erode the integrity of the native fish communities and diminish populations of species that are important to recreational and commercial fisheries (International Joint Commission 2011; Rasmussen et al. 2011).

Conclusions

Since the first RPA Assessment in 1975, the data needed to conduct a thorough evaluation of fisheries and aquatic resources have slowly improved. Comprehensive water quality data are now readily available, a nationwide assessment of the condition of freshwater streams and lakes has been conducted, socioeconomic data for extractive use are widely available, and regional information-sharing efforts are underway to facilitate the compilation and exchange of fisheries information.

Despite these improvements, data remain lacking for a comprehensive assessment of the status and trends of most aquatic biota, including the status of fish species that are an important commercial, cultural, and recreational component of society. Positive strides have been made to this end, most noticeably where jurisdictions share management authority over a common stock. On a limited basis, States have developed cooperative arrangements for the assessment and management of freshwater stocks such as Lake Erie yellow perch and walleye. The inability to assess the status and trends of a single species or species complex nationwide hinders the evaluation of large-scale factors that may be affecting aquatic populations across larger landscapes, however. These data limitation in turn affect the ability to conduct large-scale program planning efforts required by the Forest Service and other agencies. Programs are underway to improve data for larger scale assessments. Increasingly, States are standardizing the way in which they collect, store, and report data (Loftus 2006). In addition, multiple Federal agencies, including the Forest Service, collect data throughout the United States that could be applied to the assessment of status and trends of aquatic species.

One such cooperative program for sharing fisheries information is the Multi-State Aquatic Resources Information System (MARIS). Initiated in the 1990s, MARIS has made incremental progress. Assessments of the utility of MARIS (Loftus and Flather 2000; Nate and Loftus 2012) have indicated its potential for assessing states and trends of fisheries populations both within individual waterbodies and across broader regions. A component of the National Fish Habitat Action Plan (NFHAP) (see sidebar, National Fish Habitat Assessment) involves a national infrastructure to exchange data from disparate sources for multiple purposes, including the development of future national fish habitat assessments that incorporate comprehensive fisheries data. If this system is fully implemented as planned, it will provide a strong basis for future RPA Assessments of fisheries and aquatic resources.

National Fish Habitat Assessment[19]

Introduction

The States (represented by the Association of Fish and Wildlife Agencies), the U.S. Department of the Interior, and the U.S. Department of Commerce formally adopted the National Fish Habitat Action Plan (NFHAP) in early 2006. The Forest Service participates in NFHAP through several bodies of the NFHAP; including the National Fish Habitat Board, the Federal Agency Caucus, and various working groups and national fish habitat partnerships.

The focus of the NFHAP "is to protect, restore, and enhance the Nation's fish and aquatic communities through partnerships that foster fish habitat conservation and improve the quality of life for the American people" (National Fish Habitat Action Plan 2006). An initial task of the NFHAP was the development of a condition analysis of all fish habitats within the United States. This assessment has relied on existing national-level (and in some cases large regional-level) datasets of known stressors to aquatic habitats.

Methodology

The inland NFHAP assessment focused on streams and rivers of the conterminous United States using the 1-to-100,000-level National Hydrography Dataset Plus as the spatial framework. To predict the condition of fish habitats, landscape disturbance was analyzed for every river through a consistent process. This process assumed that landscape-scale patterns and human activities reflected for the variables measured correspond to patterns in local-scale stressors. Variables used to assess habitat conditions included characteristics of the catchment (elevation, slope, catchment area, soil permeability, and mean annual temperature and precipitation) and anthropogenic stressors (human population density, urban land, agricultural land, road density, fertilizer application, grazing pressure, pollution discharge sites, toxic release sites, national superfund sites, minimum density, and ground- and surface-water withdrawals). Streams were scored according to their condition as indicated by these variables in each location.

A variant of this methodology was required for Alaska and Hawaii. For this reason, making direct comparisons with the lower 48 States is difficult. For estuaries, river discharge, pollutant levels, eutrophication, and urban, agricultural, and estuarine wetland land cover were used to measure habitat stress.

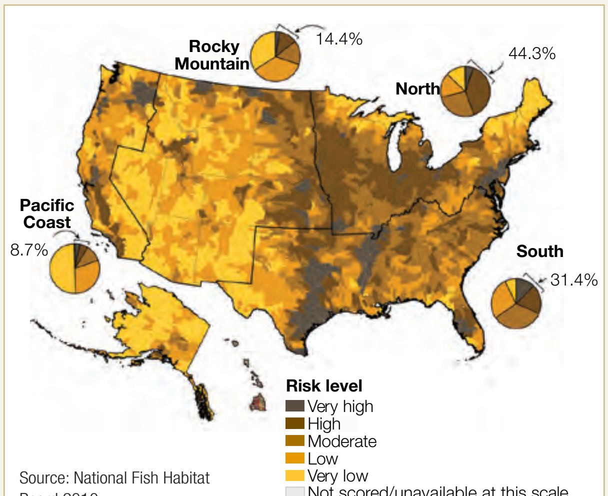
Results

In the conterminous United States, 27 percent of stream miles are at high or very high risk of current habitat degradation, and 44 percent are at low or very low risk. Areas with urban development, livestock grazing, agriculture, and point-source pollution had higher risk of degradation, as did areas with high numbers of mines and dams. Rural areas without these disturbance factors (for example, New England, the upper Midwest, and the Intermountain West) were at lower risk of degradation based on the variables analyzed (figure 133).

There is a general pattern among RPA regions of lower habitat risk as one moves east to west (figure 133). The two eastern regions were characterized by relatively high proportions of watershed in the high- or very high-risk categories. The South Region had the greatest percentage of watersheds in the very high-risk category (12 percent), whereas the North Region had the greatest proportion of watersheds in the high-risk category (39 percent). In both of these RPA regions, urban development and agriculture were important factors in explaining the location of high-risk watersheds along the northeast corridor, Florida Gulf coast, southern Mississippi valley, and east central Texas.

Watersheds composing the two western RPA regions show a general pattern of much lower habitat risk with scattered hotspots of high to very high risk (figure 133). Only 14 percent of watersheds in the Rocky Mountain Region and less than 9 percent of watersheds in the Pacific Coast Region were determined to have high or very high habitat risks. The greatest concentration of watersheds that were ranked as at least high risk occur along the eastern boundary of the Rocky Mountain Region, where agricultural development is a prominent human disturbance on the landscape. Grazing was a factor in the high-risk areas in northern Montana, whereas intensive row crop agriculture contributed to high-risk aquatic habitat in eastern Washington, southeastern Idaho, and the Central Valley in California. The effects of urban development on aquatic habitat quality can be seen in high-risk areas around Denver, CO, Salt Lake City, UT, and Fairbanks and Anchorage, AK.

Figure 133. Relative condition of riverine and near-coastal habitat based on the variables that indicate risk to aquatic habitat quality, by RPA region.



Source: National Fish Habitat Board 2010

[19] Based on the National Fish Habitat Board (2010).

Conclusions

The habitat conditions outlined in this report reflect the limited range of variables analyzed that represent or are correlated with particular habitat stressors. Some factors that are very important in specific geographic regions may not be included. Factors known to affect the condition of aquatic habitats that lacked spatially extensive and consistent collection methods were not included in the condition index. For example, although large dams and road crossings (that are in the analysis) could be used as surrogate indicators for fish passage obstructions, actual smaller scale obstructions (e.g., culverts or, conversely, fishways around dams) are not reflected in the analysis. Neither are some of the significant factors leading to species endangerment, such as invasive species (Jelks et al. 2008). Because large-scale stressors to aquatic systems, such as urbanization, agriculture, and road building, are represented in the analysis, however, the analysis has utility for evaluating major threats to aquatic systems at the geographic scale (1 to 100,000) analyzed.

Whereas the national-level compilation of scores at broader spatial units is useful for policymakers and planners in assessing national budgetary and program needs, the finer scale watershed analyses will be most useful to on-the-ground efforts to protect, restore, and enhance habitats for healthy fish populations. These analyses represent the initial attempt to characterize habitat factors affecting fish populations and will be refined as additional national-scale data become available. The data download and mapping capability are made available to fish habitat partnerships and others through an interactive web tool that will enable these partnerships to visualize specific habitat factors influencing the local and catchment watersheds (http://www.nbii.gov/far/nfhap/). This delivery mechanism is expected to facilitate application of the assessment to the implementation of restoration projects and likely result in an information exchange that will help to refine data elements for use in future assessments.

Imperiled Species

Conservation science is concerned with anticipating how natural or human-induced disturbance to ecosystems affects the pattern of commonness and rarity of the biota inhabiting that system. The rarer a species becomes, the greater its risk of extinction. Those species whose populations have reached some threshold risk of extinction are what we are calling "imperiled" species. Identifying those species that are imperiled and identifying those areas where those species are concentrated has long been used to judge the status of biodiversity (Flather and Sieg 2007; Gaston and Fuller 2008).

We continue this approach here and review the trends and geographic patterns of imperiled species, including (1) species formally listed as threatened or endangered under the ESA, and (2) species considered to be imperiled based on global conservation status ranks. We highlight changes in the counts and geographic concentrations of species under these two classifications that have occurred in the last decade to assess whether biodiversity is improving or becoming more impoverished. Finally, we tallied the number of species that have been extirpated from each State, highlighting areas where conservation efforts were insufficient to maintain species composition.

Imperilment Status

As of October 27, 2010, there were 1,368 total species formally listed as threatened or endangered within the United States, a net gain of 278 species since the 2000 RPA Assessment. The largest increases occurred among plants (152), fish (31), insects (27), mollusks (20), mammals (20), and amphibians (8). Since March 1, 2006, the listing rate has nearly doubled (about 23 species per year) over the listing rate observed for the earlier one-half of the decade (Flather et al. 2008)—a listing rate that could easily be sustained for more than a decade depending on the degree of political support for species listings and how rapidly final determinations are made on species that are currently proposed (23) or candidates[20] (253) for listing.

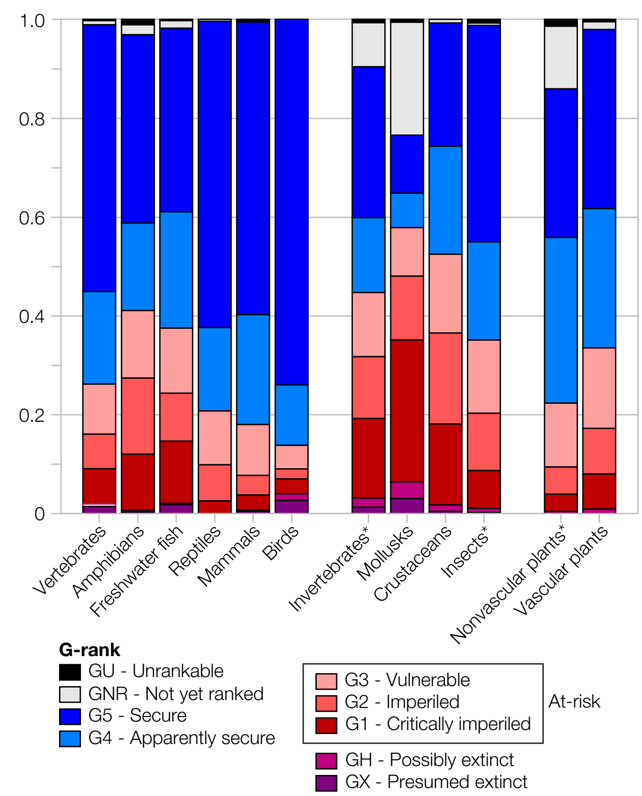
A set of conservation status ranks developed by NatureServe (2011) provided a broader biological assessment of imperilment and revealed that slightly more than one-fourth of all vertebrates and one-third of vascular plants are of conservation concern (figure 134).[21] Vertebrate species of conservation concern are prominent among amphibians (41 percent), freshwater fishes (37 percent), and reptiles (21 percent); birds ranked the lowest, with 14 percent of species assessed to be of conservation concern. Among invertebrates, mollusks (58 percent) and crustaceans (53 percent) have the greatest percentage of taxa that are of conservation concern. Taxonomic groups associated with aquatic habitats have higher proportions of imperiled species than other taxonomic groups, and there is evidence that this proportion has been increasing. Jelks et al. (2008) found that the number of freshwater fish taxa considered to be imperiled or extinct in the United States increased 179 percent between 1979 and 2008 and nearly doubled in the last 10 years

[20] Candidates are taxa for which the U.S. Fish and Wildlife Service has sufficient information on file to support proposals to list the species as threatened or endangered, but for which preparation and publication of a listing proposal is precluded by other listing activities.

[21] The data on global conservation status is based on NatureServe's Central databases (NatureServe 2010), as queried for counts of species in each conservation rank (http://www.natureserve.org/explorer/ranking.htm). Species of conservation concern are defined as those to be presumed extinct (GX), possibly extinct (GH), critically imperiled (G1), imperiled (G2), or vulnerable (G3) to extinction.

of that period. Among those species that are associated with forest habitats, the percentage of imperiled species also appears to have grown in the short term (Flather et al. in press b).

Figure 134. The proportion of species in NatureServe conservation status ranks for vertebrates, invertebrates, and plants.



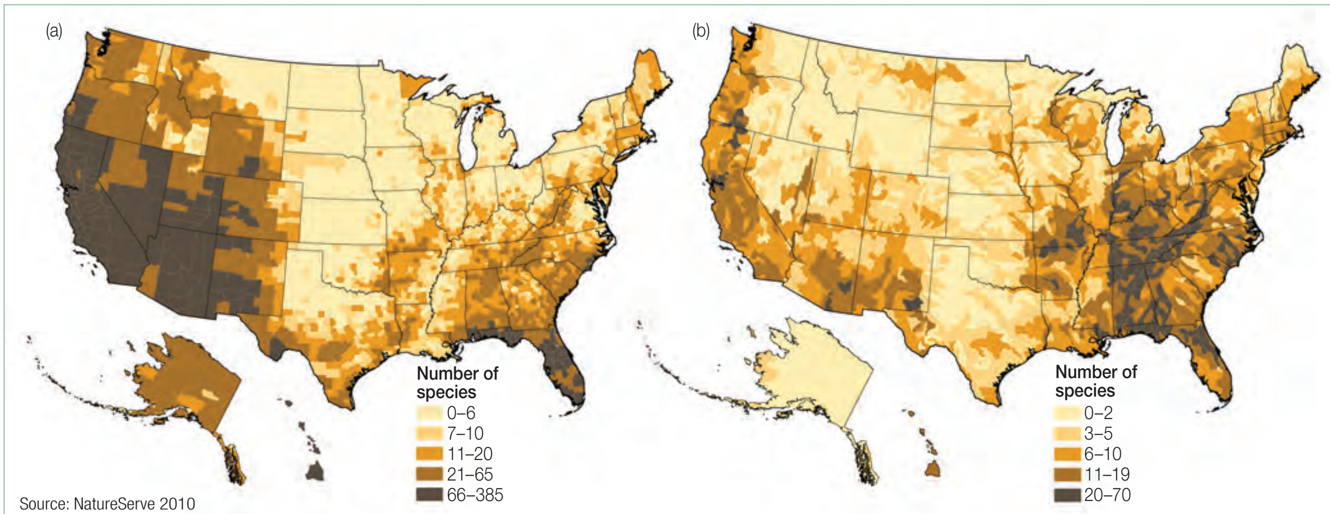
*Taxonomic groups with uncertain proportions because many species are awaiting conservation assessments.

Source: NatureServe 2011

The geographic distribution of ESA-listed species has been shown to vary geographically (Flather et al. 1994, 1998), with prominent concentrations of threatened and endangered species occurring in the southern Appalachians, peninsular Florida, coastal areas, and the arid Southwest. This pattern has remained largely unchanged for the last 15 years. Counties that have moved into the highest class of endangered species counts based on thresholds used in the 2000 RPA Assessment are often in close proximity to counties that remained in the highest endangerment class for both the 2000 and 2010 RPA Assessments. Exceptions to this pattern include emerging concentrations in the Midwest among scattered counties from east central Missouri through northern Indiana; counties along portions of the Atlantic and Gulf coasts; eastern portions of the Edwards Plateau in Texas; the basin and range region of southern New Mexico; and the Colorado Plateau region of Utah (Flather et al. in press b).

The geographic concentration of at-risk species[22] based on NatureServe's criteria show decidedly more contiguous concentrations in peninsular Florida, the Florida Panhandle, coastal California and Oregon, and the Southwestern United States (figure 135a). These more contiguous concentrations of at-risk species show some degree of association with human population density, human population growth, and areas known to support high numbers of species with restricted ranges (Stein et al. 2000). Furthermore, the riparian environments in the arid southwest maintain important habitats used by much of the terrestrial fauna in this region (Levick et al. 2008). If we focus on those taxonomic groups that are associated with aquatic habitats (figure 135b), then the southern Appalachians and

Figure 135. The geographic distribution of species assessed to be at risk of extinction (conservation ranks G1, G2, and G3) for (a) all species at the county level, and (b) species associated with aquatic habitats at the eight-digit hydrologic unit level, 2010. Legend categories reflect approximately the 0–40th percentile, 40–60th percentile, 60–80th percentile, 80–95th percentile, and >95th percentile.



Source: NatureServe 2010

[22] At-risk species include those determined to be critically imperiled (G1), imperiled (G2), and vulnerable (G3) to extinction.

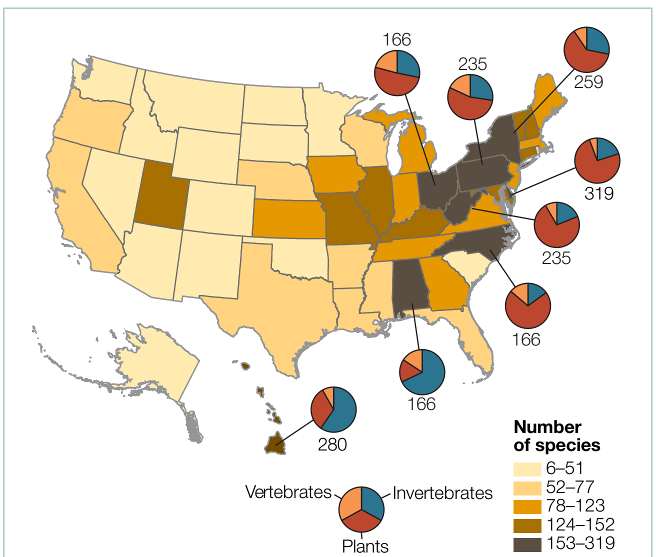
scattered watersheds in the Central United States and southeastern coastal plain emerge as prominent areas of concentration (Loftus and Flather 2012).

The geographic pattern of extirpated species[23] deviates significantly from the current distribution of listed or at-risk species (figure 136). Extirpated species are concentrated among Middle Atlantic States—a pattern that indicates how much historic biodiversity has been altered under human settlement. Given the higher proportion of public lands, the lower density of human populations, and their larger size,[24] it is not surprising that Western States have tended to lose fewer species than their eastern counterparts.

Conclusions

In a world with limited resources to direct toward biodiversity conservation, focusing on the subset of species that are thought to have the highest extinction risk is a common priority setting strategy (Flather et al. 2011). Targeting species that are vulnerable to extinction has become especially important because recent estimates of global extinction rates are two to three orders of magnitude greater than the so-called natural background level (Levin and Levin 2002). Because important ecosystem functions can be degraded with the loss of species, there is concern that the goods and services humans derive from ecological systems will become diminished as more species are lost or threatened with extinction.

Figure 136. The geographic distribution of State-level counts of species considered to be extirpated from a State for the conterminous United States, 2010. Legend categories reflect approximately the 0–30th percentile, 30–50th percentile, 50–70th percentile, 70–85th percentile, and >85th percentile. Pie charts represent the proportion of extirpated species that were plant, vertebrate, and invertebrate species.



The trends reviewed here indicate that biodiversity in the United States has continued to erode since 2000. Moreover, patterns of extirpation serve to highlight those regions where conservation efforts have failed to maintain the integrity of the expected species composition. These national patterns parallel what has been observed globally (Mooney and Mace 2009; Stokstad 2010), that despite a growing trend in conservation investment (Rands et al. 2010; Shifley in press) species imperilment has continued to increase.

Wildlife and Fish Recreation

The American public derives substantial recreational value from the Nation's wildlife and fish resources. Moreover, participation in recreational activities focused on wildlife and fish is associated with considerable contributions to local economies: hunters and anglers spent $76.6 billion and wildlife viewers spent $45.7 billion on equipment and trip-related expenditures in 2006 (USDI FWS and USCB 2006). The participation trends reviewed here are derived from the National Survey of Fishing, Hunting, and Wildlife-Associated Recreation. Participation in these activities are reviewed here rather than in the Outdoor Recreation chapter to facilitate the comparison between wildlife and fish population trends and participation in those recreational activities that depend on those populations. Details on data sources and methods are reviewed in Mockrin et al. (in press).

Hunting

The total number of hunters grew from 1955 through the 1970s, slowly declined through 1996, and then declined more markedly during the past 10 years (figure 137). After reaching a peak of 14.3 million participants in 1975, the number of people that hunted wildlife declined during the next three decades to 12.5 million participants, a decline of 12.4 percent since 1975. The hunting participation rate declined from 7.5 percent of the U.S. population to 5.5 percent between 1996 and 2006, resulting in 1.5 million fewer hunters than reported in the last RPA Assessment (Flather et al. 1999). The number of days spent hunting followed a similar pattern to the number of participants, increasing through the mid-1970s but declining since then (Mockrin et al. in press).

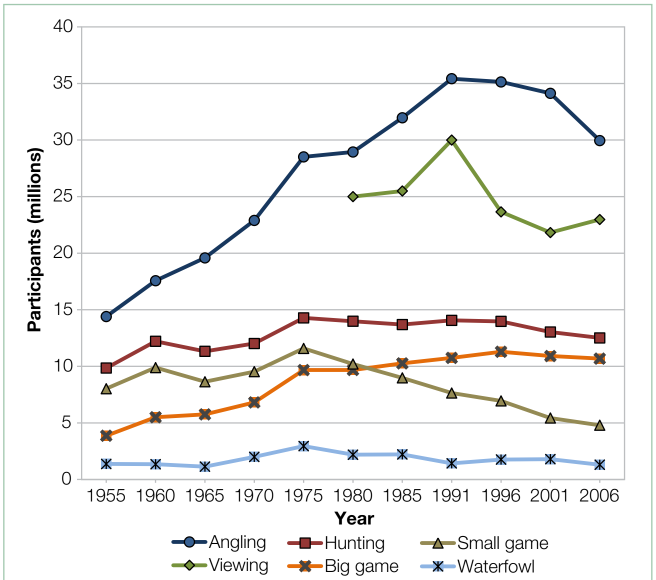
The pattern of participation among types of hunting activity varies (figure 137). Currently, big game hunting is the most popular, with 10.7 million participants in 2006. The number of

[23] Extirpation from a State is based on the State-level conservation ranks in NatureServe and document species that historically occurred within a State, but are now presumed (SX) or possibly (SH) extinct within that State. State extirpations often occur at the periphery of a species geographic range.

[24] All other things being equal, small States are likely to have more extirpations because the range and abundance of species will be smaller than in large States.

hunters seeking big game showed sustained growth through the mid-1990s, but declined 5.4 percent from 1996 to 2006. Even with these recent declines, the number of big game hunters in 2006 was nearly three times greater than the number of big game hunters in 1955. Small game hunting was the most popular form of hunting up to 1975. Since the mid-1970s, however, there has been a sustained and substantial decline in small game hunters, with fewer than 4.8 million participants pursuing small game by 2006 (a 58-percent decline). The activity with the fewest hunters is waterfowl hunting. Like small game, the number of waterfowl hunters declined after the mid-1970s. By 2006, the total number of waterfowl hunting participants was less than the number in 1955.

Figure 137. Number of participants 16 years and older in angling, hunting, and nonresidential wildlife viewing, 1955–2006.



Sources: Loftus and Flather 2012; Mockrin et al. in press; U.S. Department of the Interior, U.S. Fish and Wildlife Service; U.S. Census Bureau 2006

Regionally, the number of hunting participants declined in all RPA regions between 1996 and 2006, with significant declines (33 percent) observed in the Pacific Coast Region (figure 138). Regional trends in the number of participants since 1996 varied by hunting activity, but tended to follow national trends. The number of big game hunters increased slightly in the South Region, declined in the North and Rocky Mountain Regions, and declined significantly in the Pacific Coast Region. Small game hunter numbers declined significantly (ranging from 26 to 52 percent) in all regions except the Rocky Mountain where declines were not statistically significant. Negative trends in the number of hunters pursuing migratory game birds were indicated in all regions, with significant and notable declines in the North (26 percent) and Pacific Coast (47 percent) Regions. The number of days devoted to each form of hunting showed trends that were similar to participation trends with the exception of the number of days spent pursuing big game in the North Region, which showed a positive but nonsignificant increase despite declining participants (figure 138).

Fishing

In 2006, a total of 30 million individuals (13 percent of the U.S. population age 16 years and older) participated in recreational fishing and spent 517 million days on the water. The most popular species caught and the days spent pursuing them were black bass (161 million days), panfish (102 million days), catfish and bullheads (98 million days), crappie (91 million days), and trout (70 million days). From 1955 through 1991, the number of anglers grew steadily. Since 1991, the number of anglers has decreased by 16 percent, although the number of days spent fishing increased by 1 percent (figure 137). Despite these substantial declines, fishing is more popular than hunting, with nearly 2.5 anglers for every hunter.

Figure 138. General trends in the number of participants and days spent hunting, angling, and viewing wildlife (nonresidential), 1996–2006. Bolded arrows indicate the direction of significant trends; minus (-) and plus (+) signs indicate a trend that was not determined to be significantly different from stable.

Recreation Type	Participants				Days			
	North	South	Rocky Mountain	Pacific Coast	North	South	Rocky Mountain	Pacific Coast
Hunters	–	–	–	↘	–	–	–	↘
Big game	–	+	–	↘	+	+	–	–
Small game	↘	↘	–	↘	↘	↘	–	↘
Migratory bird	↘	–	–	↘	↘	–	↘	↘
Anglers	↘	↘	↘	↘	↘	↘	–	↘
Wildlife viewers	↘	–	+	+	+	+	–	+

Sources: Loftus and Flather 2012; Mockrin et al. in press; U.S. Department of the Interior, U.S. Fish and Wildlife Service; U.S. Census Bureau 2006

Regionally, there is little variance in the participation trends since the 2000 RPA Assessment (figure 138). All regions have undergone significant declines in the number of anglers since 1996, with the steepest declines occurring between 2001 and 2006. The number of days that anglers devote to fishing also declined significantly between 1996 and 2006 across all RPA regions except the Rocky Mountain. During the period of years reviewed in Loftus and Flather (2012), the number of days spent angling actually peaked in 1996 in the North, South, and Pacific Coast Regions; days devoted to angling peaked in 2001 for the Rocky Mountain Region. Since reaching those peaks, the number of days spent angling has declined in all regions except the South, where number of days was unchanged between the 2001 and 2006 surveys.

Wildlife Viewing

Surveys of participants in wildlife viewing began in 1980. The number of nonresidential wildlife viewers—individuals who watched wildlife more than 1 mile from home—declined by 8.1 percent between 1980 and 2006. The number of days devoted to nonresidential wildlife viewing has shown some variation from survey to survey, without a clear direction in trend. Days initially rose by a statistically significant 19 percent from 1996 to 2001, then declined slightly (5 percent) by 2006.

Nonresidential wildlife viewing shows a U-shaped trajectory in participants for each region, initially declining after 1991, then increasing from 2001 to 2006. The Rocky Mountain and Pacific Coast Regions have roughly the same number of participants. Between the two regions, however, the Rocky Mountain Region showed the smallest initial decline in number of wildlife viewers and the most positive overall trend in number of participants. Since the last RPA Assessment, the number of participants has declined significantly in the North Region, trended negative in the South Region, and trended positive in the Rocky Mountain and Pacific Coast Regions (figure 138). The total number of days spent viewing wildlife was stable or increasing for each region from 1991 to 2006. The number of days devoted to nonresidential wildlife watching has deviated somewhat from the participation trends, trending positive in the North, South, and Pacific Coast Regions and trending negative in the Rocky Mountain Region (figure 138).

Role of Public and Private Lands in Wildlife Recreation

More than one-half of all hunters reported hunting solely on private land. Between 1991 and 2006, there was a decrease in hunters using both public and private land (from a high of 30 percent to 24 percent in 2006), with these hunters shifting to rely only on private land. Public lands hosted 54 million days of hunting (25 percent of all hunting days), whereas 164 million days, or 75 percent of all hunting days, took place on private land (USDI FWS and USCB 2006). In contrast to hunting, most nonresidential wildlife viewers pursue viewing on public land. From 1991 through 2006, an average of 51 percent of all wildlife viewers used public land exclusively, with 30 percent dividing their time between public and private land and 11 percent relying exclusively on private land.

Public lands, including National Forest System (NFS) lands, are nationally important for recreation. About 205 million Americans live within 100 miles of a NFS boundary. In 2008, the Forest Service's visitor monitoring program reported an annual 14.4 million visits to NFS lands for the primary purpose of hunting, with an additional 2.3 million visits primarily for wildlife viewing.

Conclusions

The economic and ecological effects of changing participation in wildlife and fish recreation are substantial, and understanding these changes is essential if resource managers are to adjust their management goals. The United States has a long history of wildlife and fish recreation, but these recreation patterns are currently shifting. Only 5.5 percent of Americans over the age of 16 currently hunt wildlife and 10 percent view wildlife away from home. Fishing is the most popular activity, with about 13 percent of the population participating in this activity. In the last couple of decades, the number of participants in these activities has shown a general pattern of decline.

As wildlife recreation participation changes, the rationale and funding for wildlife management is also changing. Wildlife conservationists are now becoming concerned that the core principles guiding wildlife management in the United States could be in jeopardy (Mahoney and Cobb 2010). Clearly, the trends reported here do provide evidence that such concerns are justified. The number of participants in recreational hunting is not only declining in absolute terms, but also the collective voice of those who actively seek wildlife and fish for harvest or observation is declining even more substantially relative to a growing American population. Such trends suggest that relying on license fees and excise taxes on hunting and fishing equipment as the primary funding mechanism supporting wildlife conservation in the United States will be insufficient to maintain a science-based management program in the future (Regan 2010).

Chapter 14. Outdoor Recreation

Outdoor recreation plays a significant role in American lives. In this chapter, we begin by describing the outdoor recreation resources available in the United States, then describe the status and trends in outdoor recreation participation, regional variation in recreation use, and differences in participation by demographic groups. Tracking these trends is important because both the public and private sector make large investments and have management responsibilities as providers of recreation opportunities. The final section presents projections of outdoor recreation participation to the year 2060.

Resource Highlights

- Outdoor recreation resources are expected to decline on a per-person basis.
- Outdoor recreation participation continues to grow, but activity choices are changing.
- Outdoor recreation choices are strongly influenced by socioeconomic characteristics.
- Future outdoor recreation participation will reflect the preferences of a changing U.S. population.
- Growing recreation demand may be constrained by recreation resource availability.

Outdoor Recreation Resources

The United States has extensive land and water resources (table 3). Public lands held in trust by local, State, and Federal Governments are crucial resources for nature-based outdoor recreation. Although recreation also occurs on private land ownerships, data are less available to describe and evaluate the role of private lands. Therefore, we focus on public lands and their management in assessing outdoor recreation resources.

Local Government Lands

Local governments own a small percentage of total public lands, but these holdings are highly important because they are almost entirely in close proximity to people. With 83 percent of Americans living in metropolitan areas, the location of local parks and recreation areas may be more important than the size or number of facilities.

Many of these facilities are used for sports, but they also include green spaces and areas for activities such as hiking and bird watching. Across the United States, 12 percent of local governments provide park and recreation services, with the largest providers being counties, followed by municipal governments.[25] The South Region has the highest proportion of local governments providing parks and recreation services, and the Rocky Mountain Region has the lowest. The North Region has the highest number of parks and recreation units. Given its smaller population base, the Rocky Mountain Region has the highest number of park and recreation units per capita, followed by the North, South, and Pacific Coast Regions.

[25] This proportion is relatively low because nearly one-half of the Nation's 76,425 local government units are Special Districts, only 2 percent of which provide park and recreation services. The percentage is much higher for county (41 percent) and municipal (29 percent) governments.

Urban parklands are an important resource in areas of high population density. According to 2011 City Park Facts (Trust for Public Land, 2011a), the 100 most populous cities operate more than 1.5 million acres of parks and recreation areas within their city limits. Parkland area per resident varies widely. For example, even though New York City has one of the largest park areas for a high-density city, there are still only 4.5 acres per thousand residents, as compared with a less densely populated city such as Phoenix, AZ, with a similar park area, but 28 acres per thousand residents. Visitor use of these parks is extremely high: Central Park in New York City is estimated to have the highest visitation, at 35 million visitors per year.

State Lands

States manage a variety of lands that can provide recreation opportunities, including State parks, State forests, State wildlife areas, and other designations. State lands tend to occupy a niche between the heavily natural land-dependent Federal lands and the much more facility- and development-oriented local lands and parks. A key feature of State resources is their proximity to populated areas, especially in the Eastern United States, where State lands play a much more significant role in providing outdoor recreation opportunities than in the West, where Federal land dominates. Still, because of the lower population in the West, there are more State park system acres per capita in the West than in the East.

State park systems account for almost 14 million acres, and include State parks, recreation areas, historic sites, and other special categories (figure 139). Total acreage in State park systems increased 6 percent between 2002 and 2009. The North and Pacific Coast Regions have the largest area (about 5.2 million acres each), the South Region has about 2.2 million acres, and the Rocky Mountain Region about 1.4 million acres.

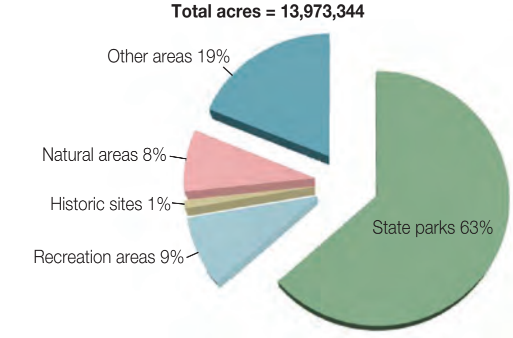
About 25 million acres of U.S. forest land are managed by State forestry agencies. The largest proportion (64 percent) is in the North Region, followed by the Pacific Coast Region (20 percent). State wildlife and fish agencies own about 19 million acres, and manage an additional 12 million acres through easements and leases (Wildlife Management Institute 1997). These lands are often available for recreation purposes, especially fishing, hunting, and wildlife watching.

Federal Lands

Federal lands cover about 640 million acres in the United States, about 28 percent of the total land area. Nearly all Federal land is open and available to the public for recreation. More than 92 percent of Federal land is located in the West, with about 36 percent of all Federal land in Alaska. The Forest Service and Bureau of Land Management manage the majority of Federal land. Table 27 shows the acres of land managed by the main U.S. land management agencies and the distribution by Resources Planning Act (RPA) region. Because the Pacific Coast Region includes large Federal holdings in Alaska, table 27 shows acreage for Alaska separately.

Congressional designations offer additional direction to the management of Federal lands that often affect the recreation opportunities available on those lands. Wilderness areas

Figure 139. Percent of State park system acres, by type of area, 2009.[a]



[a] Natural areas include environmental education sites and areas classified as scientific sites. Other areas include forests, fish, and wildlife management areas, and other miscellaneous State park system sites.

Source: USDA Forest Service 2009b

Table 27. Acres of Federal land[a] in the United States by agency and RPA region, 2008.

Federal agency	North	South	Rocky Mountain	Pacific Coast[b]	Alaska	United States	Percent of U.S. total
	thousand acres						
Forest Service	12,240	13,320	99,419	45,764	21,970	192,713	30
National Park Service	1,349	5,195	11,080	10,087	51,114	78,825	12
U.S. Fish & Wildlife Service	1,711	4,357	9,893	1708	76,836	94,504	15
Bureau of Reclamation	0	197	5,470	854	0	6,522	1
Bureau of Land Management	4	44	142,962	31,843	78,513	253,367	40
Tennessee Valley Authority	0	248	0	0	0	248	<.1
U.S. Army Corps of Engineers	2,557	7,104	3,540	526	19	13,746	2
All Federal agencies	**17,862**	**30,466**	**272,364**	**90,782**	**228,452**	**639,926**	**100.0**

[a] Acres reported by the Bureau of Reclamation and U.S. Army Corps of Engineers include water area. Data from the Tennessee Valley Authority include developed recreation lands only.

[b] Pacific Coast acreage in this column does not include Alaska.

Source: Cordell et al. in press

represent the most pristine and protected of Federal lands, with more than 109 million acres (see chapter 6 for additional information about the National Wilderness Preservation System). Other congressionally designated acres provide unique recreation resources: National Recreation Areas (NRAs), National Wild and Scenic Rivers (NWSRs), and National Recreation Trails (NRTs). NRAs are intended to serve primarily as a recreation resource and be accessible to population centers. There are 41 NRAs covering 7.4 million acres. The NWSR designation requires qualifying rivers to have outstanding scenic, wild, and/or recreation values. A little more than 12,500 miles were designated as of June 2009, with the Pacific Coast Region containing more than one-half of the designated areas. The NRT system is unique in that it can be managed by any government agency at any level of government. In 2009, there were slightly more than 20,000 miles in the system, with the East accounting for almost 70 percent of the total trail miles.

Federal Recreation Facilities

Federal lands provide numerous types of recreation facilities to accommodate the wide range of U.S. recreation demands. The Recreation Information Database (2009) records information for more than 9,000 defined recreation facilities on Federal lands. Nearly 96 percent of those facilities provide campgrounds; hiking and fishing opportunities are a distant second and third, respectively, with about 34 percent of facilities providing such opportunities. As expected, the large majority of facilities are located in the West, where most Federal land occurs, although the proportion of facilities in the West (73 percent) is less than the proportion of Federal land in the West (92 percent). Although the Rocky Mountain Region dominates in almost all categories in number of facilities, interpretive programs and visitor centers are particularly highly represented in the North Region, and boating facilities are well represented in the South Region, reflecting regional preferences and opportunities. Figure 140 shows the number of facilities available for specific recreation activities by the four RPA regions. The Rocky Mountain Region has more than 10 times the number of available Federal facilities per capita than both the North and South Regions, and nearly twice as many as the Pacific Coast Region. The combination of a much smaller population base and large concentrations of Federal land, much of which is managed for recreation use, help explain this significant advantage in the Rocky Mountain Region.

Private Lands and Enterprises

Although outdoor recreation is often associated with public lands and facilities, private lands also play an important role in outdoor recreation. Survey results indicate that total days of recreation on private forest land is a small number in relation to those on public forest land, especially in the West, but there is still a significant amount of use of private lands, particularly for certain recreation activities (table 28). The dramatic differences

Figure 140. Number of Federal recreation facilities, by activity availability (or type of facility) and RPA region, 2009.

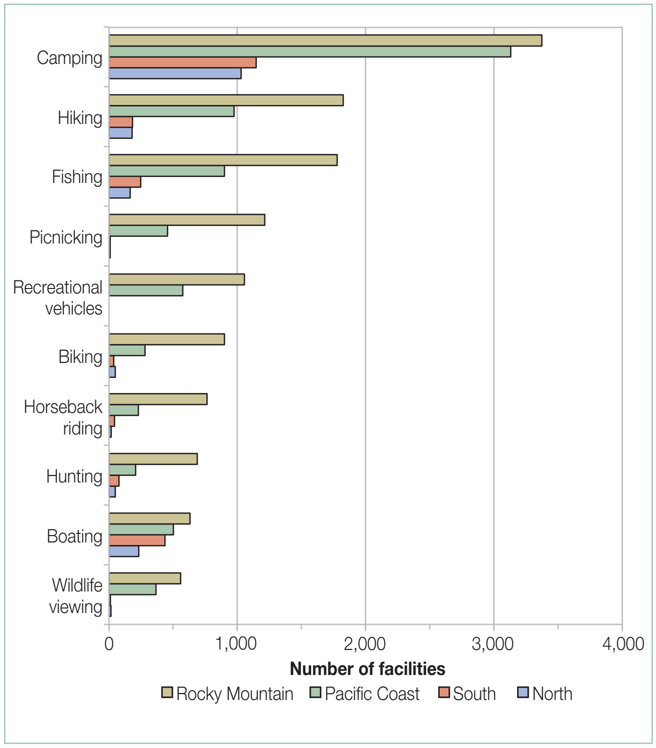


Table 28. Number and percent of annual recreation activity days on privately owned forest by activity group and region, 2005–2009.[a]

Activity group	East		West		United States		
	Annual days		Annual Days		Total private annual days	Percent of all days	All annual days
	millions	*%*	*millions*	*%*	*millions*	*%*	*millions*
Visiting recreation and historic sites	834	28	262	9	1,096	37	2,960
Viewing and photographing nature	12,175	34	3,332	9	15,507	43	35,865
Backcountry activities	580	19	237	8	817	26	3,119
Motorized activities	488	43	91	8	579	51	1,126
Hunting	242	47	38	8	280	55	512
Cross-country skiing	11	30	4	10	14	40	36

[a] Days and percentages may not sum across exactly to national totals because of rounding. Cross-country skiing was the only winter activity with sufficient annual days data in forested settings. All annual days are the sum of days that occur on private and public lands.

Source: National Survey on Recreation and the Environment 2005–2009, Version 3b, n = 5,374 between East and West reflect the larger population in the Eastern United States and the relative balance of public land. Activities such as hunting and motorized activities have traditionally been common on private lands in the East, whereas in the West there are abundant opportunities on public lands for these activities.

Many private landowners recreate on their own land and allow friends and relatives to recreate there as well. Family forest owners have indicated that recreation is one of many reasons for owning land (Butler 2008). Only 15 percent of family forest land is open to the general public for recreation, but that amounts to almost 40 million acres of forest land (Butler 2008). Recreation also occurs on agricultural land. There has been a growing trend for farms to include agritourism attractions as part of their operations, which often include allowing recreation activities such as hunting, fishing, and horseback riding (Brown and Reeder 2007). One study estimated that American farms produced recreational experiences for about 62 million people in 2001 (Barry and Hellerstein 2004).

Private lands also provide access to public lands that have recreation opportunities. Studies such as Radeloff et al. (2005, 2010) demonstrated that historic housing growth in the United States in close proximity to public lands has occurred at higher rates than overall housing growth and that these trends are likely to continue. This type of development can also be seen in close proximity to State parks, which tend to be distributed more evenly with population than Federal lands. Both primary and secondary home development provide major means of access to public lands. The number of secondary (or seasonal) homes in the United States increased from slightly more than 2 million in 1970 to about 3.6 million in 2000 (USCB 2010).

Private commercial businesses are significant providers and facilitators of outdoor recreation opportunities on both public and private lands. For example, in 2007, there were 4,413 privately operated recreational vehicle parks and campgrounds in the United States. More than 69 percent of these facilities are in the Eastern United States, with the North Region having the greatest number. Other types of private facilities include recreational and vacation camps, marinas, nature parks, and skiing facilities.

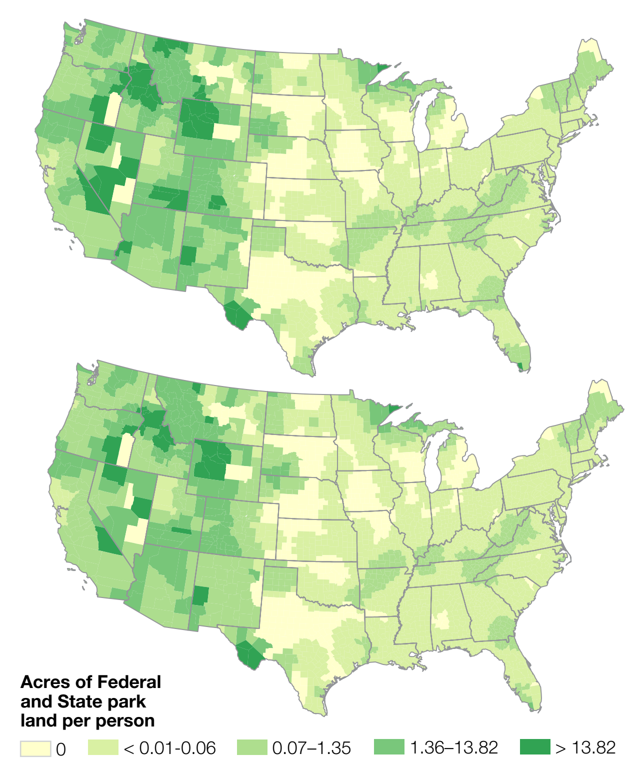
The private sector also plays an important role in providing concession services on public lands. Concessions on National Forest System lands, U.S. Army Corps of Engineer reservoirs, and the national parks include ski areas, lodges, campgrounds, camp stores, and outfitting and guide services, among others. Private-sector concessions have played a significant role in State parks for decades, operating similar types of services.

Recreation Resource Availability: Present and Future

The availability of recreation resources in relation to people can be shown geographically by mapping the distribution of population against recreation resource distribution. Because Federal lands and State lands are assumed to be relatively fixed over time, we can compare recreation resources against the U.S. population projected to 2060. If the resource base remains fixed, per capita availability can only decline over time. The ability of recreation resources to meet future recreation demands also depends on future recreation participation rates and the distribution of recreation participants in relation to recreation resources. We are not able to map the geographic distribution of participants at the same geographic scale (county level) as total population, however.

We evaluated recreation resources within 75 miles of the center of a county as a measure of opportunities for recreation activities for residents of each respective county that can be accessed within a day. The dominant influence of the western Federal lands is quite evident, as almost all of the counties with the highest per-person availability are west of the Mississippi River (figure 141). Population growth and redistribution of the

Figure 141. Acres of Federal and State park land per county resident, 2008 (top) and 2060 (bottom), within the 75-mile distance zone from the county center, based on the RPA A1B population projection.



Sources: USDA Forest Service 2008; U.S. Department of the Interior, National Park Service 2009; U.S. Department of the Interior, Bureau of Land Management 2009; USDA Forest Service 2009b population change the proportions of per-person acres available in 2060. Although the number of counties with the highest category of acres available shrinks by 2060, those areas are still concentrated in the West. Assuming constant Federal and State land area, counties that are projected to gain population will see declining recreation resource availability per resident, whereas counties projected to lose population will experience an increase in recreation resource availability per resident. Similar evaluations are available for future availability of water resources, snow, mountains, and other categories of recreation resources (Cordell et al., in press).

Outdoor Recreation Participation

Participation Trends

The number of U.S. participants[26] in 50 nature-based outdoor recreation activities (table 29) increased 7.1 percent between 2000 and 2009, and the number of activity days increased 40 percent (Cordell 2012).[27] Outdoor recreation participation grew dramatically through the 1960s and 1980s. Traditional activities, such as fishing, maintained popularity.[28] Activities such

Table 29. Trends in number and percentage of people age 16 and older participating in nature-based outdoor activities, 1994–1995, 1999–2001, and 2005–2009.[a]

Activity	1994–1995 total participants[b]	1999–2001 total participants[c]	2005–2009 total participants[d]	2005–2009 percent of population	Percent change 1999–2001 to 2005–2009
	millions				
View natural scenery	NA	127.1	149.8	63.7	17.9
Visit outdoor nature center/zoo	110.9	121.0	133.3	56.6	10.2
Sightsee	117.5	109.0	123.9	52.7	13.7
View wildflowers/trees	NA	93.8	121.3	51.6	29.4
View wildlife besides birds and fish	62.8	94.2	118.1	50.2	25.4
Visit a beach	128.8	84.4	102.0	43.3	20.7
Swim in lakes, streams, etc.	87.4	85.5	97.5	41.5	14.0
View or photograph birds	54.3	68.5	84.1	35.7	22.8
Day hike	53.5	69.1	79.7	33.9	15.4
Visit a wilderness	NA	67.2	79.1	33.6	17.7
Gather mushrooms/berries	NA	60.0	77.2	32.8	28.6
View salt/freshwater fish	27.6	52.3	63.5	27.0	21.4
Visit waterside besides beach	NA	53.2	56.5	24.0	6.3
Developed camp	46.5	55.3	56.0	23.8	1.1
Warmwater fish	49.3	47.6	55.7	23.7	17.1
Motorboat	59.5	50.7	55.0	23.4	8.6
Visit archaeological sites	36.1	44.0	48.8	20.8	11.1
Off-highway vehicle drive	35.9	36.0	48.4	20.6	34.5
Take Boat tours or excursions	NA	40.8	46.1	19.6	13.1
Bicycle on mountain/hybrid bike	NA	44.0	42.7	18.1	– 3.0
Primitive camp	31.4	33.1	34.2	14.5	3.2
Coldwater fish	25.1	28.4	30.9	13.1	8.7
Saltwater fish	22.9	21.4	25.1	10.7	17.2
Backpack	17.0	21.5	23.2	9.9	7.9
Canoe	17.9	19.3	22.8	9.7	18.2
Waterski	22.7	16.0	21.3	9.0	33.1
Use personal watercraft	12.0	19.1	21.1	9.0	10.9
Horseback ride on trails	15.1	15.8	16.1	6.8	1.6
Downhill ski	22.8	17.4	15.9	6.8	– 8.5
Snorkel[e]	16.2	13.6	15.2	6.5	11.8
Kayak	3.4	7.0	14.2	6.0	103.8
Mountain climb	9.0	13.2	12.4	5.3	– 5.9
Snowboard	6.1	9.1	12.2	5.2	33.7
Snowmobile	9.6	11.3	10.7	4.5	– 5.5
Anadromous fish	11.0	8.6	10.7	4.5	24.1
Sail	12.1	10.4	10.4	4.4	– 0.4
Cave	9.5	8.8	10.4	4.4	18.4

[26] A participant is any individual 16 years of age or older who engaged in one or more recreation activities during the 12 months before the survey interview date.

[27] The National Survey on Recreation and the Environment (NSRE) is the primary source of data for participation trends. It is a general population telephone survey of people 16 years of age and older that asks about outdoor recreation participation and other topics related to conservation and natural resources.

[28] Hunting and fishing numbers from the NSRE vary from the numbers reported by the U.S. Fish and Wildlife Service (FWS) survey presented in Chapter 13. Hunting and fishing, as referenced for the NSRE respondents, includes any amount of participation, whether or not it was the primary activity of choice for an outing, whereas the FWS survey focuses on primary participants. Surveys are also conducted in different years, complicating comparison of trends.

Table 29 (continued). Trends in number and percentage of people age 16 and older participating in nature-based outdoor activities, 1994–1995, 1999–2001, and 2005–2009.[a]

Activity	1994–1995 total participants[b]	1999–2001 total participants[c]	2005–2009 total participants[d]	2005–2009 percent of population	Percent change 1999–2001 to 2005–2009
	millions				
Rock climb	7.5	9.0	9.8	4.2	9.5
Row	10.7	8.6	9.4	4.0	8.9
Orienteer	4.8	3.7	6.2	2.6	67.8
Cross-country ski	8.8	7.8	6.1	2.6	– 21.7
Migratory bird hunt	5.7	4.9	4.9	2.1	– 1.1
Ice fish	4.8	5.7	4.8	2.1	– 15.5
Surf	2.9	3.2	4.7	2.0	46.3
Snowshoe	NA	4.5	4.1	1.7	– 9.4
Scuba dive	NA	3.8	3.6	1.5	– 5.6
Windsurf	2.8	1.5	1.4	0.6	– 10.1

[a] Numbers are annual estimates based on pooled National Survey on Recreation and the Environment data from the three time periods.

[b] 1994–1995 participants based on 201.26 million people age 16+ (Woods & Poole Economics 2007).

[c] 1999–2001 participants based on 214.02 million people age 16+ (2000 Census).

[d] 2005–2009 participants based on 235.30 million people age 16+ (2008 Census estimate).

[e] Snorkeling in 1994–1995 included scuba diving.

NA = Data not collected for this activity in 1994–1995. NSRE = National Survey on Recreation and the Environment.

Sources: NSRE 1994–1995 (n = 17,217); NSRE 1999–2001 (n = 52,607); and NSRE 2005–2009 (n = 24,073)

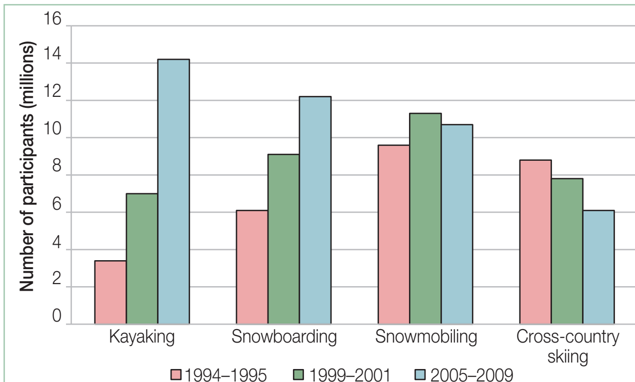
as camping, canoeing, kayaking, and bicycling grew rapidly, influenced partly by improving equipment technology. New activities appeared and there were few declines in participation.

Table 29 presents trends in participation in nature-based outdoor recreation activities in three time periods between 1994 and 2009. The most popular outdoor activity was viewing natural scenery. Activities oriented toward viewing and photographing nature have been among the fastest growing activities, both in terms of number of participants and days of participation. Off-highway vehicle driving realized a 34-percent increase in participants. Several physically challenging activities, such as kayaking, snowboarding, and surfing also had relatively large increases.

Although there were increases in the number of participants for the majority of activities during the last decade, there were declines in several activities. Most of the traditional winter recreation activities, with the exception of snowboarding, experienced decreasing participation rates and days of activity. Activities with decreasing participation rates also exhibited declines in the total number of activity days. In addition, several activities that had increased numbers of participants experienced a drop in total days of activity, indicating that the average number of days per participant declined. Examples included day hiking and horseback riding on trails (Cordell 2012).

Figure 142 illustrates how rapidly outdoor activities can shift in popularity. Kayaking and snowboarding showed strong increases in participation between the mid-1990s and mid-2000s, whereas cross-country skiing and, more recently, snowmobiling have been in decline.

Figure 142. Number of participants in four outdoor recreation activities in three time periods.[a]



[a] Numbers are annual estimates based on pooled National Survey on Recreation and the Environment (NSRE) data from the three time periods.
Source: NSRE

We grouped nature-based recreation activities into seven composites that either occur in similar recreation settings or have a similar focus:

- Visiting recreation and historic sites—family gatherings, picnicking, visiting beaches, visiting historic or prehistoric sites, and camping.
- Viewing and photographing nature—viewing and photographing birds, natural scenery, other wildlife, wildflowers, trees, etc.
- Backcountry activities—backpacking, day hiking, horseback riding on trails, mountain climbing, and visiting a wilderness or primitive area.

- Motorized activities— motorboating, off-highway vehicle driving, snowmobiling, using personal watercraft, and waterskiing.
- Hunting and fishing—anadromous fishing (salt to freshwater migratory fish, e.g., salmon), coldwater fishing, warmwater fishing, saltwater fishing, big game hunting, small game hunting, and migratory bird hunting.
- Nonmotorized boating—canoeing, kayaking, rafting, rowing, and sailing.
- Snow skiing and snowboarding—cross-country skiing, downhill skiing, and snowboarding.

Figure 143 summarizes the trends across the seven composite groups of activities using a 3-year moving average of the total annual number of activity days, indexed to the year 2000. The indexed values represent the percentage change since 2000. Motorized activities showed growth up to about 2005. This activity group, along with hunting and fishing, visiting recreation and historic sites, backcountry activities, and nonmotorized boating, ended up toward the end of this decade at about the same level of days of participation as in 2000. Visiting recreation and historic sites and nonmotorized boating showed moderate growth of between 10 to 20 percent in total activity days. Various forms of skiing declined during this decade. Viewing and photographing nature activities grew considerably, however.

Trends in the composites of activities can mask considerable differences among individual activities. Viewing and photographing nature showed the greatest growth, but there was variation among activities within this category. Although all five activities showed growth by the middle years of this decade, there was slower growth for viewing and photographing birds and for visiting nature centers. As a group of activities, the ones shown in figure 144 showed consistent growth patterns, likely indicating increasing interest in nature.

In contrast, nonmotorized boating had varying trends. Canoeing, rowing, and sailing maintained about the same level of total days of activity as in 2000. Kayaking and rafting showed moderate growth up through the middle years, but by 2006, rafting had dropped to less than its 2000 level before rebounding somewhat in 2008. Kayaking grew steadily throughout the decade, with only a slight dip in 2006 (figure 145).

A final example is the trends in motorized activity participation (figure 146). Until the middle years of this decade, only snowmobiling was declining. That downward trend continued

Figure 143. Trend in annual activity days for seven composites of nature-based outdoor recreation activities, 2000–2008 (indexed to total activity days in 2000).

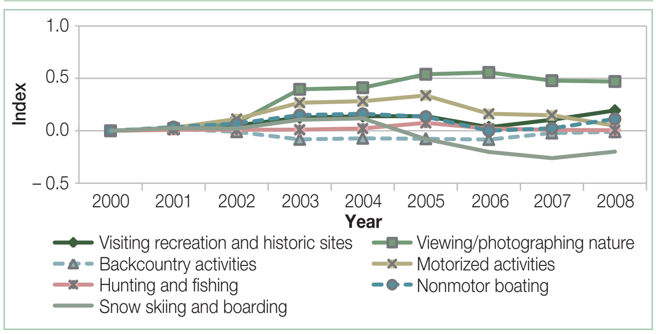


Figure 144. Trend in annual activity days for viewing and photographing nature activities, 2000–2008 (indexed to total activity days in 2000).

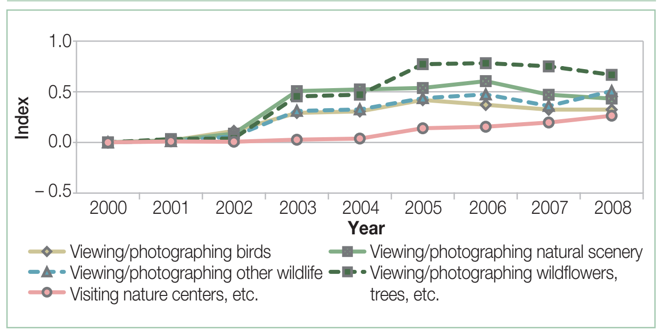


Figure 145. Trend in annual activity days for nonmotorized boating activities, 2000–2008 (indexed to total activity days in 2000).

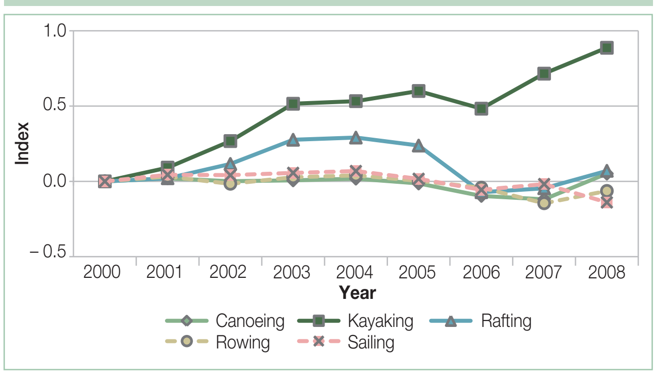
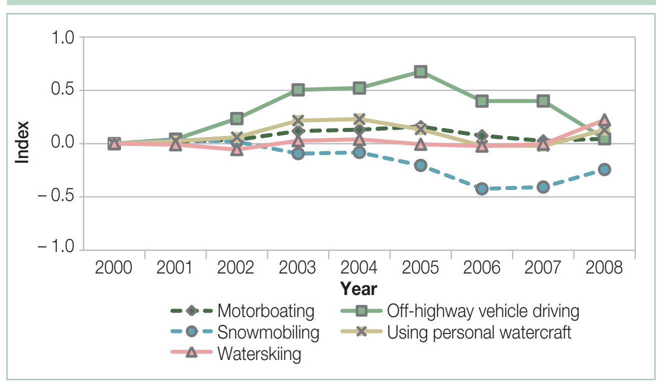


Figure 146. Trend in annual activity days for motorized activities, 2000–2008 (indexed to total activity days in 2000).



through 2006 but rebounded slightly through 2008. Off-highway vehicle driving grew steadily until 2005 before falling back to its 2000 level by 2008. Only snowmobiling had a lower level of participation in 2008 than it had in 2000.

Demographics and Recreation Trends

Demographic characteristics play an important role in individual choices of outdoor recreation activities. Significant changes are expected in recreation participation as the U.S. population becomes older and more ethnically and racially diverse. Gender, race, age, education, income, and rural or urban residency all contribute to explaining differences in recreation participation.

Across the seven recreation activity groups, there were several common findings. Non-Hispanic Whites tended to dominate participation in all groups. The exception is that Native Americans were as likely to participate in backcountry activities. Males were more likely than females to participate in all groups except visiting recreation or historic sites and viewing and photographing nature. People who are young to middle aged and had college educations and higher incomes also tended to be more likely to participate in most activity groups. Place of residence was influential in hunting activities and motorized and nonmotorized activities (rural residents were more likely to participate) and in backcountry activities and snow skiing (urban residents were more likely to participate).

The demographic groups consistently less likely to participate were African-Americans, people 65 or older, and people with less education and lower incomes. Females, Hispanics, and Asians were less likely to participate in some activities, but the pattern varied across activities. Understanding the constraints on participation would improve the ability of recreation providers to deliver recreation opportunities.

Green et al. (2012) focused on the role of social factors such as the lack of time, money, transportation, facilities, or information, and crowding at sites, poorly maintained facilities, and pollution as constraints felt by potential recreationists. People over age 65 tended to participate less because they felt constrained for health reasons, but they felt less constrained in terms of time and money. Constraints between genders varied considerably. Men felt more constrained than women only because of limited time, whereas women felt more constrained than men by many factors, including family obligations, money, transportation issues, and safety concerns. Immigrants felt most constrained by language barriers. People with lower incomes felt constrained by a number of factors, including not only money, but also health issues, inadequate transportation, and outdoor pests. Urban dwellers were more likely to feel constrained by time, inadequate transportation, crowded sites, and safety problems than were rural dwellers.

African-Americans, Asians, and Hispanics all generally felt more constrained than non-Hispanic Whites. Asians felt less deterred than Whites by crowded sites, and Hispanics felt more constrained about language issues (Green et al. 2012). In-depth field research (Chavez 2012) on Latino recreationists, conducted mostly in southern California, indicated that most people preferred to receive information about recreation areas by word of mouth, particularly from family and friends. For Latinos, onsite information, such as bulletin boards, signage, and brochures, was most beneficial when it was site-specific, for example, the best times to visit the area to avoid crowds, safety-related information, and specific camping rules. Some of the constraints most strongly experienced by Latinos included "feeling uncomfortable in the outdoors," finding travel and recreation in natural areas "too much trouble," and being discriminated against while traveling to or when recreating in natural areas. Study respondents also indicated a desire for more Latino employees at the recreation areas.

Given the growing diversity of the American population, the relatively low participation rates of all groups except non-Hispanic Whites are a concern for overall future recreation participation. Similarly, the aging population may require different types of recreation opportunities. Recreation activities that have been dominated by rural residents are also likely to decline, as the American population becomes increasingly more urban.

Recreation Participation by Region

Differences in participation in outdoor recreation activities among regions reflect regional population, recreation resource availability, and recreation preferences. Table 30 presents the percentage of outdoor recreation participants for the seven composite recreation activity groups by the four RPA regions. The North Region, with the highest proportion of the U.S. population, tends also to have the highest percentage of total recreation participants, but not necessarily the highest percentage of the regional population participating.

Youth Recreation

The National Kids Survey (NKS) was started in 2007 to provide information on outdoor activity of youth age 6 to 19. From data collected between 2007 and 2009, the NKS indicated that youth spent significant time outdoors, with the dominant activity being "just playing or hanging out outdoors," followed by biking, jogging, walking, skateboarding, etc. (table 31). Whereas participation rates tend to increase in the middle age groups, there tended to be a decline in the 16–19 age group, with a few exceptions. Youth in the 6–15 age group spent more time outdoors than those in the 16–19 age group. Hispanic youth spent more time outdoors than other ethnic groups. Girls generally spent less time outdoors than boys.

Table 30. Percent of recreation participants by RPA region in seven recreation activity groups.[a]

Activity group	RPA region	All participants	U.S. population	Regional population participating
Visiting recreation and historic sites	North	39.8	38.6	78.8
	South	31.9	33.6	74.5
	Rocky Mountain	9.4	9.4	79.9
	Pacific Coast	18.9	18.4	80.4
Viewing and photographing nature	North	38.6	38.6	74.8
	South	32.7	33.6	71.6
	Rocky Mountain	9.8	9.4	77.0
	Pacific Coast	18.9	18.4	76.7
Backcountry activities	North	38.2	38.6	40.2
	South	27.6	33.6	34.4
	Rocky Mountain	12.4	9.4	54.7
	Pacific Coast	21.8	18.4	49.6
Motorized activities	North	37.9	38.6	34.4
	South	32.9	33.6	35.4
	Rocky Mountain	10.8	9.4	41.0
	Pacific Coast	18.4	18.4	36.1
Hunting and fishing	North	37.0	38.6	32.6
	South	37.3	33.6	37.8
	Rocky Mountain	10.5	9.4	37.7
	Pacific Coast	15.2	18.4	28.0
Nonmotor boating	North	42.1	38.6	22.7
	South	28.7	33.6	17.7
	Rocky Mountain	9.4	9.4	20.6
	Pacific Coast	19.9	18.4	22.4
Snow skiing and boarding	North	46.8	38.6	13.4
	South	15.4	33.6	5.2
	Rocky Mountain	12.5	9.4	15.0
	Pacific Coast	25.3	18.4	15.6

[a] Percentages sum to 100 within each activity group in the first two columns.

Source: National Survey on Recreation and the Environment (NSRE) 2005–2009, Versions 1-4. N = 24,073. Interview dates: 1/05 to 4/09

Table 31. Percent of youth participating in an outdoor activity at least once in the preceding week by type of outdoor activity and by age group.

Outdoor activity	Age 6–9	Age 10–12	Age 13–15	Age 16–19
Just play outdoors or hang out	86.5	94.9	80.9	68.1
Bike, jog, walk, skate board, etc.	84.8	87.2	67.4	78.4
Listen to music, watch movies, or use electronic device outdoors	39.4	46.8	74.8	64.5
Play or practice team sports	47.2	49.6	61.0	47.3
Read, study while sitting outdoors	42.2	52.4	39.1	50.4
Play other sports, e.g., tennis, golf	43.9	50.3	29.2	30.1
Attend camps, field trips, outdoor classes	36.4	37.9	37.1	28.8
Bird watch, wildlife view, etc.	38.8	39.2	36.9	25.3
Swim, dive, snorkel, etc.	41.4	43.6	24.9	18.6
Hike, camp, fish, etc.	39.5	23.9	32.3	26.6
Ride motorcycles, ATVs, other off-road vehicles	19.4	15.7	23.1	21.1
Snow ski, snowboard, cross-country ski	3.8	9.3	13.3	11.3
Boat, jet ski, water ski, etc.	7.0	8.1	9.1	10.7
Row, kayak, canoe, surf, etc.	8.3	9.5	6.8	8.8
Other outdoor activities	9.5	10.9	10.8	8.1

ATV = all-terrain vehicle.

Source: National Survey on Recreation and the Environment (NSRE) National Kids Survey, N = 1,201. Interview dates: 9/15/07 to 4/27/09

The National Survey of Fishing, Hunting, and Wildlife-Associated Recreation also looked at youth trends in hunting. Whereas participation in hunting among those age 16 and older has declined during the last two decades, the number of girls 6 to 15 years old who hunt nearly doubled between 1991 and 2006, and the number of boys of that age who hunted stayed about level. Despite the increase in young female hunters, they still numbered less than one-fourth of the more than 1.2 million young male hunters in 2006 (Aiken and Harris 2012).

Results from the 2009 Outdoor Foundation recreation survey (The Outdoor Foundation 2009) indicated that youth participation in outdoor activities is high at early ages. Male participation rates tend to decline between ages 16 and 25, then begin to rise again. Female participation rates also begin to decline at age 16, but begin to increase in the 21 to 25 age group, although female participation rates are lower than male rates in both youth and adulthood.

Over the past 3 years of the Outdoor Foundation's annual participation survey, youth participation (6 to 17 years) declined more than 11 percent between 2006 and 2007 and declined 6 percent between 2007 and 2008. The decline was most pronounced among the youngest age group, those aged 6 to 12, with a sharper decline among girls. There is now a significant gap between boys' and girls' participation that did not exist when the annual surveys began. Youth are most often introduced to outdoor recreation by their family and friends, with parents being the top influence by a large margin.

Role of Public Lands

Federal lands provide crucial recreation opportunities, particularly in the Western United States. Table 32 reports recreation visits to lands managed by the five primary Federal providers of recreation opportunities. Whereas the National Park Service, U.S. Fish and Wildlife Service, Bureau of Land Management, and Forest Service provide a wide range of recreation opportunities, the U.S. Army Corps of Engineers primarily provides opportunities associated with water recreation on its reservoir systems.

State park systems are a major provider of recreation opportunities, often located in closer proximity to population centers than Federal lands. State park visits from 1992 to 2008 are shown in table 33 for the Nation and for the four RPA regions.

Table 32. Millions of recreation visits to Federal lands, 1996–2008.

Year	National Park Service	U.S. Fish & Wildlife Service	Bureau of Land Management	Forest Service	U.S. Army Corps of Engineers
1996	266	30	57	NA	372
1997	275	30	61	NA	378
1998	287	32	61	NA	381
1999	287	35	55	NA	379
2000	286	37	54	NA	NA
2001	280	39	52	214	NA
2002	277	38	53	NA	358
2003	266	40	53	NA	349
2004	277	40	54	205	359
2005	274	38	56	196	362
2006	273	38	55	180	371
2007	276	40	58	179	363
2008	275	41	57	176	357
2009	286	43	57	174	370

NA = data not available.

Table 33. Millions of visits to State park system areas by RPA region, 1992–2008.[a]

Year	North	South	Rocky Mountain	Pacific Coast	U.S. Total
1992	312.2	162.9	49.0	179.6	703.8
1993	325.6	164.1	52.6	182.5	724.8
1994	329.3	167.7	54.3	174.3	725.5
1995	351.3	169.0	58.9	173.1	752.3
1996	358.5	152.3	58.8	176.0	745.6
1997	355.5	147.6	57.2	223.1	783.4
1998	354.7	153.1	59.9	193.1	760.8
1999	375.0	152.9	56.4	182.6	766.8
2000	370.6	151.5	58.9	205.6	786.6
2001	367.9	149.0	59.0	190.2	766.0
2002	367.7	145.0	60.9	184.6	758.2
2003	351.6	143.5	61.1	178.8	735.0
2004	340.2	135.6	62.2	180.8	718.8
2005	342.6	130.7	62.9	175.2	711.5
2006	373.7	131.3	61.7	173.5	740.2
2007	371.4	135.6	57.1	168.9	732.8
2008	370.6	134.5	63.7	179.2	748.0
2009	357.0	133.5	64.3	172.2	727.1

[a] The time period covered by each report is the previous 12-month period of July 1 to June 30. For example, the 2009 report covers July 1, 2008, through June 30, 2009. In a few cases, some States did not report visitation statistics for certain years. Previous year statistics were used in place of missing data. States and years include Idaho in 2007 and 2006 (used 2005 data), Hawaii in 2006 (used 2005 data), New Hampshire in 2005 and 2006 (both used 2004 data), Illinois in 2004 (used 2003 data), and Rhode Island in 2004 (used 2003 data).

Source: National Association of State Park Directors 2009

Recreation Participation in the Future

We examined adult recreation participation for 17 recreation activity composites, which we organized into seven activity groups (table 34). We modeled per capita participation and average annual days per participant. We calculated total participants and total annual days of participation by multiplying the RPA scenario population projections by the participation rate and average days per participant. Projections were done for each of the three RPA scenarios without climate variables. Then, we ran the models with climate variables for each of the nine RPA scenario-climate combinations (table 2) (Bowker and Askew 2012; Bowker et al. 2012).

Key differences in the model variables drive the future trends in recreation participation. Population growth often is the most important driver, and therefore the RPA A2 scenario, with the largest projected population growth, often has the greatest

Table 34. Participants and participation in outdoor recreation activities, 2008.[a]

Activity group and activity	Participants (*millions*)	Participation rate (*percent*)
Visiting developed sites		
Developed site use-family gatherings, picnicking, developed camping	192.7	81.9
Visiting interpretive sites—nature centers, zoos, historic sites, prehistoric sites	157.4	66.9
Viewing and photographing nature		
Birding	81.4	34.6
Viewing—viewing, photography, study, or nature gathering related to fauna, flora, or natural settings	189.4	80.5
Backcountry activities		
Challenge activities—caving, mountain biking, mountain climbing, rock climbing	25.1	10.7
Equestrian	16.4	7.0
Hiking-day hiking	78.3	33.3
Visiting primitive areas—backpacking, primitive camping, wilderness	90.1	38.3
Motorized activities		
Motorized off-road use	47.9	20.4
Motorized snow use	9.4	4.0
Motorized water use	62.0	26.3
Hunting and fishing		
Hunting—small game, big game, migratory bird, other	27.9	11.9
Fishing—anadromous, coldwater, saltwater, warmwater	72.7	30.9
Nonmotorized winter activities		
Downhill skiing-downhill skiing, snowboarding	23.7	10.1
Winter activities—cross-country skiing, snowshoeing	7.8	3.3
Nonmotorized water activities		
Swimming—swimming, snorkeling, surfing, diving, visiting beaches or watersides	143.2	60.9
Floating—canoeing, kayaking, rafting	39.8	16.9

[a] Activities are individual or activity composites derived from the National Survey on Recreation and the Environment (NSRE). Participants are determined by the product of the average weighted frequency of participation by activity for NSRE data from 2005–2009 and the adult (> 16) population in the United States during 2008 (235.4 million).

Source: NSRE 2005–2009, Versions 1 to 4 (January 2005 to April 2009), N = 24,073

changes, whereas the RPA B2 scenario has the smallest. Income growth also has differential effects on participation. In activities that require more capital or income for effective participation, such as developed skiing, challenge activities, equestrian activities, hunting, and motorized activities, the combination of population growth and higher income growth in scenario RPA A1B resulted in larger participation changes than RPA A2.

The effects of population growth were often offset by more indirect effects. A growing population combined with a stable public land base and declining private natural land base resulted in a decline in per capita recreation opportunities during the projection period. These declines tend to have negative effects on recreation participation. Increasing population density tends to have a negative effect on recreation participation as a result of crowding. In most cases, population growth is sufficient to result in overall growth in total participants and total days of participation, even when participation rates and/or average days of participation are projected to decline.

Generally, land and water availability positively influence activity participation. Therefore, declines in the per capita area of forest and rangeland and Federal land induced participation declines in spatially extensive activities such as equestrian, hunting, motorized off-road driving, visiting primitive areas, and viewing and photographing nature. Similarly, participation in water-based activities such as swimming, motorized boating, and nonmotorized boating were all positively correlated with the per capita availability of water area.

Climate variables were added to the projection models to test whether participation and participation intensity were sensitive to climate effects. Temperature, precipitation, and evapotranspiration variables were tested, with a single climate variable introduced into each recreation activity model. More details about the use of climate variables in the participation models can be found in Bowker et al. (2012).

Adding climate variables to the projection models did not greatly change future participation except for a few activities. Generally, the effect of the climate variables was a slight increase or decrease in the metrics compared with the "no climate change" projection. For snowmobiling and undeveloped skiing, the effect of the climate variables was substantial decreases in the number of participants and annual participation days. Table 35 lists the general circulation models (GCMs) used as

Table 35. List of climate models used in the RPA scenario-climate combinations (Climate 1, Climate 2, and Climate 3) in the recreation participation models.

RPA scenario	Climate 1	Climate 2	Climate 3
A1B	CGCM3.1	CSIRO-Mk3.5	MIROC3.2
A2	CGCM3.1	CSIRO-Mk3.5	MIROC3.2
B2	CGCM2	CSIRO-Mk2	HadCM3

the basis for the climate projections for the results listed as "Climate 1," "Climate 2," and "Climate 3" in tables 36 through 51. The results of participation models are shown in a series of tables (tables 36 to 51) that describe the results with no climate change (No CC) (i.e., historical climate trends are assumed to continue) for each of the three RPA scenarios and also with results for the nine RPA scenario-climate combinations.

Visiting Developed Sites

The activities associated with developed site use include venues popular with all age groups. Per capita participation is currently high and is projected to remain relatively constant across all the RPA scenarios. RPA A1B showed the greatest change from 2008, with a 3-percent increase (table 36). Days per participant are projected to decline slightly. Incorporating climate variables resulted in consistently lower results, but the effect was quite small across all RPA scenario-climate combinations.

Visiting interpretive sites is also popular across all ages and occurs primarily in developed settings. The projections indicate participation rates could increase 4 to 9 percent by 2060 across the RPA scenarios (table 37). For this activity, climate effects resulted in little difference in participation rates but consistently projected higher numbers of days per participant. The greater participation rate growth in this activity group compared with developed site use has several possible causes: developed site use is negatively correlated with age, which is expected to rise by 2060, and positively correlated with available Federal land per capita. Those variables are less important in interpretive site participation.

Viewing and Photographing Nature

This category includes birding and nature viewing, which adds viewing wildlife and nature, gathering, and nature study. Adult participation in birding averaged 35 percent in 2008. Nearly 81 percent of adults participated in the more broadly defined nature viewing during the same period (table 38). The participation rate for nature viewing was projected to increase by up to 4 percent to 2060, whereas the participation rate for birding could vary from a 4-percent decrease to an 8-percent increase. RPA A1B yielded the highest participation-rate growth, primarily because of higher incomes, which correlate positively with the viewing activities. The days per participant declined across all RPA scenarios, resulting in one of the largest relative declines in days per participants across all activities. Adding climate variables to the model had little effect on the results.

Backcountry Activities

Backcountry activities are pursued in undeveloped but accessible lands. Challenge activities are often associated with young and affluent adults. The participation rate is projected to increase under all of the RPA scenarios, by 4 to 20 percent, with the largest increase projected for RPA A1B (table 39).

Table 36. Developed site projected participation and use by American adults, 2008–2060, by RPA scenario and related climate futures.

RPA scenario	2008	2060	2060			
		No CC	No CC	Climate 1	Climate 2	Climate 3
	adult per capita participation		*percent increase (decrease) from 2008*			
RPA A1B	0.819	0.840	3	2	1	1
RPA A2	0.819	0.829	1	0	0	(1)
RPA B2	0.819	0.830	1	0	0	0
	days per participant		*percent increase (decrease) from 2008*			
RPA A1B	11.67	11.49	(2)	(3)	(4)	(4)
RPA A2	11.67	11.48	(2)	(3)	(3)	(4)
RPA B2	11.67	11.52	(1)	(3)	(3)	(2)

CC = climate change.

Table 37. Interpretive site projected participation and use by American adults, 2008–2060, by RPA scenario and related climate futures.

RPA scenario	2008	2060	2060			
		No CC	No CC	Climate 1	Climate 2	Climate 3
	adult per capita participation		*percent increase (decrease) from 2008*			
RPA A1B	0.669	0.728	9	9	8	7
RPA A2	0.669	0.705	5	4	5	4
RPA B2	0.669	0.706	6	5	5	5
	days per participant		*percent increase (decrease) from 2008*			
RPA A1B	7.81	8.40	8	9	10	13
RPA A2	7.81	8.12	4	6	5	8
RPA B2	7.81	8.11	4	6	6	6

CC = climate change.

Table 38. Nature viewing projected participation and use by American adults, 2008–2060, by RPA scenario and related climate futures.

RPA scenario	2008	2060	2060			
		No CC	No CC	Climate 1	Climate 2	Climate 3
	adult per capita participation		*percent increase (decrease) from 2008*			
RPA A1B	0.805	0.810	4	3	3	2
RPA A2	0.805	0.810	1	0	1	0
RPA B2	0.805	0.815	1	1	1	1
	days per participant		*percent increase (decrease) from 2008*			
RPA A1B	169.6	150.5	(11)	(12)	(13)	(14)
RPA A2	169.6	154.8	(9)	(10)	(10)	(10)
RPA B2	169.6	155.3	(8)	(10)	(10)	(9)

CC = climate change.

The higher participation growth is driven by higher projected income relative to RPA A2 and B2. Days per participant are almost unchanged across RPA scenarios. The effects of climate on the projections were generally positive or were no different than the results with no climate effects.

Participation in equestrian or trail riding per capita is projected to increase between 2 and 19 percent by 2060 across RPA scenarios (table 40). The increase is particularly high for RPA A1B, which has the highest income growth. The number of days per participant changes very little across RPA scenarios, suggesting that higher income participants have more competing uses for their time. Incorporating climate change into the models consistently increased participation rates compared with the model with no climate change, showing considerably larger differences than for most activity groups. Whereas climate change had a positive effect on participation rates, it had a negative effect on days per participant, which is opposite of the trend projected without climate effects. The effect of climate change varies considerably across the nine outcomes and some of the effects are quite large, with 15- to 20-percent decreases in days per participant.

Hiking is the most popular single backcountry activity, with 33-percent adult participation in 2008. By 2060, the participation rate is projected to increase between 3 and 10 percent across RPA scenarios, with the largest growth in RPA A1B (table 41). Hiking is the only activity for which Hispanic ethnicity resulted in a higher participation rate than other ethnic groups. Days spent hiking are projected to increase slightly more than participation. Models that incorporated climate change consistently projected smaller increases in

Table 39. Challenge activity projected participation and use by American adults, 2008–2060, by RPA scenario and related climate futures.

RPA scenario	2008	2060	2060			
		No CC	No CC	Climate 1	Climate 2	Climate 3
	adult per capita participation		*percent increase (decrease) from 2008*			
RPA A1B	0.107	0.126	18	15	20	20
RPA A2	0.107	0.114	7	5	4	9
RPA B2	0.107	0.115	7	8	7	6
	days per participant		*percent increase (decrease) from 2008*			
RPA A1B	4.77	4.71	(1)	0	1	1
RPA A2	4.77	4.69	(2)	0	0	1
RPA B2	4.77	4.73	(1)	1	0	1

CC = climate change.

Table 40. Equestrian activity projected participation and use by American adults, 2008–2060, by RPA scenario and related climate futures.

RPA scenario	2008	2060	2060			
		No CC	No CC	Climate 1	Climate 2	Climate 3
	adult per capita participation		*percent increase (decrease) from 2008*			
RPA A1B	0.07	0.083	19	22	26	34
RPA A2	0.07	0.071	2	10	5	12
RPA B2	0.07	0.072	4	9	8	9
	days per participant		*percent increase (decrease) from 2008*			
RPA A1B	16.3	16.8	3	(4)	(9)	(20)
RPA A2	16.3	16.8	3	(10)	(4)	(15)
RPA B2	16.3	16.8	3	(6)	(6)	(8)

CC = climate change.

participation rates than the models without climate change, but had almost no effect on days per participant.

The final backcountry activity is visiting primitive areas. The participation rate is projected to decline between 1 and 9 percent across RPA scenarios (table 42). Increased population density and declines in wilderness, forest, and rangeland acres per capita appeared to influence the participation rate decline. Activity days per participant were projected to decline slightly less than participation rates. Climate effects consistently led to larger declines than the results with no climate change.

Motorized Activities

We considered three categories of motorized activities: off-road driving, motorized water use, and motorized snow use. Participation in off-road driving is projected to stay about the same under RPA A1B, as opposed to declining 7 and 18 percent in RPA scenarios B2 and A2, respectively (table 43). The larger decline in RPA A2 can be attributed to lower projected income growth than in RPA A1B and a greater projected decline in private forest land and rangeland than in RPA B2. Annual days per participant are also projected to decline, ranging from 3 to 7 percent across all alternatives.

Motorized water use has the highest participation rate among motorized activities. Under the RPA A1B scenario, the participation rate is expected to increase between 5 and 15 percent, whereas rates are expected to decline under RPA A2 and B2 (table 44). Income growth under RPA A1B is the biggest factor affecting this difference. The projection models with climate variables consistently projected smaller increases or larger declines than the models with no climate variables.

Table 41. Day hiking projected participation and use by American adults, 2008–2060, by RPA scenario and related climate futures.

RPA scenario	2008	2060	2060			
		No CC	No CC	Climate 1	Climate 2	Climate 3
	adult per capita participation		*percent increase (decrease) from 2008*			
RPA A1B	0.333	0.365	10	8	5	4
RPA A2	0.333	0.360	8	4	5	3
RPA B2	0.333	0.357	7	5	5	4
	days per participant		*percent increase (decrease) from 2008*			
RPA A1B	22.9	24.2	6	7	6	6
RPA A2	22.9	24.2	6	6	6	6
RPA B2	22.9	24.3	6	7	6	6

Table 42. Primitive area projected participation and use by American adults, 2008–2060, by RPA scenario and related climate futures.

RPA scenario	2008	2060	2060			
		No CC	No CC	Climate 1	Climate 2	Climate 3
	adult per capita participation		*percent increase (decrease) from 2008*			
RPA A1B	0.383	0.381	0	(1)	(2)	(5)
RPA A2	0.383	0.363	(5)	(8)	(6)	(9)
RPA B2	0.383	0.365	(5)	(6)	(6)	(6)
	days per participant		*percent increase (decrease) from 2008*			
RPA A1B	13.2	13.1	(1)	(3)	(5)	(5)
RPA A2	13.2	13.0	(1)	(5)	(4)	(5)
RPA B2	13.2	13.1	(1)	(3)	(3)	(4)

CC = climate change.

Table 43. Motorized off-road projected participation and use by American adults, 2008–2060, by RPA scenario and related climate futures.

RPA scenario	2008	2060	2060			
		No CC	No CC	Climate 1	Climate 2	Climate 3
	adult per capita participation		*percent increase (decrease) from 2008*			
RPA A1B	0.204	0.203	0	(1)	1	1
RPA A2	0.204	0.169	(18)	(18)	(18)	(16)
RPA B2	0.204	0.189	(8)	(7)	(7)	(8)
	days per participant		*percent increase (decrease) from 2008*			
RPA A1B	21.6	20.2	(6)	(6)	(3)	(3)
RPA A2	21.6	20.2	(7)	(5)	(4)	(4)
RPA B2	21.6	20.3	(6)	(5)	(5)	(5)

CC = climate change.

Table 44. Motorized water projected participation and use by American adults, 2008–2060, by RPA scenario and related climate futures.

RPA scenario	2008	2060	2060			
		No CC	No CC	Climate 1	Climate 2	Climate 3
	adult per capita participation		*percent increase (decrease) from 2008*			
RPA A1B	0.263	0.304	15	14	11	5
RPA A2	0.263	0.257	(2)	(7)	(4)	(10)
RPA B2	0.263	0.265	1	(3)	(2)	(3)
	days per participant		*percent increase (decrease) from 2008*			
RPA A1B	15.3	16.0	4	3	2	0
RPA A2	15.3	14.3	(6)	(8)	(7)	(9)
RPA B2	15.3	14.9	(2)	(4)	(4)	(4)

CC = climate change.

Motorized snow use (snowmobiling) has one of the largest projected declines in participation rates across all activities. By 2060, rates are projected to decline between 13 and 72 percent, with much larger declines in the RPA scenarios with climate change (table 45). The climate effects are much more variable within RPA A1B than for RPA A2 or B2. Income growth in RPA A1B slows the decline in the projections without climate effects. Days per participant decline slightly when climate is not considered, but those declines are larger under all RPA scenario-climate combinations.

Hunting and Fishing

The adult hunting participation rate is projected to decline between 22 and 35 percent across RPA scenarios by 2060 (table 46). The RPA A2 scenario shows the biggest decrease. Increased education levels, increased population density, diminishing availability of private and public land, and strong negative relationships between growing minority populations and hunting appear to be influencing the decline in participation rate. Days per hunter are also projected to decline, from 12 to 14 percent across RPA scenarios. Models with climate effects resulted in a marginally negative effect across RPA scenario-climate combinations.

The participation rate for fishing is projected to decline from 3 to 10 percent, with the largest decline under RPA A2 (table 47). Fishing days per participant are projected to fall between 3 and 8 percent. The effect of climate on fishing participation rates was negative, but the effect on days per participant was not consistent across RPA scenarios.

Nonmotorized Winter Activities

Developed skiing (including snowboarding) participation rates are projected to increase from 4 to 45 percent across RPA scenarios. Income growth is a strong driver in skiing participation, resulting in the largest increases in the RPA A1B scenario, whereas other scenarios show much more modest increases (table 48). Days per participant are projected to remain largely unchanged except under the RPA A1B scenario, in which a 9- to 10-percent increase is projected. Climate effects on participation rates are not consistent across RPA scenario-climate combinations; climate effects on days per participant vary little from the effects with no climate.

Undeveloped skiing includes cross-country skiing and snowshoeing. With the exception of RPA A1B with no climate effects, participation rates are projected to decline up to 63 percent (table 49). Climate effects markedly increase the decline in participation rates across all RPA scenario-climate combinations. Days per participant are projected to increase slightly with no climate effects, but decline in eight of the nine projections with climate effects, although the differences are relatively small.

Table 45. Motorized snow activity projected participation and use by American adults, 2008–2060, by RPA scenario and related climate futures.

RPA scenario	2008	2060	2060			
		No CC	No CC	Climate 1	Climate 2	Climate 3
	adult per capita participation		*percent increase (decrease) from 2008*			
RPA A1B	0.04	0.035	(13)	(32)	(49)	(72)
RPA A2	0.04	0.031	(23)	(60)	(43)	(69)
RPA B2	0.04	0.032	(21)	(49)	(46)	(51)
	days per participant		*percent increase (decrease) from 2008*			
RPA A1B	7.25	7.04	(3)	(10)	(24)	(24)
RPA A2	7.25	6.95	(4)	(9)	(18)	(22)
RPA B2	7.25	7.12	(2)	(13)	(14)	(13)

CC = climate change.

Table 46. Hunting projected participation and use by American adults, 2008–2060, by RPA scenario and related climate futures.

RPA scenario	2008	2060	2060			
		No CC	No CC	Climate 1	Climate 2	Climate 3
	adult per capita participation		*percent increase (decrease) from 2008*			
RPA A1B	0.119	0.093	(22)	(24)	(25)	(28)
RPA A2	0.119	0.082	(31)	(34)	(33)	(35)
RPA B2	0.119	0.092	(23)	(25)	(25)	(24)
	days per participant		*percent increase (decrease) from 2008*			
RPA A1B	19.1	16.8	(12)	(12)	(14)	(14)
RPA A2	19.1	16.8	(12)	(12)	(12)	(14)
RPA B2	19.1	16.8	(12)	(13)	(12)	(12)

CC = climate change.

Table 47. Fishing projected participation and use by American adults, 2008–2060, by RPA scenario and related climate futures.

RPA scenario	2008	2060	2060			
		No CC	No CC	Climate 1	Climate 2	Climate 3
	adult per capita participation		*percent increase (decrease) from 2008*			
RPA A1B	0.309	0.300	(3)	(6)	(8)	(6)
RPA A2	0.309	0.277	(10)	(17)	(13)	(8)
RPA B2	0.309	0.282	(9)	(13)	(12)	(8)
	days per participant		*percent increase (decrease) from 2008*			
RPA A1B	18.5	17.5	(5)	(5)	(6)	(7)
RPA A2	18.5	17.2	(7)	(6)	(6)	(8)
RPA B2	18.5	17.7	(4)	(4)	(4)	(3)

CC = climate change.

Table 48. Developed skiing projected participation and use by American adults, 2008–2060, by RPA scenario and related climate futures.

RPA scenario	2008	2060	2060			
		No CC	No CC	Climate 1	Climate 2	Climate 3
	adult per capita participation		*percent increase (decrease) from 2008*			
RPA A1B	0.101	0.147	45	44	43	43
RPA A2	0.101	0.114	11	11	9	4
RPA B2	0.101	0.115	13	8	17	14
	days per participant		*percent increase (decrease) from 2008*			
RPA A1B	7.19	7.90	10	9	9	9
RPA A2	7.19	7.26	1	0	0	(1)
RPA B2	7.19	7.31	2	0	2	1

CC = climate change.

Table 49. Undeveloped skiing projected participation and use by American adults, 2008–2060, by RPA scenario and related climate futures.

RPA scenario	2008	2060	2060			
		No CC	No CC	Climate 1	Climate 2	Climate 3
	adult per capita participation		*percent increase (decrease) from 2008*			
RPA A1B	0.033	0.035	6	(18)	(36)	(63)
RPA A2	0.033	0.029	(8)	(50)	(30)	(60)
RPA B2	0.033	0.030	(6)	(35)	(34)	(38)
	days per participant		*percent increase (decrease) from 2008*			
RPA A1B	6.58	6.72	2	(3)	(6)	(5)
RPA A2	6.58	6.69	2	(4)	(4)	(7)
RPA B2	6.58	6.74	3	(4)	0	(2)

CC = climate change.

Nonmotorized Water Activities

This category consists of various kinds of outdoor swimming, including related activities like snorkeling, surfing, diving, and visiting beaches or watersides. Swimming is the fourth most popular outdoor activity, with a 61-percent adult participation rate (table 50). Differences in projected participation-rate increases primarily reflect population growth differences across RPA scenarios. Climate variables had almost no effect on participation rate projections. Days per participant are projected to increase slightly under RPA A1B, whereas they decline slightly under both RPA A2 and B2. Climate change had a negative effect on days per participant.

Floating activities include canoeing, kayaking, and rafting. By 2060, the participation rate is projected to increase slightly under RPA A1B without climate effects and to have no change or decrease when climate effects are included. Participation rates decline for both RPA B2 and A2, with stronger declines projected when climate is considered (table 51). Days per participant were virtually unchanged across all RPA scenario-climate combinations.

Conclusions

Public lands are crucial resources for nature-based outdoor recreation. Although the total land area owned by local governments is modest relative to State and Federal Governments, those lands are important for providing recreation opportunities in close proximity to where most of the population lives. The private sector also plays a significant role as both a provider and a facilitator of outdoor recreation opportunities, including as a partner with Federal and State agencies for the development and operation of concessions that supply visitor services.

The outlook for recreation resources is generally for declining opportunities per person. Assuming the public land base for outdoor recreation remains stable into the future, an increasing population will result in decreasing per-person opportunities for recreation across most of the United States. Although there are many other factors involved in recreation supply, it is likely that recreation resources will become less available as more people compete to use them. A major challenge for natural resource managers and planners will be to ensure that recreation opportunities remain viable and grow along with the population. This goal would more than likely be accomplished through management and site attribute inputs and plans, rather than through any major expansions or additions to the natural resource base for recreation.

Choices in outdoor recreation activities have changed over time in response to changing preferences, demographics, and recreation opportunities. Overall, there has been growth in nature-based outdoor recreation participation since the last RPA Assessment, continuing a long-term trend. At the same time, recreation visitation to State parks and Federal lands has not increased at similar rates, indicating that recreationists are also using other

Table 50. Swimming projected participation and use by American adults, 2008–2060, by RPA scenario and related climate futures.

RPA scenario	2008	2060	2060			
		No CC	No CC	Climate 1	Climate 2	Climate 3
	adult per capita participation		*percent increase (decrease) from 2008*			
RPA A1B	0.609	0.676	11	11	11	11
RPA A2	0.609	0.645	6	6	6	6
RPA B2	0.609	0.642	5	6	5	5
	days per participant		*percent increase (decrease) from 2008*			
RPA A1B	24.0	25.1	5	3	1	1
RPA A2	24.0	23.7	(1)	(4)	(3)	(4)
RPA B2	24.0	23.8	(1)	(3)	(3)	(3)

CC = climate change.

Table 51. Floating activity projected participation and use by American adults, 2008–2060, by RPA scenario and related climate futures.

RPA scenario	2008	2060	2060			
		No CC	No CC	Climate 1	Climate 2	Climate 3
	adult per capita participation		*percent increase (decrease) from 2008*			
RPA A1B	0.169	0.171	3	0	(7)	(20)
RPA A2	0.169	0.146	(11)	(23)	(15)	(27)
RPA B2	0.169	0.155	(7)	(15)	(14)	(16)
	days per participant		*percent increase (decrease) from 2008*			
RPA A1B	6.50	6.50	0	0	(1)	(1)
RPA A2	6.50	6.49	0	0	0	(1)
RPA B2	6.50	6.51	0	0	0	0

CC = climate change.

recreation resources. The change in recreation preferences at least partly reflects changing demographics in the American public. As the population ages and becomes more racially and ethnically diverse, it is unclear whether current recreation opportunities will meet future needs. Based on the available data, we still project future growth for most recreation activities.

The five outdoor recreation activities projected to have the fastest growth in participation rate across the three RPA scenarios are developed skiing, challenge activities, equestrian activities, motorized water activities, and day hiking. In contrast, the activities with the largest projected participation rate declines are motorized off-road activities, motorized snow activities, hunting, fishing, and floating activities. Participation rate changes for the remaining activities will be marginal. Several of the activities with projected participation rate growth, such as developed skiing and equestrian activities, tend to require substantial financial commitments. This factor partially explains the low current participation rates and may limit growth in participant numbers depending on the distribution of future income growth.

Population growth in all RPA scenarios is high enough that the total number of participants and the total number of days for most activities are projected to increase regardless of the direction of the trends in participation rates or days per participant (tables 52 and 53). Exceptions occur for the RPA B2 scenario for hunting, for which total days decline compared with 2008; snowmobiling, for which participant numbers and total days of participation drop substantially from 2008; and undeveloped skiing, for which the majority of RPA scenario-climate

Table 52. Changes in total outdoor recreation participants, 2008–2060, for all activities across all RPA scenarios and climate futures.[a]

Activity	2008 participants[b]	2060 participant range[c]		2060 average participant change[c]	2060 participant range[d]		2060 average participant change[d]
	millions	*millions*	*percent*	*millions*	*millions*	*percent*	*millions*
Visiting developed sites							
Developed site use	194	273–346	42–77	+ 116	271–339	40–75	+ 112
Interpretive site use	158	231–294	48–84	+ 106	231–289	46–83	+ 104
Viewing and photographing nature							
Birding	82	118–149	46–81	+ 53	115–144	40–76	+ 47
Nature viewing	190	267–338	42–76	+ 114	268–333	41–75	+ 112
Backcountry activities							
Challenge	25	38–48	50–86	+ 19	37–48	47–90	+ 18
Equestrian	17	24–31	44–87	+ 11	25–35	50–110	+ 13
Day hiking	79	117–150	50–88	+ 55	114–143	45–82	+ 50
Primitive area use	91	120–152	34–65	+ 47	119–145	31–60	+ 42
Motorized activities							
Off-road driving	48	62–75	29–56	+ 21	62–76	28–58	+ 21
Motorized water	62	87–112	41–81	+ 40	84–111	35–78	+ 35
Motorized snow (snowmobiling)	10	10–13	10–37	+ 3	4–10	(56)–6	– 2.5
Consumptive							
Hunting	28	30–34	8–23	+ 5	29–34	5–21	+ 4
Fishing	73	92–115	28–56	+ 33	89–115	22–58	+ 30
Nonmotorized winter							
Developed skiing	24	38–54	58–127	+ 23	36–54	50–126	+ 21
Undeveloped skiing	8	10–13	32–67	+ 4	5–10	(42)–28	– 1
Nonmotorized water							
Swimming	144	210–268	47–85	+ 99	212–266	47–85	+ 99
Floating	40	52–65	30–62	+ 20	47–62	18–56	+13

[a] Activities are individual or activity composites derived from the National Survey on Recreation and the Environment (NSRE). Participants are determined by the product of the average weighted frequency of participation by activity for NSRE data from 2005–2009 and the U.S. adult (> 16) population during 2008.

[b] Since initial values for 2008 differ across RPA scenarios, RPA A1B is used for a starting value.

[c] Participant range across A1B, A2, B2 without climate considerations.

[d] Participant range across the nine RPA scenario-climate combinations.

Source: NSRE 2005–2009, Versions 1 to 4 (January 2005 to April 2009), N = 24,073

Table 53. Changes in total outdoor recreation days, 2008–2060, for all activities across all RPA scenarios and climate futures.[a]

Activity	2008 days[b]	2060 days range[c]		2060 average days change[c]	2060 days range[d]		2060 average days change[d]
	millions	*millions*	*percent*	*millions*	*millions*	*percent*	*millions*
Visiting developed sites							
Developed site use	2,246	3,121–3,949	40–74	+ 1,294	3,055–3,796	36–69	+ 1,185
Interpretive site use	1,249	1,899–2,417	53–91	+ 952	1,935–2,435	55–95	+ 988
Viewing and photographing nature							
Birding	2,162	3,008–3,798	40–74	+ 1,246	2,941–3,654	36–69	+ 1,141
Nature viewing	32,461	41,805–52,835	30–61	+ 14,635	41,550–51,288	28–58	+ 13,597
Backcountry activities							
Challenge	121	178–219	49–83	+ 86	179–232	48–92	+ 89
Equestrian	263	388–503	49–92	+ 196	369–482	40–83	+ 166
Day hiking	1,835	2,901–3,682	59–98	+ 1,470	2,825–3,541	54–93	+ 1,366
Primitive area use	1,239	1,630–2,046	33–63	+ 622	1,562–1,946	26–57	+ 519
Motorized activities							
Off-road driving	1,053	1,264–1,532	21–46	+ 357	1,274–1,611	21–53	+ 385
Motorized water	958	1,304–1,806	37–90	+ 596	1,245–1,763	30–84	+ 495
Motorized snow (snowmobiling)	69	74–91	8–33	+ 16	23–65	(6)–(67)	– 27
Consumptive							
Hunting	538	506–576	(5)–8	+ 14	494–575	(8)–7	– 8
Fishing	1,369	1,665–2020	23–46	+ 514	1,602–1,958	17–41	+ 397
Nonmotorized winter							
Developed skiing	178	274–437	61–150	+ 179	258–422	50–146	+ 165
Undeveloped skiing	52	69–87	35–70	+ 29	28–64	(45)–25	– 5
Nonmotorized water							
Swimming	3,476	5,037–6,429	46–83	+ 2,446	4,396–6,257	42–80	+ 2,298
Floating	262	338–422	30–62	+ 128	309–409	18–56	+ 83

[a] Activities are individual or activity composites derived from the National Survey on Recreation and the Environment (NSRE). Participants are determined by the product of the average weighted frequency of participation by activity for NSRE data from 2005–2009 and the U.S. adult (> 16) population during 2008.

[b] Since initial values for 2008 differ across RPA scenarios, RPA A1B is used for a starting value.

[c] Participant range across A1B, A2, B2 without climate considerations.

[d] Participant range across the nine RPA scenario-climate combinations.

Source: NSRE 2005–2009, Versions 1 to 4 (January 2005 to April 2009), N = 24,073

combinations indicate declines in both participant numbers and days. For most activities, the largest number of future participants and days of participation occur under RPA A2, the scenario with the highest population growth. Activities that are strongly influenced by income, however, were projected to grow the most under RPA A1B, including challenge, equestrian, motorized water, and developed skiing activities.

Climate can affect individual willingness to participate in recreation activities and/or affect recreation resource availability and quality. The climate variables used in the recreation models were limited to those coming directly from the RPA climate projections, or variables derived from those basic variables. Generally, the climate variables used in these recreation models were presumed to affect willingness to participate and frequency of participation directly. Despite the lack of existing data, it is reasonable to expect that climate change will affect resource availability. For example, in the case of hunting and fishing, increasing temperatures will likely affect the distribution of plant and animal species that are fundamental to maintaining fish and game populations. Moreover, changes in precipitation may influence local snow cover and thus affect seasonal availability for activities like snowmobiling and undeveloped skiing. Disentangling the effects of the climate variables on recreation participation is difficult. Further exploration of these direct and indirect relationships, at both local and macro levels, will be fundamental to improving forecasts of recreation behavior in the future.

Chapter 15. Future Resource Challenges and Opportunities

The 2010 Resources Planning Act (RPA) Assessment results indicate that America's renewable natural resources will continue to be important in meeting diverse demands for goods and services. The growing population, coupled with economic growth, will put pressure on natural landscapes, and biophysical stressors, including climate change, will continue to influence the condition of natural ecosystems. This section draws on the RPA Assessment results to present examples of challenges facing policymakers and resource managers and to present opportunities to address these challenges so that we can continue to conserve the renewable natural resources of the United States to meet the needs of future generations.

Challenge: Conserving Natural Landscapes in the Face of Urbanization and Low-Density Development

The combination of U.S. population growth and economic growth will strongly influence future development patterns. We projected a loss of both forest and rangelands, primarily to urban and other developed uses, in all of the RPA scenarios. Development patterns differ in their effects on natural landscapes. Urbanization tends to expand from existing urbanized areas, usually converting entire landscapes by removing a large portion of natural vegetation. In contrast, lower density development in rural landscapes removes less natural vegetation, but the resulting pattern increases fragmentation. Fragmentation is mainly a local yet widely dispersed phenomenon; even a small area of resource loss can effectively fragment a large total resource area. Both types of development increase the susceptibility of the affected landscapes to multiple stresses, such as invasive species and altered fire regimes.

The challenges are twofold for urban and natural resource planners and managers: (1) maximizing the ecosystem services from a small natural resource base within the urban area and (2) sustaining ecosystem services from a diminishing natural resource base outside the urban zone. Urban resource planners will need to manage ecological processes so that ecosystem health and productivity adapts to and is sustained on the small urban resource base. At the broader scale, regional planners need to manage resources in the face of low-density development that is now occurring in nonurban areas across a large and diverse landscape that is managed by a variety of jurisdictions. Federal land managers are faced with the effects of development around and within public land boundaries (see sidebar, Housing Growth in and Around Public Lands), and State and local jurisdictions are faced with providing services such as fire protection to a more dispersed population.

Opportunities

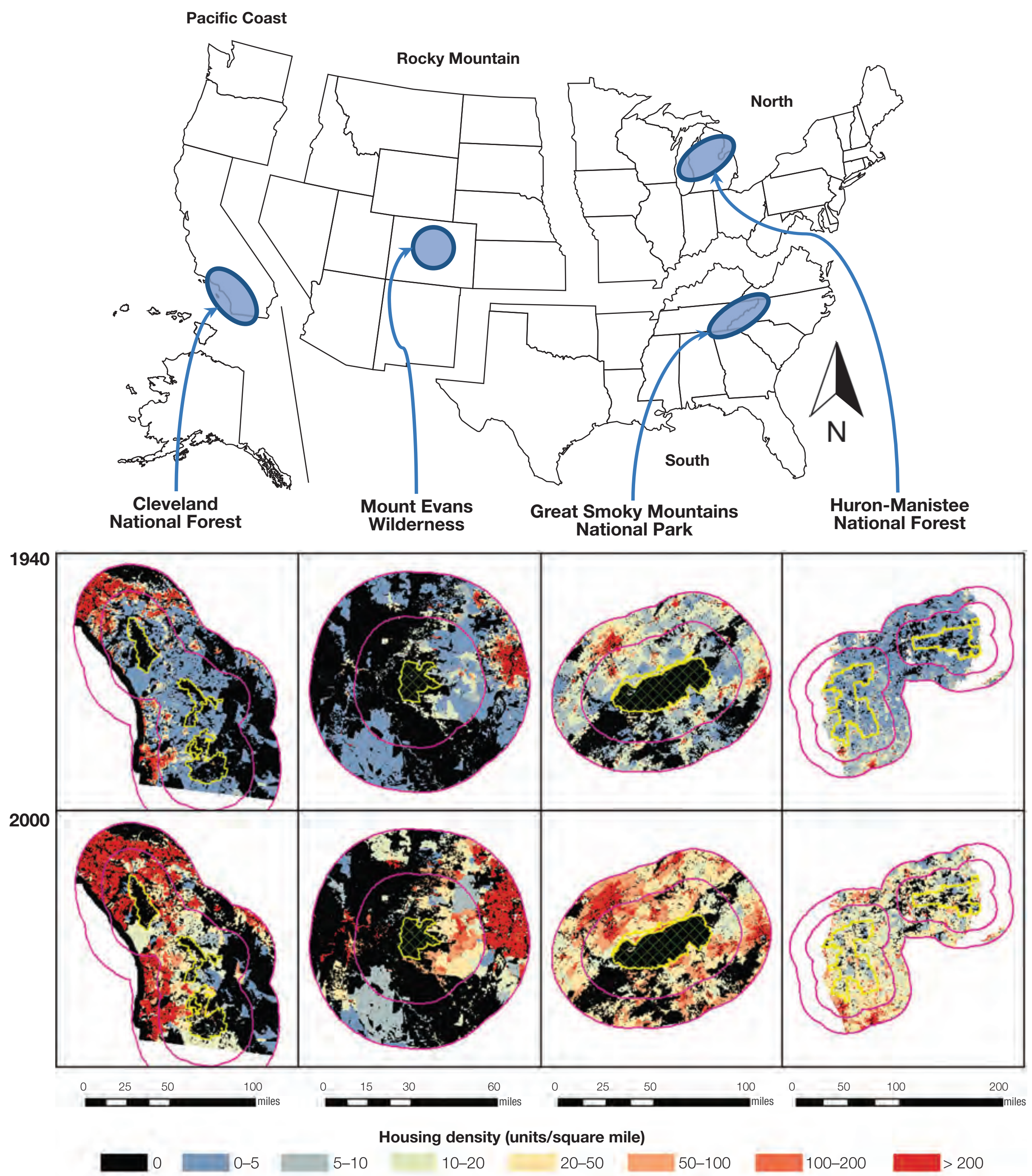
Urban vegetation and its management can significantly influence human health and ecosystem services in and around cities. A number of decisionmaking tools have been designed to aid with optimal vegetation design and management practices to improve the ability of trees and urban forests to provide ecosystem services. These tools enable users to collect local data and analyze urban forest composition, ecosystem services, and values. i-Tree is a suite of urban forest analysis software to aid managers and the public in assessing their urban forest ecosystem and street tree populations (http://www.itreetools.org/). Urban and community forestry programs also provide opportunities to educate urban residents about the contribution of trees to their welfare.

At the broader landscape scale, where low-density development threatens the integrity of natural ecosystems, a variety of analytical tools exist that can be used to evaluate management and policy options to maintain intact natural ecosystems. The measures of landscape pattern and fragmentation presented in chapter 6 provide an essential starting point for such evaluations by identifying broad regional patterns and trends. These measures can be used to identify the most efficient way to increase intact environments or minimize further fragmentation, or to evaluate opportunities to improve overall connectivity across landscapes for any of the land cover types. Habitat connectivity has long been discussed in the context of forest-dependent species and may also be important for the migration of tree species in response to climate change. The wetlands predictive model, also described in chapter 6, could be used to (1) predict wetland conversion risk, (2) prioritize wetland areas for conservation based on conservation value and risk of conversion, (3) evaluate wetland habitat connectivity, and (4) aid planning decisions for projected urban development to lessen wetland conversion potential. Smart Growth principles (http://www.epa.gov/dced/index.htm) can be used in both rural and urban environments to evaluate development decisions that affect natural landscapes. Although these many tools and approaches can be used to evaluate and design management options to conserve natural landscapes, accomplishing these goals will require cooperation across a variety of ownership and jurisdictions.

Housing Growth in and Around Public Lands

The effects of housing development around public lands were described previously (sidebar, Housing Growth Near Public Lands, chapter 6). Four case studies provide more specific examples of the ecological consequences attributable to housing development adjacent to Federal protected areas (Radeloff et al. 2010). Figure 147 shows the change in housing density between 1940 and 2000 in proximity to these four sites.

Figure 147. Changes in housing density, 1940–2000, within 15 and 30 miles of four case study areas: the Cleveland National Forest, Mount Evans Wilderness Area, Great Smoky Mountains National Park, and the Huron-Manistee National Forest.



Case 1: Cleveland National Forest in Southern California

Housing growth, and the associated road network, is limiting dispersal of mammalian carnivores such as mountain lion, bobcat, and badger among protected area units that support native habitats (Crooks 2002). Furthermore, the increasing presence of humans in this landscape has increased fire frequency and predisposed the landscape to invasion by exotic grasses (Talluto and Suding 2008).

Case 2: Mount Evans Wilderness Area in Colorado

Exurban development linked to Denver, CO, is encroaching from the east. Isolation effects are less of a concern here given the substantial area of other public lands to the west. The Mount Evans Wilderness Area, however, has experienced increasingly high recreational use that has altered vegetation and game population demography (Braun et al.1993; Wilderness.net undated).

Case 3: Great Smoky Mountains National Park in Tennessee

Protected areas located in the Eastern United States have been subject to a greater intensity of encroachment because they tend to be smaller and less buffered by large expanses of public land, as found in the Western United States. Housing densities around the park have increased substantially since the 1940s, nearly enveloping the park by 2000. This pattern of housing growth has contributed to the degeneration of air quality within the park (Shaver et al. 1994) and has been associated with increasing poaching pressure on wild ginseng (e.g., see http://www.nationalparkstraveler.com/2009/02/gingseng-poachers-great-smoky-mountains-national-park-receive-jail-time).

Case 4: Huron-Manistee National Forest in Michigan

The prevalence of private in-holdings (48 percent of the land within the administrative boundary of the national forest is privately owned) within the Huron-Manistee presents special conservation challenges. Fire suppression activities to protect homes in the vicinity of the national forest have altered the historic disturbance regime. The altered regime has reduced habitat availability for the endangered Kirtland's warbler that, for breeding, prefers the young jack pine forests established after fire (Mayfield 1993). Moreover, housing growth within the forest's boundary has increased warbler exposure to nest parasitism from brown-headed cowbirds that forage in residential areas, further eroding warbler reproduction (Kelly and DeCapita 1982).

These case studies all illustrate that housing development, even in rural settings, can cause multiple and interacting conservation threats (Pidgeon et al. 2007) and therefore present resource managers with challenging problems to solve if these threats are to be mitigated. Within the Forest Service, Research and Development could monitor and understand resource effects traceable to an increasing human footprint in and near the lands for which it has resource stewardship responsibility. State and Private Forestry could educate the public at the level of individual landowners to increase awareness of home development effects to natural resources. The National Forest System (NFS) could implement regulations and management directed at ameliorating effects within their boundaries and could acquire or exchange lands that will serve to buffer ecosystems from the expanding footprint of human development. Furthermore, the Forest Service could promote existing, while helping to develop new, Federal, State, and local tax incentive programs designed to reduce the cost of private resource stewardship activities, leading to biodiversity conservation and sustainable resource development (Robles et al. 2008; Stein et al. 2010a, 2010b).

Challenge: Enhancing the Market Value of Wood Resources

The RPA scenarios point to a challenge of enhancing future market value of wood resources for both forest management and technology research and development. The annual U.S. timber harvest peaked in the late 1980s. Timber prices and aggregate market value of wood resources have since declined. Going forward, future real timber prices and timber revenues in the United States will remain relatively static for RPA scenarios with anticipated demands for solidwood and paper products and only modest expansion in wood energy consumption (e.g., the RPA B2 and RPA historical fuelwood scenarios). In those scenarios, projected timber demands for forest products are sufficient to sustain, but not substantially enhance, timber revenues. At the other extreme, in the RPA A1B scenario, timber prices and revenues are projected to escalate along with expansion in U.S. and global wood biomass consumption for energy. Technologies and market conditions that would facilitate economic conversion of higher value biomass into higher value energy, chemicals, or biofuels do not yet exist, however. Thus, enhancing market value of wood resources remains a challenge faced by forest managers and the forest product and biomass energy research and development community.

Opportunities

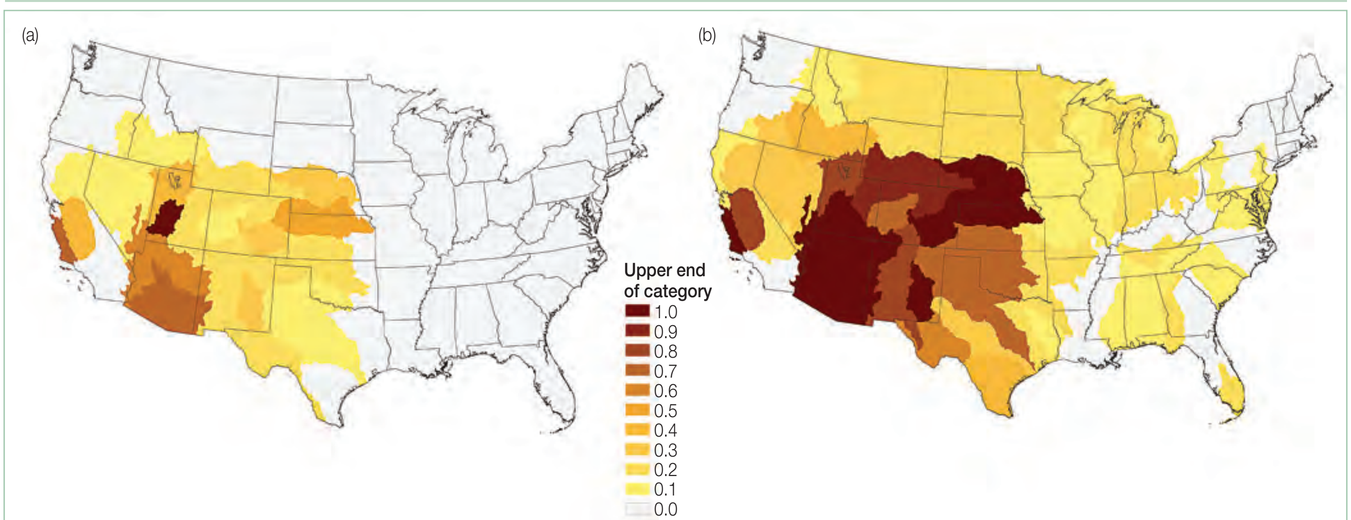
Studies show that the lowest rates of deforestation and forest carbon emissions occur in global regions with the highest rates of forest product output and industrial roundwood harvest, such as North America and Europe (Ince 2010). Enhancing the flow of timber revenues helps to sustain forest management and provides an economic rationale for policies favoring sustainable forests and good forestry practices. If future technology development and wood demands provide enhanced timber revenues, then historic experience suggests that forests and forest management will thrive. If the value of timber declines, however, through low-value use, limited demand, or insufficient forest product technology development, the future sustainability of forests will be compromised.

A range of strategies exists to meet the challenge of enhancing market values for wood resources. One such strategy is to grow wood resources that have properties anticipated as desirable for future products or energy needs in the 21st century (Wegner et al. 2010). Another strategy is to orient wood product development and marketing to take advantage of inherent green characteristics of wood as a raw material and enhance market value of wood products. For example, there are potential "game changers" in green building codes and standards that could result in a fundamental market shift favoring higher value wood use in building construction (Bowyer et al. 2010). Another strategy is to merge forest product technology with other technological developments that offer higher value or more revenue. Examples include (1) integrated forest product biorefining, such as production of biofuel and biochemicals at existing pulp mills (Belin et al. 2008; Thorp and Murdock-Thorp 2008); (2) the use of electronic information and communication technology to create more useful and higher value applications for paper board packaging (Ince et al. 2005); and (3) the use of cellulose nanofibers or cellulose nanocrystals to enhance the value of existing products by increasing their strength or durability, or to provide new products, such as thinner electronic display screens (Agenda 2020 Technology Alliance 2010). These areas of technology development should be supported by coordinated research and development strategies aimed at creating higher market value for wood resources and maintaining global competitiveness for forest products, thus enhancing the flow of revenues to forest owners. An ancillary benefit of such policies would be to help give long-range forest planners and managers a better basis for assessing the future for forest resources in the overall economy, so they can justify the planting of trees and management of forests today knowing there will be adequate revenues to generate profitable returns when the trees are harvested decades from now.

Challenge: Adapting to Expected Water Shortages in an Uncertain World

The assessment of the vulnerability of U.S. water supplies to shortage indicates that large areas of the West face the prospect of increasing water shortages as the century progresses, as a result of both increasing demand and decreasing supply. Other, more localized areas of the United States may also face increasing shortages that were not detected at the large spatial scale of the assessment. As indicated in figure 148, however, considerable uncertainty remains about the level of vulnerability. Figure 148 shows the minimum and maximum levels of vulnerability for 2060 for each assessment subregion (ASR) across the nine RPA scenario-climate combinations evaluated. If the ASRs experience the minimum projected change by 2060, only 28 ASRs are projected to face a positive probability of shortage, and only 5 have a probability above 0.5 (figure 148a). At the other extreme, using the maximum projected change, 74 ASRs are projected to face a positive probability of shortage, and 21 of those ASRs have a probability above 0.5 (figure 148b).

Figure 148. Composite of vulnerability (probability of shortage), by ASR, projected for 2060 based on the nine RPA scenario-climate combinations: (a) minimum and (b) maximum.



The vulnerability analysis shows what would happen if water demand were to progress as if water shortages were not becoming ever more common and serious—i.e., no adaptive actions are taken during the projection period. Therefore, the vulnerability results show the areas at greatest risk of future shortages, and thus those areas with the greatest need to consider adaptation options. The primary forces behind this increasing vulnerability—human population growth and climate-driven decline in water yield—are very difficult to alter, but other options exist for addressing the projected shortages. The challenge for society, in light of the uncertainties about the levels of vulnerability, is to carefully consider each option and begin to facilitate adoption of the most promising ones.

Opportunities

Although increases in reservoir storage may help address water shortages in some locations, the RPA Assessment indicates that large storage increases generally are not the answer. Three other options should be carefully evaluated. These options are particularly pertinent because they can be implemented incrementally, and thus are well suited to an uncertain world. The first option is to improve water use efficiency. As the analysis of water demand shows, great strides have already been made in several water use sectors in lowering the amount of water used per demand unit. The analysis assumes continued progress in this area, but options probably exist for even greater improvements, especially in irrigated agriculture in the West. A second option, related to the first, is to use water pricing to encourage conservation. This option is already in use in many locations, especially in the municipal sector, and will certainly play an increasing role in water-short areas. A third option, one that has great potential, is increased use of water trading, allowing water to be shifted through voluntary trades to higher valued uses. Although water trading and water banking are already common in some areas, significant institutional and legal constraints limit expansion of water trading, especially across State lines. Of course, these options bring their own formidable challenges, but if the projected shortages prove to be realistic, the incentives for change will be compelling.

Challenge: Designing Integrated Management Strategies To Conserve Biodiversity

Biodiversity in the United States continues to erode. Conserving biodiversity will require strategies that consider the role of both private and public land. Habitat on privately owned land is more fragmented than on public land, and given the increasing development pressure on private land, public land will serve a growing role in the conservation of imperiled species. For example, NFS lands provide habitat for more listed and imperiled species than do those of any other Federal agency (Stein et al. 2008). Private land will also serve a crucial role in biodiversity conservation, however, if only because most U.S. land is privately owned. Robles et al. (2008) found that 60 percent of forest species of conservation concern occurred on private forests in the conterminous United States.

Private land is particularly crucial for conserving biodiversity in the Eastern United States, where public lands account for a much smaller proportion of the land base. For example, many private lands in the Southeastern United States not only support concentrations of at-risk species, but are also considered to have a high risk of forest conversion (Stein et al. 2010a, 2010b). The homogenization of habitats that often occurs with intensive land management reduces biodiversity and must be counterbalanced by preserving the integrity and diverse features of forest, grassland, shrubland, and agricultural habitats.

Opportunities

Collaborative efforts across public and private lands are vital to maintaining the ecosystem services from the Nation's flora and fauna. Failure to take a broad programmatic and policy view of biodiversity conservation will risk further erosion of our biological heritage in the future. Monitoring designs, discovery of habitat relationships, and completion of viability assessments will require increasing research investments to document population trends, identify emerging at-risk species, design management actions to recover at-risk species, and determine when key populations have been restored—all of which serve to increase our conservation capacity.

Within the Forest Service, NFS and State and Private Forestry managers can work together to implement complementary actions to preserve and restore habitats through (1) land acquisition or conservation easements that will target priority areas via public-private partnerships, (2) design of cost-reduction and tax incentive programs that facilitate species conservation (e.g., Forest Legacy and Forest Stewardship Programs), (3) development of resource certification systems that require biodiversity conservation standards (Robles et al. 2008), (4) training on forestry best management practices that have been shown to minimize water quality effects (Ince 2010), and (5) development of market-based instruments to reward landowners for biodiversity conservation (Bishop et al. 2008).

Challenge: Information To Conduct Broad-Scale Resource Assessments

Assessments of the current and future conditions of renewable resources rely on data from a variety of public and private sources. Given its national focus, the RPA Assessment must draw on data from Federal, State, and nongovernmental sources. The availability of credible, unbiased, and well-documented data is vital to underpinning this work and other broad-scale assessments. The availability and quality of data varies widely across resource areas and ownerships.

Data limitations from several resource areas are illustrative of these challenges. Data on recreationally important wildlife and fish populations and harvest are problematic because State jurisdiction over the management of resident wildlife and fish makes it difficult to merge inventories across State borders. This data limitation has been a long-noted impediment to the Forest Service's ability to conduct comprehensive assessments of status and trends among most aquatic species—a constraint that, in turn, hinders the evaluation of large-scale factors that may be affecting aquatic populations. In many cases, this challenge is defined by data access, not data existence. Estimating populations and harvests of terrestrial and aquatic species across large geographic areas is conceptually simple; the inventories upon which those estimates are based, however, are logistically difficult and expensive to implement (Morellet et al. 2007). Data describing the status and trends of rangeland vary widely across ownership categories and are generally not comparable among agencies or even within different regions in the same agency. Although weather and climate data appear abundant, most of the data are collected close to weather stations, so large areas of the United States, particularly in the West and at high elevation, are not served by any type of weather data collection.

Natural disturbances, human development, and climate all interact in their effects upon natural resources. Understanding these interactions requires data designed to support analysis across multiple resources. Data to support analysis of resource interactions are very challenging, as they need to be linked temporally, spatially, and by common definitions. Integrated data are vital to supporting analyses that can link changes in socioeconomic and biophysical characteristics (e.g., human population, land use, climate, and landscape pattern) to changes in forest and rangeland resources, water, recreation, and biodiversity.

Opportunities

There are opportunities for coordinated approaches to data collection and monitoring among Federal, State, nongovernmental, and academic institutions that could meet the needs of resources managers at all scales. Ameliorating many of the pressures on wildlife resources stemming from habitat loss and degradation, land use intensification, and climate change will require multijurisdictional and regional efforts that would benefit from monitoring data that can be aggregated easily across broad geographic areas. In some cases, the data limitation issue can be solved by mechanisms that facilitate data sharing through distributed information systems that will accept diverse data input but have designed standardization to permit merging across sources (Nate and Loftus 2012).

The disjointed, sparse, and incomplete data situation for rangeland presents a unique opportunity for land management agencies to agree on and implement interagency standards, guidelines, and protocols. Such coordination would reduce redundancy, improve cost effectiveness, and provide a common data structure that could be used to make meaningful inferences regardless of ownership at the national level. The joint Forest Service-Natural Resources Conservation Service-Bureau of Land Management agreement to use a common definition of ecological/range sites to describe rangeland vegetation is an example of one interagency approach.

Land cover monitoring through remote sensing is now well established in the United States, but research is needed to learn better ways to combine that information with other data sources and to interpret their meaning. Synoptic monitoring of land cover is now well coordinated among Federal agencies because of initiatives during the past decade. There has also been substantial research progress in understanding the effects of land cover patterns on natural ecosystem functioning during the past three decades. The major opportunities now are to improve the use of available synoptic data by combining it with other available data (such as ground-based forest and resource inventories), to improve our ability to predict changes in patterns resulting from land use changes, and to articulate the consequences of changes in terms of the sustainability of natural resources and the ecological functions that depend on them.

Challenge: Meeting Future Outdoor Recreation Demands

Increases are projected for total outdoor recreation participants and total days of participation. These increases will put additional pressure on what is expected to be a largely fixed public land and water base. The largest growth in number of participants is projected to occur for activities associated with visiting developed sites and nature viewing, for which more than 100 million participants may be added by 2060. Outdoor recreation activities projected to have the fastest growth in participation rates included developed skiing, day hiking, and motorized water activities. Developed infrastructure is necessary to accommodate many of these needs, and extensive trail systems are needed for others.

Recreation preferences may also change in response to the changing demographic composition of the U.S. population. A population with an increasing average age may require additional opportunities for less physically challenging activities. Different racial and ethnic groups currently prefer different activities and recreation settings (see sidebar, Addressing Outdoor Recreation Needs of Latinos). Shifts in preferences are reflected in traditional activities such as hunting and fishing activities, which have seen declining participation rates since the early 1990s. Climate change may also affect opportunities in terms of the physical resource base (e.g., effects on regional snow cover) and of climatic conditions for participating in different activities (e.g., participating fewer days because of heat).

As the number of recreationists continues to increase, public recreation managers will face problems of infrastructure deterioration and deferred maintenance. These problems are repeated at the national, State, and local levels, and the economic downturn has hindered the ability of public agencies to maintain their recreation facilities. The effects of climate change could further exacerbate this problem, e.g., sea level rise threatening coastal recreation facilities (Walls et al. 2009).

Opportunities

Researchers and recreation managers have a wealth of knowledge about recreationists and their preferences. Although not complete in every regard, synthesizing and better communicating what is known could provide useful guidance for recreation managers at local, State, and Federal recreation sites. Synthesizing information often helps highlight gaps in knowledge, which could be used to prioritize information needs to address future recreation management challenges.

Most public-sector recreation providers are expecting continued tight budgets into the future. There has been major growth in recent years in conservation land trusts and innovative conservation financing tools that includes partnerships with government agencies, however (Walls et al. 2009). Although outdoor recreation has not been the focus of these conservation efforts, it would be worth exploring a larger role for outdoor recreation.

Concerns about the physical fitness of Americans and about their connections with nature as the population becomes increasingly urban present opportunities to create new management and research partnerships. Outdoor recreation provides numerous opportunities for exercise, ranging from physically challenging activities such as mountain climbing to less strenuous activities such as visiting interpretative sites. Recreationists are usually simultaneously exposed to natural environments while pursing these activities. There are opportunities to design education programs that address both health and nature education needs and to design recreation opportunities that encourage people to use outdoor recreation to improve their health and well-being.

Addressing Outdoor Recreation Needs of Latinos

The ethnic and racial profile of the United States is undergoing a major shift. In the decades ahead, people of color will constitute a majority of the population. Few racial or ethnic groups have had as great an effect on the demography of the United States as Latinos. Research conducted over 15 years in southern California has helped better understand the recreation needs of Latinos (Chavez 2012).

Many Latinos report having only one day off from work per week, thus they are primarily “day use” visitors. This knowledge is crucial in determining when use will be heaviest and what sites may require concentration of resources. Site design should consider the strong desire for family time and family bonding through large family group outings. Meeting the development needs of Latino visitors may require renovation or equipment upgrades, such as installing larger picnic tables, placing groups of tables together, and providing several trash receptacles to accommodate larger visitor groups. Some consideration should be made for the longer period Latinos tend to stay at sites—perhaps having services and facilities such as group play areas for volleyball or soccer, drinking water, and toilets.

Communication is key to serving Latinos at outdoor recreation sites. Translating materials into Spanish is recommended, and providing materials that have been back-translated (wherein a message is translated to Spanish, then translated back to English) would be even better. In regards to translation, traditional use of brochures at the site entrances, signs along the road, and notes on bulletin boards are acceptable. Alternate communication strategies, such as onsite bilingual hosts and interpretations, also can be helpful.

Challenge: Sustainable Management of Natural Resources Under Climate Change

This assessment has explored the implications of climate change on renewable resources. In these analyses, climate change influences forest growth, water availability, quality and quantity of wildlife habitat, tree cover area, and participation in various recreation activities across the United States. Although much is known about the potential effects of climate change on renewable resources, much is still to be learned (U.S. CCSP 2008a; Hibbard et al. 2010). For example, although wildfires are a natural process that structures ecosystems, recent analyses suggest that climate is altering historical fire dynamics and may alter the patterns beyond that to which the biota is adapted (Westerling et al. 2006, 2011). Plants and animals will thus be affected directly by the changes in climate and indirectly by changes to natural disturbances such as fire, insect outbreaks, and disease. Furthermore, feedbacks between the land surface and climate will complicate our ability to anticipate ecosystem responses. For example, recent studies have shown that land use changes affect local temperature and precipitation (Fall et al. 2009), and these effects, in turn, can alter vegetation dynamics and future land use decisions. Thus, resource response projections are more complicated than what may be suggested based simply on changes in elevated greenhouse gases and corresponding changes in temperature and precipitation. These interactions are important to consider in renewable resource management.

Opportunities

Sustainable management of natural resources in the face of climate change will require the implementation of existing management actions and the development of novel management strategies. The mix of management actions to address climate change, what are often referred to as adaptive strategies, have been categorized into resistance options (forestall effects and protect highly valued resources), resilience options (improve the capacity of ecosystems to return to desired conditions after disturbance), and response options (facilitate transition of ecosystems from current to new conditions) (Millar et al. 2007). As environmental conditions continue to change from the effects of climate change, sustaining the current or historical landscape will be challenging and may have to be abandoned, in the longer term, as a traditional resource management goal (U.S. CCSP 2008b). Continued implementation of current management actions designed to remedy insect and disease outbreaks, air and water quality issues, wildfire, habitat alteration and fragmentation, and legacy effects of land management will support the ability of plants and animals to resist the near-term effects of climate change. Moreover, restoration of degraded ecosystems will return ecosystems to their characteristic structure and function, thus enhancing their resilience to some climate change effects. Finally, proactive response management could help retain important ecosystem services that would otherwise erode under climate change if not for targeted novel actions that promote landscape connectivity, enhance natural regeneration, increase habitat diversity and redundancy, facilitate species transitions, and expand the genetic guidelines for planting (Joyce et al. 2009; Millar et al. 2007). Environmental variability, the inevitability of surprise, and the range of management objectives across the United States imply that no single approach will fit all situations. Therefore, sustainable management of natural resources in the face of climate change will require a commitment to monitoring environmental, social, and economic systems if society is to adjust its management adaptively. The choices for sustainable management of natural resources will be influenced by the availability of information, vulnerability of ecological and socioeconomic systems, complexity of resource interactions, and the inherent uncertainties associated with climate change.

Chapter 16. Conclusions

The United States has abundant natural resources, but there is little doubt that demands for forest, rangeland, and water resources will increase in the future in response to a growing population. We expect the resource base to be able to meet some future demands, but the outlook for other goods and services is more uncertain. Increasing demands on a shrinking natural land base and increased competition for water set the stage for continued conflicts in the use and management of renewable resources.

The findings of this assessment are largely consistent with previous Resources Planning Act (RPA) Assessments. Population growth continues to be a main driver of resource change. The recent recession and slow recovery have slowed the pace of development, but a return to stronger growth in the long term is expected.

Urbanization and low-density development will reduce forest and rangeland area, reshape landscape conditions, and alter wildlife communities in the absence of concerted action to reduce development effects. As urban area expands, urban forests can play an increased role in providing an array of ecosystem services to urban residents and in minimizing effects on surrounding landscapes.

Development pressures are projected to affect forest land more than rangelands because population growth is more concentrated in regions where forests occur. Incentives to convert forest land are highly influenced by the expected economic returns among competing land uses. The effects of economic globalization on forest product markets have been tracked through successive assessments, and they remain important. Currently, global demands are providing export growth for some forest products, whereas domestic markets continue to be negatively affected by the U.S. housing market. The future of forest product markets across the 2010 RPA scenarios is highly sensitive to assumptions about biomass use for bioenergy domestically and globally. In the absence of major new demands, such as bioenergy, the outlook continues to be for relatively flat timber prices, indicating little incentive either to retain forest land or to invest in forest management. This outlook is consistent with the last RPA Assessment, which raised similar concerns about sufficient incentives for sustainable forest management. Although a large increase in biomass energy would significantly increase timber prices and returns to landowners, it could also lead to competition with agricultural uses and changes in forest composition, particularly the accelerated expansion of pine plantations at the expense of natural pine in the Southern United States. Rangelands are less threatened by conversion than forest land. The effects of fragmentation from activities such as housing development and oil and gas development, however, pose threats to rangeland integrity.

The outlook for carbon storage in this RPA Assessment is not as positive as in the previous assessment, which reported that although the size of the annual addition to carbon stocks was declining in the future, the forest was expected to remain a carbon sink. In this assessment, the forest becomes a source of emissions in all RPA scenarios, a result of forest loss and changes in carbon storage per acre of forest.

The outlook for water in the last RPA Assessment was relatively positive because of slow increases in withdrawal rates compared with population growth, but potential effects on instream flows were raised as a concern. In this assessment, the effects of climate change on water yield and water use were found likely to greatly exacerbate water use conflicts and increase the vulnerability of the U.S. water supply to shortage. Although water use efficiency has improved substantially, further improvements are not likely to be sufficient to avoid tradeoffs between water uses. There are already well-developed water markets, particularly in the West. Expansion of water trading and water banking has potential if legal and institutional constraints can be overcome.

This assessment continues to find reasons for concerns about biodiversity—including increasing numbers of at-risk species and threats to habitat from land conversion and fragmentation. Given the relatively high incidence of at-risk species among those organisms that inhabit aquatic ecosystems, the resolution of water use conflicts will need to consider the potential biodiversity effects associated with water supply vulnerabilities.

Increases in the number of participants in outdoor recreation are projected, consistent with previous RPA Assessments. A continuing concern is whether a stable public land base will be able to meet increasing demands without exacerbating conflicts among users and causing increasing congestion. A large share of Federal recreation resources are not located in close proximity to population centers, putting additional pressure on local, State, and Federal facilities that are in close proximity.

The future outlook for natural resources is complicated by climate change. Climate change, particularly in concert with other natural and human stressors, will increasingly affect the future condition of the Nation's forests and rangelands and their ability to provide the goods and services demanded by the American public. Although RPA Assessments have included analyses of the effects of climate change since 1990, in this assessment, we expanded our ability to incorporate climate effects across various resource areas. We explored the effects of projected temperature and precipitation changes on water availability, forest growth, terrestrial habitats, tree cover, and recreation activities. These analyses suggest that climate change will change natural ecosystems and human choices in ways that we understand, but also in ways that will surprise us.

Future Challenges

The use of scenarios in the 2010 RPA Assessment enabled us to link socioeconomic assumptions with climate projections to provide a consistent set of alternative futures in which we could explore potential effects on renewable resources across the United States. The range of results across RPA scenarios stresses the need to develop forest and rangeland policies that are flexible enough to be effective under a wide range of future socioeconomic and climate conditions. Given the geographic variation in results, it will also be important to develop local and regional solutions to resource management issues. The outcomes portrayed in the assessment projections are not inevitable. These outcomes are based on a continuation of current policies. During the 2010 RPA Assessment update cycle, we will evaluate the effects of policy options on resource outcomes.

Many policies and management strategies can be used to change the direction of future trends. Changes in markets, technology, trade flows, government policies, and public values will all play key roles in shaping responses to changing resource conditions. Although markets are quite effective at providing incentives for commodity products, incentives to provide other ecosystem services are limited. Increased use of payments for ecosystem services could provide incentives to landowners to maintain a wide array of services, but much progress remains to be made in this area. Other types of programs, such as land retirement programs, conservation easements, and tradable development permits are all options that can contribute to sustaining forest and rangelands. Timely actions from policymakers and resource managers are needed. The results from this assessment provide a scientific foundation for their actions.

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Appendix A: Projected Tree Canopy Cover Change

Table A-1. Projected change in tree canopy cover by State between 2000 and 2060 using land use change projections for three Resource Planning Act (RPA) scenarios.

State	Number of Counties		RPA A1B		RPA A2		RPA B2	
	Total	Analyzed[1]	Change	Relative Change[2]	Change	Relative Change[2]	Change	Relative Change[2]
			%	%	%	%	%	%
Alabama	67	67	– 3.2	– 4.5	– 2.4	– 3.4	– 2.0	– 2.8
Arizona	15	15	0.1	0.3	0.1	0.4	0.0	0.2
Arkansas	75	75	– 4.7	– 8.5	– 3.6	– 6.5	– 3.2	– 5.8
California	58	57	– 1.4	– 4.0	– 1.5	– 4.1	– 1.0	– 2.9
Colorado	63	62	– 1.7	– 6.8	– 1.5	– 6.2	– 1.2	– 4.7
Connecticut	8	8	– 2.8	– 3.9	– 3.3	– 4.5	– 1.7	– 2.3
Delaware	3	3	– 2.4	– 5.9	– 2.6	– 6.4	– 1.6	– 4.0
District of Columbia	1	0	NA	NA	NA	NA	NA	NA
Florida	67	67	– 4.6	– 8.5	– 4.9	– 9.1	– 3.6	– 6.7
Georgia	159	159	– 6.6	– 9.9	– 5.1	– 7.6	– 4.5	– 6.8
Idaho	44	44	– 0.4	– 0.9	– 0.3	– 0.7	– 0.2	– 0.5
Illinois	102	102	– 0.5	– 3.3	– 0.3	– 1.9	– 0.4	– 2.6
Indiana	92	92	– 2.4	– 8.6	– 1.6	– 5.7	– 1.4	– 5.2
Iowa	99	99	– 0.2	– 1.5	– 0.1	– 0.8	– 0.1	– 1.1
Kansas	105	105	– 0.1	– 1.0	– 0.1	– 1.0	– 0.1	– 0.8
Kentucky	120	120	– 5.0	– 9.0	– 3.9	– 7.0	– 3.1	– 5.6
Louisiana	64	64	– 3.0	– 5.9	– 2.3	– 4.4	– 1.9	– 3.6
Maine	16	16	– 1.5	– 1.7	– 1.2	– 1.4	– 0.9	– 1.0
Maryland	24	23	– 6.3	– 12.2	– 5.9	– 11.6	– 4.5	– 8.8
Massachusetts	14	14	– 4.1	– 5.9	– 4.4	– 6.4	– 2.7	– 3.9
Michigan	83	83	– 1.9	– 3.3	– 1.6	– 2.7	– 1.2	– 2.1
Minnesota	87	87	– 1.6	– 4.6	– 1.3	– 3.7	– 1.0	– 3.1
Mississippi	82	82	– 3.0	– 4.9	– 2.2	– 3.5	– 1.9	– 3.1
Missouri	115	114	– 3.0	– 7.1	– 2.2	– 5.3	– 1.9	– 4.7
Montana	56	56	– 1.2	– 4.5	– 1.0	– 3.6	– 0.8	– 3.0
Nebraska	93	93	– 0.2	– 3.6	– 0.1	– 2.4	– 0.1	– 2.1
Nevada	17	17	– 0.4	– 2.8	– 0.3	– 2.5	– 0.3	– 2.2
New Hampshire	10	10	– 3.4	– 4.0	– 3.0	– 3.6	– 2.3	– 2.7
New Jersey	21	21	– 7.3	– 13.1	– 8.4	– 15.1	– 4.9	– 8.8
New Mexico	33	33	– 0.2	– 1.0	– 0.1	– 0.8	– 0.1	– 0.7
New York	62	62	– 1.4	– 2.1	– 1.2	– 1.8	– 0.8	– 1.1
North Carolina	100	100	– 3.9	– 6.1	– 3.3	– 5.1	– 2.7	– 4.2
North Dakota	53	53	– 0.1	– 1.7	0.0	– 1.5	0.0	– 1.6
Ohio	88	88	– 0.9	– 2.3	– 0.8	– 2.0	– 0.5	– 1.3
Oklahoma	77	77	– 1.3	– 4.8	– 1.0	– 4.0	– 0.9	– 3.3
Oregon	36	36	– 1.0	– 2.4	– 1.0	– 2.4	– 0.7	– 1.7
Rhode Island	5	5	– 9.2	– 14.8	– 10.0	– 16.1	– 5.5	– 8.9
South Carolina	46	46	– 4.3	– 6.6	– 3.7	– 5.8	– 2.9	– 4.4
South Dakota	66	66	0.3	6.1	0.2	4.4	0.2	4.3
Tennessee	95	95	– 4.3	– 7.3	– 3.9	– 6.5	– 2.8	– 4.7
Texas	254	254	– 1.2	– 5.4	– 0.8	– 3.6	– 0.8	– 3.8
Utah	29	29	– 1.2	– 6.4	– 1.2	– 6.2	– 0.9	– 4.9
Vermont	14	14	– 3.5	– 4.5	– 2.5	– 3.2	– 2.3	– 3.0
Virginia	135	97	– 3.1	– 4.6	– 2.4	– 3.5	– 2.2	– 3.2
Washington	39	39	– 1.6	– 3.3	– 1.7	– 3.6	– 1.1	– 2.4
West Virginia	55	55	– 4.6	– 5.6	– 2.9	– 3.6	– 2.7	– 3.3
Wisconsin	72	72	– 0.9	– 1.9	– 0.7	– 1.5	– 0.6	– 1.2
Wyoming	23	23	– 0.2	– 1.6	– 0.2	– 1.2	– 0.2	– 1.1
Total	**3,109**	**3,066**	**– 1.6**	**– 4.7**	**– 1.3**	**– 3.9**	**– 1.1**	**– 3.2**

[1] Number of counties analyzed in analysis.

[2] Relative change = (cover year 2060 to cover year 2000)/cover year 2000.

NA = not applicable.

Appendix B. List of Acronyms

ASR	assessment subregion (98 water basins in the conterminous United States)
AUM	animal unit month
BBS	North American Breeding Bird Survey
bgd	billion gallons per day (water)
BLM	Bureau of Land Management
CRP	Conservation Reserve Program
DOE	Department of Energy
DOI	Department of the Interior
DPI	disposable personal income
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act of 1973
FA	forage availability
FD	forage demand
FHM	Forest Health Monitoring
FIA	Forest Inventory and Analysis
FWS	U.S. Fish and Wildlife Service
GCM	general circulation model
GFPM	Global Forest Products Model
GHG	greenhouse gas
GDP	gross domestic product
HFW	historical fuelwood
HWP	harvested wood products
IPCC	Intergovernmental Panel on Climate Change
IPCC AR4	IPCC Fourth Assessment Report
IPCC TAR	IPCC Third Assessment Report
IUCN	International Union for the Conservation of Nature
kWh	kilowatt hour
MARIS	Multi-State Aquatic Resources Information System
MODIS	Moderate Resolution Imaging Spectroradiometer
MSPA	Morphological Spatial Pattern Analysis
NASS	National Agricultural Statistics Service
NFHAP	National Fish Habitat Action Plan
NFS	National Forest System
NLCD	National Land Cover Database
NKS	National Kids Survey
NPP	net primary productivity
NRA	National Recreation Area
NRT	National Recreation Trail
NRCS	Natural Resources Conservation Service
NRI	National Resources Inventory
NSRE	National Survey on Recreation and the Environment
NWPS	National Wilderness Preservation System
NWSR	National Wild and Scenic River
OSB	oriented strand board
PAD-US	Protected Areas Database of the United States
PI	personal income
RFS	renewable fuel standard
RPA	Resources Planning Act
SRWC	short-rotation woody crops
TCSI	Terrestrial Climate Stress Index
USDA	U.S. Department of Agriculture
USFAS	U.S. Forest Assessment System
USFPM	U.S. Forest Products Module
USGS	U.S. Geological Survey
WRR	water resource region

Appendix C. List of Scientific Names

	Common Name	Scientific Name
Birds	American wigeon	*Anas americana*
	Blue-winged teal	*Anas discors*
	Brant	*Branta bernicla*
	Canada goose	*Branta canadensis*
	Canvasback	*Aythya valisineria*
	Chukar	*Alectoris chukar*
	Dusky Canada goose	*Branta canadensis occidentaiis*
	Emperor goose	*Chen canagica*
	Forest grouse, including	
	Blue grouse	*Dendropagus obscurus*
	Ruffed grouse	*Bonasa umbellus*
	Spruce grouse	*Falcipennis Canadensis*
	Gadwall	*Anas strepera*
	Green-winged teal	*Anas crecca*
	Grey partridge	*Perdix perdix*
	Mallard	*Anas platyrhynchos*
	Mourning dove	*Zenaida macroura*
	Northern bobwhite	*Colinus virginianus*
	Northern pintail	*Anas acuta*
	Northern shoveler	*Anas clypeata*
	Prairie grouse, including	
	Greater prairie-chicken	*Tympanuchus cupido*
	Lesser prairie-chicken	*Tympanuchus pallidicinctus*
	Sage grouse	*Centrocercus urophasianus*
	Sharp-tailed grouse	*Tympanuchus phasianellus*
	Quail, including	
	California quail	*Callipepla californica*
	Gambel's quail	*Callipepla gambelii*
	Montezuma quail	*Cyrtonyx montezumae*
	Mountain quail	*Oreortyx pictus*
	Scaled quail	*Callipepla squamata*
	Redhead	*Aythya americana*
	Ring-necked pheasant	*Phasianus colchicus*
	Ross' goose	*Chen rossii*
	Scaup, including	
	Greater scaup	*Aythya marila*
	Lesser scaup	*Aythya affinis*
	Snow goose	*Chen caerulescens*
	Tundra swans	*Cygnus columbianus*
	White-fronted goose	*Anser albifrons*
	Wild turkey	*Meleagris gallopavo*
	Woodcock	*Scolopax minor*
Mammals	American black bear	*Ursus americanus*
	Cottontail, including	
	Appalachian cottontail	*Sylvilagus obscures*
	Desert cottontail	*Sylvilagus audubonii*
	Eastern cottontail	*Sylvilagus floridanus*
	Marsh rabbit	*Sylvilagus palustris*
	New England cottontail	*Sylvilagus transitionalis*
	Nuttall's cottontail	*Sylvilagus nuttallii*
	Swamp rabbit	*Sylvilagus aquaticus*
	Elk	*Cervus elaphus*
	Mule deer	*Odocoileus hemionus*
	Pronghorn	*Antilocapra americana*
	Squirrel, including	
	Abert's squirrel	*Sciurus aberti*
	Arizona gray squirrel	*Sciurus arizonensis*
	Fox squirrel	*Sciurus niger*
	Gray squirrel	*Sciurus carolinensis*

	Common Name	Scientific Name
Mammals	Mexican fox squirrel	*Sciurus nayaritensis*
	Red squirrel	*Tamiasciurus hudsonicus*
	White-tailed deer	*Odocoileus viriginianus*
Aquatic Species	Asian carp	*Hypophthalmichthys nobilis* or *Hypophthalmichthys molitrix*
	Black bass	*Micropterus salmoides* or *Micropterus dolomieu*
	Bullhead	*Ameiurus* spp.
	Catfish	*Ictalurus* spp.
	Crappie	*Pomoxis* spp.
	Lake trout	*Salvelinus namaycush*
	Panfish	a generic name referring to a small fish suitable for frying, in this case generally *Perca* sp., *Pomoxis* sp, or *Lepomis* sp.
	Quagga mussel	*Dreissena rostriformis bugensis*
	Round goby	*Neogobius melanostomus*
	Salmon (Pacific, western, northwestern)	*Oncorhynchus* spp.
	Sea lamprey	*Petromyzon marinus*
	Sea-run cutthroat trout	*Oncorhynchus clarkii clarkii*
	Spiny water flea	*Bythotrephes longimanus*
	Steelhead trout	*Oncorhynchus mykiss*
	Trout	Any of several chiefly freshwater game fish of the genera *Oncorhynchus, Salvelinus*, or *Salmo*
	Walleye	*Sander vitreus*
	Yellow perch	*Perca flavescens*
	Zebra mussel	*Dreissena polymorpha*
Plants	Alaska yellow-cedar	*Chamaecyparis nootkatensis*
	American elm	*Ulmus americana*
	Atlantic white-cedar	*Chamaecyparis thyoides*
	Ash	*Fraxinus* spp.
	Ashe juniper	*Juniperus ashei*
	Aspen	*Populus* spp.
	Bald cypress	*Taxodium* Rich.
	Balsam fir	*Abies balsamae*
	Balsam poplar	*Populus balsamifera*
	Basswood	*Tilia* spp.
	Beech	*Fagus grandifolia*
	Black ash	*Fraxinus nigra*
	Black cherry	*Prunus serotina*
	Black locust	*Robinia pseudoacacia*
	Black oak	*Quercus velutina*
	Black spruce	*Picea mariana*
	Black walnut	*Juglans nigra*
	Bur oak	*Quercus macrocarpa*
	Cheatgrass	*Bromus tectorum*
	Cherry	*Prunus* spp.
	Cherrybark oak	*Quercus falcate var. pagodifolia*
	Chestnut oak	*Quercus prinus*
	Cottonwood	*Populus* spp.
	Crested wheatgrass	*Agropyron cristatum*
	Dalmatian toadflax	*Linaria dalmatica*
	Douglas-fir	*Pseuditsuga menziesii*
	Eastern hemlock	*Tsuga canadensis*
	Eastern redcedar	*Juniperis virginiana*
	Eastern white pine	*Pinus strobus*
	Eurasian watermilfoil	*Myriophyllum spicatum*
	Gray birch	*Betula populifolia*
	Hickory	*Carya* spp.
	Hackberry	*Celtis occidentalis*
	Intermediate wheatgrass	*Thinopyrum intermedium*
	Jack pine	*Pinus banksiana*
	Juniper	*Juniperis* spp
	Knapweed	*Centaurea solstitialis, C. diffusa, C. maculosa, Acroptilon repens*

Appendix C. List of Scientific Names (continued)

	Common Name	Scientific Name
Plants	Leafy spurge	*Euphorbia esula*
	Loblolly pine	*Pinus taeda*
	Lodgepole pine	*Pinus contorta*
	Longleaf pine	*Pinus palustris*
	Mesquite	*Prosopis* spp
	Northern red oak	*Quercus rubra*
	Northern white-cedar	*Thuja occidentalis*
	Nuttall oak	*Quercus nutallii*
	Overcup oak	*Quercus lyrata*
	Palms	*Palmae* spp.
	Paper birch	*Betula papyrifera*
	Pecan	*Carya illinoinensis*
	Persimmon	*Diospyros virginiana*
	Pin cherry	*Prunus pensylvanica*
	Pinyon pine	*Pinus edulis*
	Pitch pine	*Pinus rigida*
	Pond cypress	*Taxodium ascendens*
	Pond pine	*Pinus serotina*
	Ponderosa pine	*Pinus ponderosa*
	Red brome	*Bromus rubens*
	Red maple	*Acer rubrum*
	Red oak	*Quercus falcata*
	Red pine	*Pinus resinosa*
	Red spruce	*Picea rubens*
	River birch	*Betula nigra*
	Sand pine	*Pinus clausa*
	Sassafras	*Sassafras albidum*
	Scarlet oak	*Quercus coccinea*
	Scotch pine	*Pinus sylvestris*
	Shortleaf pine	*Pinus echinata*
	Silver maple	*Acer saccharinum*
	Slash pine	*Pinus elliottii*
	Starthistles	*Centaurea* spp.
	Sugar maple	*Acer sacchurum*
	Sugarberry	*Celtis laevigata*
	Swamp chestnut oak	*Quercus michauxii*
	Sweetbay	*Laurus nobilis*
	Sweetgum	*Liquidambar styraciflua*
	Sycamore	*Platanus occidentalis*
	Tamarack	*Larix laricina*
	Virginia pine	*Pinus virginiana*
	Water hickory	*Carya aquatica*
	Water tupelo	*Nyssa sylvatica*
	Western juniper	*Juniperus occidentalis*
	White ash	*Fraxinus amiricana*
	White oak	*Quercus alba*
	White spruce	*Picea glauca*
	Whitebark pine	*Pinus albicaulis*
	Willow	*Salix* spp.
	Willow oak	*Quercus phellos*
	Yellow birch	*Betula alleghaniensis*
	Yellow poplar	*Liriodendron tulipifera*
Other	Asian longhorned beetle	*Anoplophora glabripennis*
	Emerald ash borer	*Agrilus planipennis*
	Gypsy moth	*Lymantria dispar*
	Ips beetles	*Ips* spp.
	Mountain pine beetle	*Dendroctonus ponderosae*
	Southern pine beetle	*Dendroctonus frontalis*
	White pine blister rust	*Cronartium ribicola*

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