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Outlook for Appalachian-Cumberland Forests:

A SUBREGIONAL REPORT

from the Southern Forest Futures Project

Tara Keyser, Joy Malone, Claudia Cotton, and Jeffrey Lewis



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The Authors:

Tara Keyser is a Research Forester for Upland Hardwood Ecology and Management Work Unit, Southern Research Station, U.S. Department of Agriculture Forest Service;

Joy Malone is a Recreation Staff Officer at the Daniel Boone National Forest, Southern Region, U.S. Department of Agriculture Forest Service; **Claudia Cotton** is a Forest Soil Scientist at the Daniel Boone National Forest, Southern Region, U.S. Department of Agriculture Forest Service; and

Jeffrey Lewis is a Forester at the Daniel Boone National Forest, Southern Region, U.S. Department of Agriculture Forest Service.

Cover photos

MAIN IMAGE: new growth on northern red oak (David Lee, Bugwood.org)
TOP ROW L TO R: white oak fruits (Paul Wray, Iowa State University, Bugwood.org); northern red oak leaves (Becca MacDonald, Sault College, Bugwood.org); dormant northern red oak (David Lee, Bugwood.org); white oak foliage (David Stephens, Bugwood.org); spraying insecticidal soap to treat infested hemlocks (Great Smoky Mountains National Park Resource Management Archive, USDI National Park Service, Bugwood.org)

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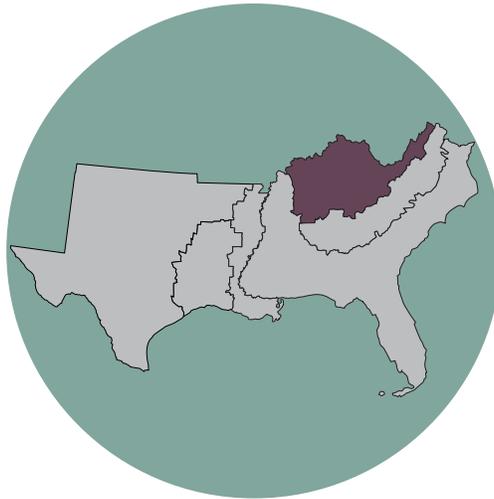
Southern Research Station
200 W.T. Weaver Blvd.
Asheville, NC 28804



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**A SUBREGIONAL REPORT
FROM THE SOUTHERN FOREST FUTURES PROJECT**



Tara Keyser, Joy Malone, Claudia Cotton, and Jeffrey Lewis

PROLOGUE

The Southern Forest Futures Project Co-Leaders

David N. Wear, *Project Leader*,
Center for Integrated Forest Science and Synthesis,
U.S. Forest Service, Southern Research Station,
Research Triangle Park, NC 27709

John G. Greis, *Resource Analyst*,
State & Private Forestry,
U.S. Forest Service, Southern Region
Tallahassee, FL 32399

This report describes a set of likely forest futures and the management implications associated with each for the Appalachian-Cumberland highland, one of five subregions of the U.S. South. Its findings are based on the findings of the Southern Forest Futures Project, a multi-agency effort to anticipate the future and to analyze what the interaction of future changes might mean for forests and the benefits they provide in the 13 Southern States. The Futures Project investigators examined a labyrinth of driving factors, forest outcomes, and human implications to describe how the landscape of the South might change. Their findings, which are detailed in a 17 chapter technical report (Wear and Greis 2013) and synthesized in a compact summary report (Wear and Greis 2012), consist of analyses of specific forecasts and natural resource issues. Because of the great variations across

southern forest ecosystems, the Futures Project also draws out findings and management implications for each of five subregions (fig. P1) including the one addressed in this report.

Why spend several years sorting through the various facets of this complicated puzzle? The reasons are varied but they all revolve around one notion: knowing more about how the future might unfold can improve near term decisions that have long-term consequences. For example, knowing more about future land use changes and timber markets can guide investment decisions. Knowing more about the intersection of anticipated urbanization, intensive forestry, and imperiled species can guide forest conservation policy and investments. And knowing more about the potential development of fiber markets can inform and improve bioenergy policies.

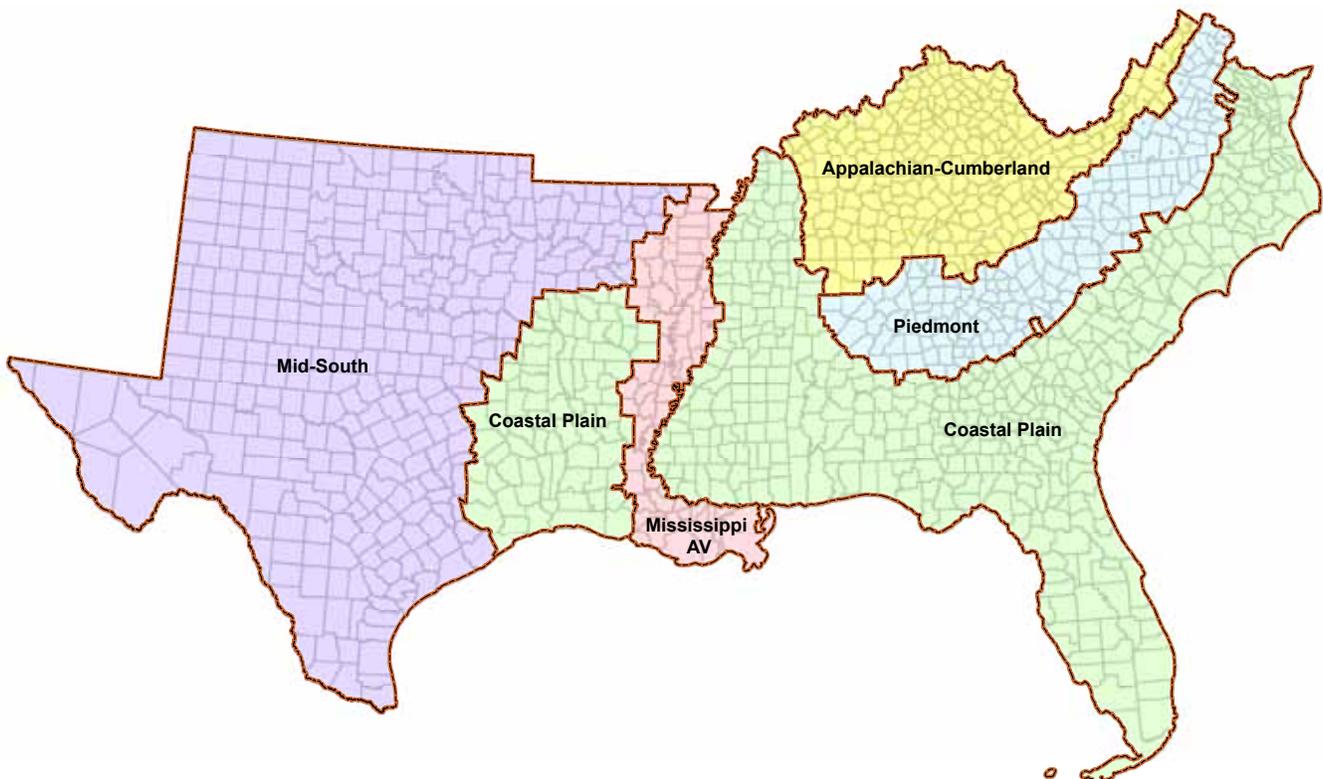


Figure P1—The five subregions of the U.S. South.

Consequently, the intended users of the Futures Project findings are natural resource decisionmakers, professionals, and policy analysts as well as those members of society who care about natural resource sustainability.

From the dozens of detailed topic-specific findings in the technical report, 10 were identified and discussed in the Futures Project summary report. They are:

- The interactions among four primary factors will define the future forests of the South: population growth, climate change, timber markets, and invasive species.
- Urbanization is forecasted to cause losses in forest acreage, increased carbon emissions, and stress to forest resources.
- Southern forests could sustain higher timber production levels; however, demand is the limiting factor, and demand growth is uncertain.
- Increased use of wood-based bioenergy could generate demands that are large enough to trigger changes in forest conditions, management, and markets.
- A combination of factors, including population growth and climate change, has the potential to decrease water availability and degrade quality; forest conservation and management can help to mitigate these effects.
- Nonnative invasive species (insects, pathogens, and plants) present a large but uncertain potential for ecological changes and economic losses.
- Fire-related hazards in wildlands would be exacerbated by an extended fire season combined with obstacles to prescribed burning that would accompany increased urbanization (particularly in response to air quality and highway smoke issues).
- Private owners continue to control forest futures, but ownership patterns are becoming less stable.
- Threats to species of conservation concern are widespread but are especially concentrated in the Coastal Plain and the Appalachian-Cumberland highland.
- Increasing populations would increase demand for forest-based recreation while the availability of land to meet these needs is forecasted to decline.

The impetus for the Southern Forest Futures Project comes from a desire to understand how a wide variety of dynamics including economic, demographic, and environmental changes might affect forest resources. An assessment of some aspects of forest sustainability (Wear and Greis 2002a, 2002b) was completed a decade ago, but the rapid pace of change and the sudden emergence of new and complex natural resource issues prompted a new study that could take advantage of recent science findings and forecasting methods. In December 2007 the Futures Project got underway under the joint sponsorship of the U.S. Department of Agriculture Forest Service and the Southern Group of State Foresters.

Designing the Futures Project

The Futures Project investigators started by identifying a set of relevant questions and then defining a targeted and robust process for answering them. Their process consisted of enumerating the critical socioeconomic and biophysical changes affecting forests, defining the most important management and policy information needs, and addressing forecasts and questions at the most useful scale of analysis. A series of public information gathering sessions addressed the first two stages of the process: more than 600 participants with a wide array of backgrounds and perspectives—at 14 meetings, with at least one meeting in each of the 13 Southern States—contributed input on what they saw as the important issues and future uncertainties affecting forests (Wear and others 2009). These meetings shaped the thinking about alternative futures and led to the selection and definition of meta-issues, each of which describes an interrelated complex of questions (for example, the bioenergy meta-issue is constructed from a set of questions that address conversion technologies, impacts on sustainability, Federal and State policies, and economic impacts).

The South defines a discernible biological and socioeconomic region of the United States, but also contains a vast diversity of biota and socioeconomic settings within its boundaries. The meta-issues and the forecasts of future conditions were analyzed at the broad regional level, with results broken down to finer grains of analysis where feasible and appropriate. However, the broad-scale approach was not considered adequate to address specific implications that these forecasts and issue analyses hold for forest management and restoration activities in more localized conditions; doing so required a scale that more closely matched the different forest ecosystem types in the South (fig. P2).

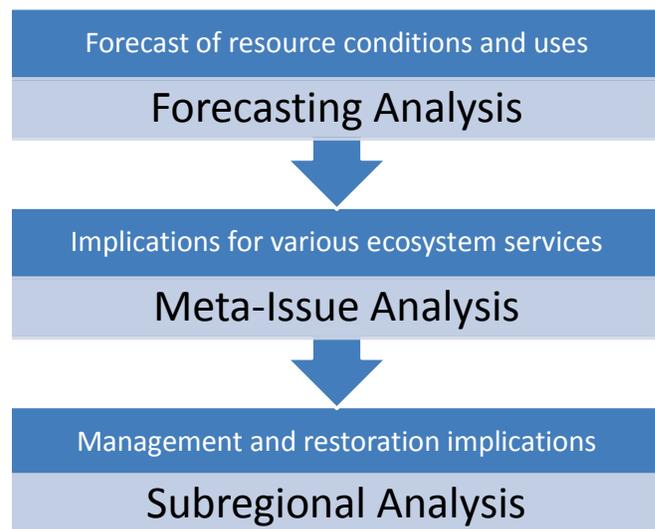


Figure P2—The three phases of the Southern Forest Futures Project.

Thus the second phase of the Futures Project, in which separate efforts examined the management/restoration implications for the five subregions of the South: Coastal Plain, Piedmont, Appalachian-Cumberland highland, Mississippi Alluvial Valley, and Mid-South (which includes all of Texas and Oklahoma). Still further spatial resolution was provided by breaking the subregions into a number of ecological sections; some issues are discussed at that scale as well.

The analytical centerpiece of the Futures Project is a set of forecasting models contained in the U.S. Forest Assessment System, which was developed for the U.S. Forest Service 2010 Resources Planning Act (RPA) Assessment as a means of conducting national forecasts. The system uses global projections of climate, technological, population, and economic variables to drive the simulation of changes in land uses, forest uses, and forest conditions at a fine spatial scale—thus facilitating subregional and other fine scale analyses. Specific RPA scenarios were chosen that define the set of variables that “drive” the forecasts, linking national economic and climate changes to the worldviews contained in international climate assessments (Intergovernmental Panel on Climate Change 2007).

Although the Futures Project tiered directly to the 2010 RPA Assessment (USDA Forest Service 2012), its investigators developed more specific implications for the South within the bounds of the scientific literature.

Perhaps the only absolute truth about any forecast is that it will be an inaccurate description of future reality to one degree or another and that the best—that is, the most accurate—forecast is not likely to be known ahead of time. As a result, forecasters hedge their expectations of future conditions by including a range of plausible futures and thus addressing the risk of generating precise forecasts of the wrong future.

The Futures Project investigators considered a large number of scenarios based on the 2010 RPA Assessment and public input, and then narrowed them to a half dozen that captured the broad range of potential conditions. These “Cornerstone Futures” define six combinations of climate, economic, population, and forest-products sector projections (fig. P3). The assumption was that unfolding events would be captured by a future that is close to one of the Cornerstone Futures. The validity of this assumption, however, will only be revealed by the course of future events.

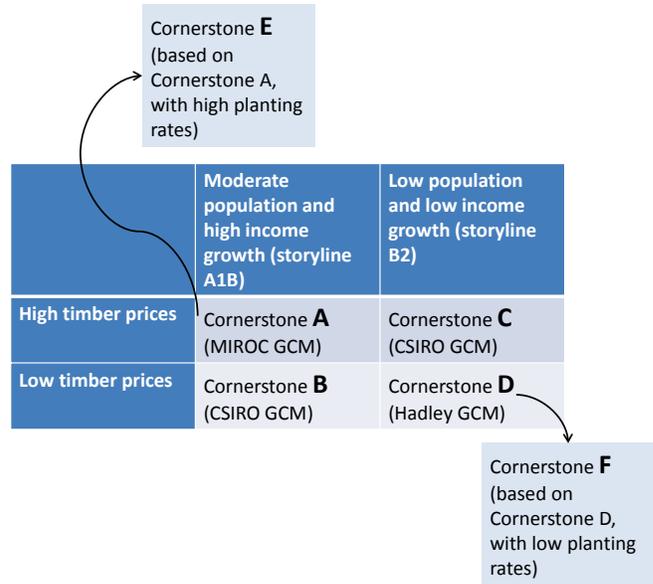


Figure P3—Six Cornerstone Futures, each of which represents a general circulation model (MIROC3.2, CSIROCM3.5, CSIROCM2, or HadCM3) paired with one of two emission scenarios (A1B representing low-population/high-economic growth, high energy use, and B2 representing moderate growth and use) and two timber price futures; and then extended by evaluating forest planting rates above and below current levels. Sources: Intergovernmental Panel on Climate Change (2007); USDA Forest Service (2012).

Forecasts provide practical insights only when they are examined in the light of specific issues and historical changes. The meta-issues provided specific questions to be addressed using the forecasts along with other available information. For some meta-issues, such as water or fire, additional models helped translate forest forecasts into specific implications. For other meta-issues, such as taxes or ownership, a more qualitative approach linked the analysis of meta-issues to forecasts. But for each meta-issue, the analysis started with a thorough synthesis of historical trends, a description of the current situation, and a summary of the relevant scientific literature.

This report draws together the findings from the 17 chapters of the Southern Forest Futures Project technical report (Wear and Greis 2013) to isolate the findings of most critical consequences for management and policy decisionmaking within the Appalachian-Cumberland highland. The findings described here also offer an interpretation of the most important findings from the technical report and their implications for forest management and restoration activities within the Appalachian-Cumberland highland.

The Cornerstone Futures

Southern Forest Futures Project investigators developed six Cornerstone Futures (A to F) to describe the factors that are likely to drive changes in southern forests. The Cornerstone Futures were selected to represent the range of findings from a much broader set of possibilities that were developed by combining county-level population/income and climate projections, assumptions about future timber scarcity, and assumptions about tree planting rates (Wear and Greis 2012, 2013).

County-level forecasts of population and income, variables critical to the Cornerstone Futures, were projected within the context of two global perspectives on socioeconomic change—downscaled descriptions of demographic change and economic growth (Intergovernmental Panel on Climate Change 2007)—to construct global forecasts of climate changes and their implications. The first yielded about a 40-percent growth in overall population from 2010 to 2060, and the second yielded a higher rate of 60 percent. The projections vary by county, with the populations of some counties growing substantially and others shrinking.

Timber price futures either describe increasing or decreasing scarcity with an orderly progression of real prices: assumed to be 1 percent per year from a base in 2005 through 2060. Real returns to agricultural land uses were also held constant throughout the forecasts for all Cornerstone Futures.

Each of the population/income projections embedded in the Cornerstone Futures is linked to a worldwide emissions storyline that drives alternative climate forecasts. The result was three climate projections driven by the population/economic projections and downscaled to the county level. Forecasted variables included changes in temperature, precipitation, and derived potential evapotranspiration. One climate forecast was selected for each of the Cornerstone Futures in a way that incorporated the full range of climate projections. These are taken from four downscaled climate models—MIROC3.2, CSIROCM2.3.2, CSIROCM3.5, and HadCM3.

Cornerstones A through D are defined by the matrix formed by intersecting low and high population and income forecasts with increasing and decreasing timber price futures as described above:

Cornerstone A—High population/income growth with increasing timber prices and baseline tree planting rates.

Cornerstone B—High population/income growth with decreasing timber prices and baseline tree planting rates.

Cornerstone C—Low population/income growth with increasing timber prices and baseline tree planting rates.

Cornerstone D—Low population/income growth with decreasing timber prices and baseline tree planting rates.

These four Cornerstones assume rates of post-harvesting tree planting that are based on future planting forecasts derived from planting frequencies between the latest two forest survey periods for all States and all major forest types (data from Forest Inventory and Analysis, Southern Research Station, U.S. Forest Service). Because this was a period of rapid expansion in planted pine, perhaps associated with displacement of harvesting from the Western United States, baseline rates were set at 50 percent of the observed frequencies.

Cornerstones E and F depart from the first four, with Cornerstone E increasing planting rates by 50 percent for Cornerstone A (strong economic growth and expanding timber markets); and Cornerstone F decreasing planting rates by 50 percent for Cornerstone D (reduced economic growth and decreasing timber markets).

Forecasts for the Cornerstone Futures provide the foundation for understanding the potential implications of the meta-issues identified by the Futures Project.

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ABSTRACT

The U.S. Appalachian-Cumberland highland consists of about 62.3 million acres in portions of Alabama, Georgia, North Carolina, Tennessee, Kentucky, and Virginia; and is divided into five sections—Blue Ridge Mountains; Interior Low Plateau; Northern Ridge and Valley; Southern Ridge and Valley; and Cumberland Plateau and Mountains. Appalachian-Cumberland forests provide a multitude of ecological services and societal benefits. This publication presents results from the Southern Forest Futures Project specific to the Appalachian-Cumberland subregion, along with associated challenges to forest management. Forecasted scenarios suggest that environmental conditions, nonnative insects and diseases, forest fragmentation, and increased societal pressure on forest land could create novel conditions that affect ecosystem structure and function. Continued changes in the societal forces that shape forest conditions, including urbanization, have the potential to affect many of the ecosystem services provided by Appalachian-Cumberland forests, including commercial and noncommercial forest products (such as timber harvesting and mushroom collecting), water quantity and quality, recreation, wildlife habitat, and biological complexity.

Keywords: Appalachian-Cumberland, conservation, forest management, Southern Forest Futures Project.

KEY FINDINGS

- The Appalachian-Cumberland highland consists of five sections: Blue Ridge Mountains, Cumberland Plateau and Mountains, Northern Ridge and Valley, Southern Ridge and Valley, and Interior Low Plateau. It encompasses about 62.3 million acres, of which 51.9 million acres are held by non-Federal entities in parts of Alabama, Georgia, North Carolina, Tennessee, Kentucky, and Virginia. Detailed synthesis of the 17-chapter Southern Forest Futures Project technical report (Wear and Greis 2013) reveals numerous key findings specific to the Appalachian-Cumberland highland.
- Families and individuals own two out of every three acres of private forest land in the South. The majority of family forest owners hold 1 to 9 acres. However, the majority of family forest acres are in holdings of 100 acres or more. Parcelization and fragmentation of forests are expected to continue as private owners divest their holdings in the future.
- Unlike other areas of the South (such as the Piedmont and Coastal Plain, which are dominated by softwoods) where changes in forest conditions are more heavily influenced by harvesting and forest management and are thereby linked to future timber markets, Appalachian-Cumberland landscapes are dominated by hardwoods, meaning that the condition and status of forests are most heavily influenced by urbanization-driven land use changes, changes that are closely linked to population and income.
- The Appalachian-Cumberland highland is forecasted to experience an increase in temperature under all projections. Relative to the 10-year historical average (1997 to 2006), however, only minor changes in average decadal precipitation are forecasted.
- Although one of the smaller subregions of the South, the Appalachian-Cumberland highland contains a highly diverse suite of plant and animal communities and contains many endemic species that depend on its specific physical, climatic, and biological attributes. Urbanization-driven changes in land use coupled with loss of forest land and loss of forest connectivity near metropolitan areas could threaten the diversity and abundance of bats, salamanders, and concentrations of sensitive plant species. Furthermore, increased habitat fragmentation could make migration in response to climate and disturbances difficult. Recreational use, which is expected to increase concomitant with increased urbanization will likely be an additional pressure on rare and endemic communities.
- Regardless of climate, a change from forest to urban land uses, coupled with increases in population, would increase water supply stress across the Appalachian-Cumberland highland. Because water stress is sensitive to population changes, the highest proportional increase in water stress is expected to occur where urban land uses and rates of urbanization and population growth are forecasted to be highest.
- The invasion of forest communities by nonnative invasive plants is driven by habitat fragmentation, parcelization, increasing population, increasing recreation use, and forest disturbance—all of which are forecasted to increase under all projections. Climate change would likely accelerate the rate of invasion in a given area, but would also facilitate movement of specific species into new ecosystems. Loss of forest productivity, coupled with the negative effects nonnative invasive plants have on other ecosystem services, would make the control of invasive plants an important ecological as well as economic concern.

- Insects and diseases are a prominent disturbance in Appalachian-Cumberland forests and will continue to influence forest structure, function, and composition during the next 50 years. Insect and disease outbreaks have the potential to all but eliminate certain species (such as eastern and Carolina hemlocks) from the ecosystem, with cascading ecological consequences.
- Compared to other subregions (Piedmont, Coastal Plain, Mississippi Alluvial Valley, and the Mid-South) of the South, the Appalachian-Cumberland highland is forecasted to experience the highest growth rate of urban land use.
- The forecasted area of non-Federal urban land in the Appalachian-Cumberland highland is expected to increase from the 1997 base of about 3.9 million acres to 10.6 million acres by 2060, an increase of about 172 percent under projections of high population and economic growth. Under all projections, non-Federal forest area is forecasted to decrease by 5 (1.4 million acres) to 13 percent (3.7 million acres) over the next 50 years (2010 to 2060). Loss of forest acreage, largely a consequence of urbanization-driven changes in land use, is most visible in and around current Appalachian-Cumberland population centers. Cropland and pastureland uses, which are heavily driven by timber prices, are also expected to decrease at varying degrees.
- From 1998 to 2008, the forest products industry divested about three-fourths of its timber holdings. Of the States that have land in the Appalachian-Cumberland highland, most of the increases in corporate ownership have been in timber investment management organizations. Two States, Alabama and Georgia, also experienced an increase in real estate investment trusts.
- Based on moderate population growth predictions, the projected growth for the South is about 60 percent. Growth rates for participation in outdoor recreation activities are expected to increase as well.
- Recreation participation is expected to increase over the next 50 years. For some activities, the annual per capita participation could decrease over the next 50 years. However, even with decreasing rates of participation, the increasing population numbers would mean that the overall participation in all activities would increase. At the same time, the land base for forest recreation activities is expected to be either fairly stable (for public land), or decreasing (private lands). Demand for forest land available for recreational activities will likely continue to increase as land available for those activities decreases.
- Wildfire will continue to be a threat to life and property throughout the Appalachian-Cumberland highland, and would be exacerbated by continued population growth, increased recreation pressure, and climate change. Projections of the extent of drying and increased wildfire potential vary according to the climate assumptions and season, ranging from severe drying conditions as measured by the potential drought index to little difference in dryness.

CHAPTER 1.

The Forests and People of the Appalachian-Cumberland Highland

One of five subregions of the U.S. South (along with the Coastal Plain, Piedmont, Mid-South, and Mississippi Alluvial Valley), the Appalachian-Cumberland highland emerges from the Piedmont to the east and south and from the Coastal Plain to the west, encompassing parts of Alabama, Georgia, North Carolina, Tennessee, Kentucky, and Virginia. It contains about 62.3 million acres and is divided into five sections (figs. 1 and 2): Blue Ridge Mountains, Interior Low Plateau, Northern Ridge and Valley, Southern Ridge and Valley, and Cumberland Plateau and Mountains (Bailey and others 1994).

Forests across the subregion are broadly characterized by age class distribution (with age classes divided into 10-year segments) and management type—oak-pine (*Quercus* spp.–*Pinus* spp.), planted pine, natural pine, upland hardwoods, lowland hardwoods, and nonstocked stands (stands that have <10 stocking in live trees). The upland hardwood forest management type dominates, followed distantly by oak-pine stands. The oak-pines, lowland hardwood, and natural pines approximate a normal distribution, with the majority of stands ages 31 to 60 years. In contrast, upland hardwoods are heavily skewed towards the older age classes and the majority of planted pine stands are in the younger age classes (fig. 3).

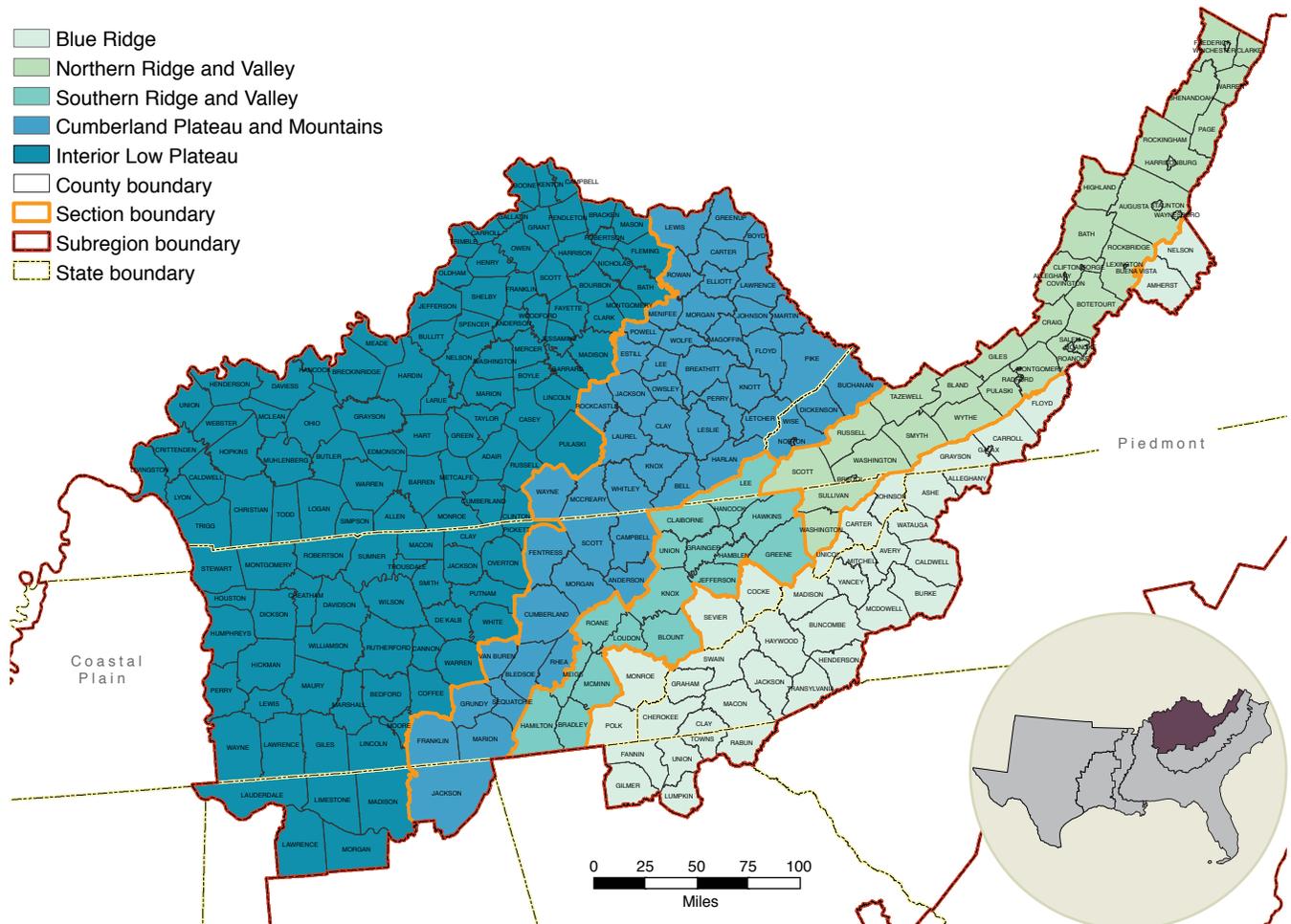


Figure 1—U.S. Appalachian-Cumberland sections and counties.

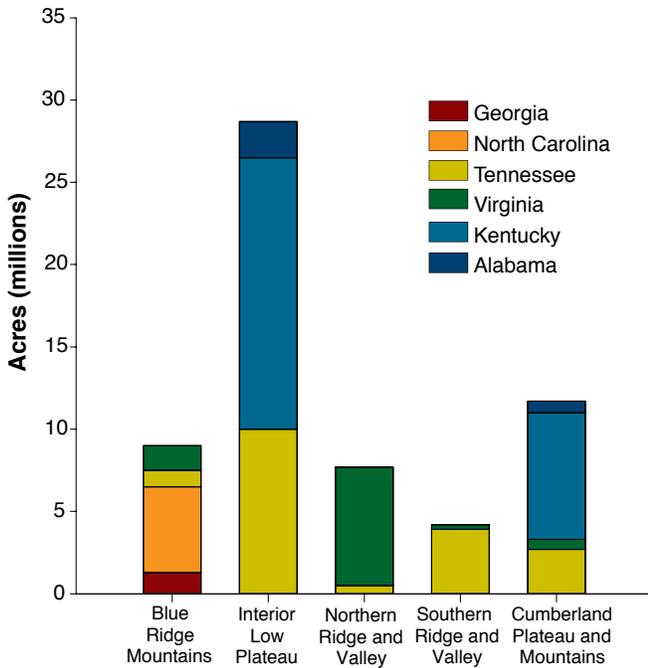


Figure 2—Area by section (Blue Ridge, Interior Low Plateau, Northern Ridge and Valley, Southern Ridge and Valley, and Cumberland Plateau and Mountains) and State in the U.S. Appalachian-Cumberland highland.

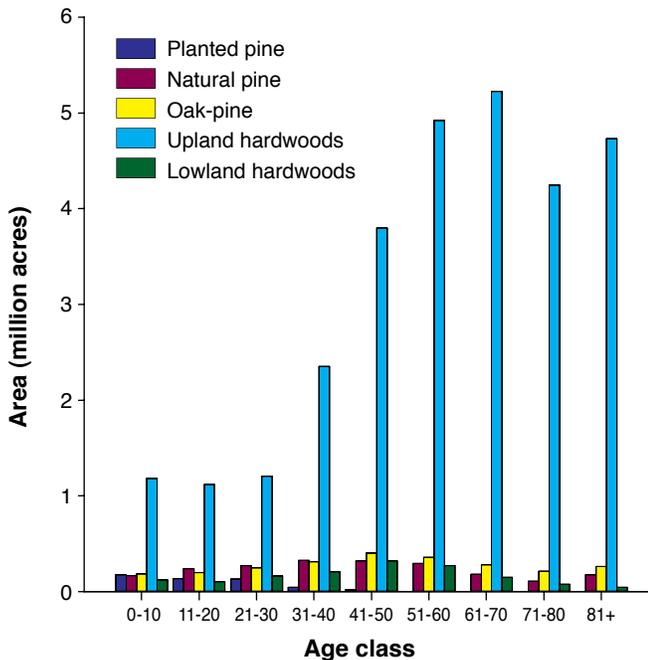


Figure 3—Age class distribution, 2010, of planted pine, natural pine, oak-pine, upland hardwoods, and lowland hardwoods forest management types across the U.S. Appalachian-Cumberland highland.

What is non-Federal land?

For the purposes of this publication, non-Federal land includes land held by private organizations, individuals, families, local governments, Indian reservations, and U.S. States. It does not include U.S. military bases or lands managed by the U.S. Department of Agriculture and the U.S. Department of the Interior.

Blue Ridge Mountains

The Blue Ridge Mountains section is located southeast of the Northern Ridge and Valley section and northwest of the western Piedmont (fig. 1). Most of the section occurs in western North Carolina, with smaller parts occurring in southwestern Virginia, eastern Tennessee, and northern Georgia. Blue Ridge counties in Virginia are Floyd, Carroll, Nelson, Amherst, and Grayson; in eastern Tennessee they are Cocke, Sevier, Monroe, Unicoi, Carter, Polk, and Johnson; in northern Georgia they are Rabun, Towns, Union, Lumpkin, Fannin, and Gilmer; and in North Carolina, they are Alleghany, Ashe, Watauga, Avery, Mitchell, Yancey, McDowell, Madison, Buncombe, Haywood, Burke, Caldwell, Henderson, Jackson, Transylvania, Macon, Clay, Cherokee, Graham, and Swain.

The section covers 9,735,550 acres, of which 6,422,080 acres are held by non-Federal entities. The terrain is very mountainous, with relatively large urban areas concentrated around the section’s largest city, Asheville, NC. Across the section, forest land covers 6,422,070 acres, or 67 percent of the non-Federal land base. Because flat and gentle terrain is uncommon throughout the section, only 21 percent of the non-Federal land base is classified as agricultural land (pastureland or cropland).

Landform—The Blue Ridge Mountains section is a high upland characteristic of a dissected mature erosion surface (Smith 1994). It consists of several distinct topographic areas (U.S. Department of Agriculture Natural Resources Conservation Service 2006), including the Blue Ridge Escarpment on its eastern edge, the New River Plateau on its northern edge, interior low and intermediate mountains throughout, intermountain basins between major mountains, and—most common—high mountains (with 46 peaks >6,000 feet). Elevations range from about 400 feet in the southern part to >6,600 feet at the crest of the Great Smoky and Black Mountain ranges (U.S. Department of Agriculture Natural Resources Conservation Service 2006). The three highest peaks east of the Mississippi River (Mt. Mitchell at 6,680 feet, Mt. Craig at 6,647 feet, and Clingman’s Dome at 6,643 feet) are all in this section.

The section was formed by tectonic faulting and uplift of resistant, crystalline bedrock that has eroded into rounded, broad, high mountains with little or no structural grain (McNab and Avers 1994). The bedrock geology consists mostly of Precambrian metamorphic rock formations with a few small bodies and windows of igneous and sedimentary rocks. The degree of metamorphism varies but generally decreases westward. Bedrock is composed primarily of quartzite, schist, gneiss, granite, rhyolite, basalt, and gabbro (McNab and Avers 1994).

Soils—Soils in the Blue Ridge Mountains section consist mostly of Ultisols and Inceptisols. The soils are dominantly well drained, strongly acidic, highly leached, and have clay-enriched subsoil. On average, soil moisture is sufficient to meet plant needs throughout the year. Soils are generally moderately deep, and boulders and rock outcrops are common on upper slopes but are not extensive (McNab and Avers 1994). Soils at elevations >4,800 feet can have a frigid temperature regime. These are very general descriptions, as the soils in this section are quite variable because of the high variability in bedrock, landform, and climate within short distances.

Forest composition—Upland hardwoods dominate the forested acreage in the Blue Ridge Mountains section, while that of the oak-pines and natural pines vary (fig. 4). Overall, the age class distribution of upland hardwoods is heavily skewed towards the older age classes while

the oak-pines and natural pines appear more normally distributed (fig. 4). Planting pine in this section appears to be a recent phenomenon (fig. 4). The five most abundant species/species-groups across the section are nested in the higher level “upland hardwoods” management type (fig. 5).

Mixed hardwood forests comprise the majority of the acreage in the Blue Ridge Mountains section. Although the mixed-hardwood forest type is well distributed across age classification, oak-dominated forests—chestnut oak/black oak/scarlet oak (*Q. prinus*–*Q. velutina*–*Q. coccinea*), white oak/northern red oak/hickory (*Q. alba*–*Q. rubra*–*Carya* spp.), and chestnut oak—are all skewed towards the oldest age class (>81 years). The forest type with some of the highest productivity (in terms of volume growth) is the yellow-poplar (*Liriodendron tulipifera*)/white oak/northern red oak, most of which are 60 to 80 years; unlike the oak-dominated forests, this type has a larger representation in the younger age classes. This trend is likely driven by the abundance of fast-growing yellow-poplar, which was likely the result of past harvesting (particularly on higher quality sites) without the presence of adequate advance oak reproduction prior to harvest (Loftis 1990a, 1990b).

Of particular interest in the Blue Ridge Mountains section are its high elevation (>5,000 feet) grassy balds and heath balds. Grassy balds are large meadows or treeless areas that are dominated by grass species and home to

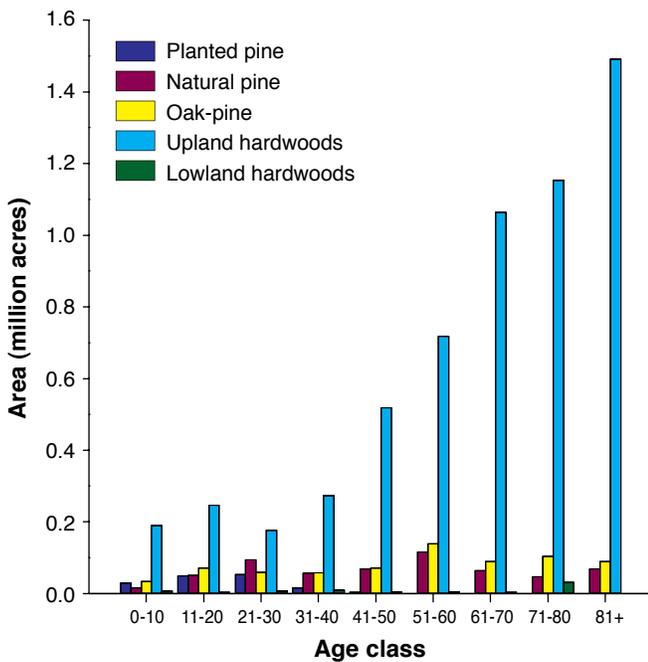


Figure 4—Age class distribution, 2010, of planted pine, natural pine, oak-pine, upland hardwoods, and lowland hardwoods forest management types in the Blue Ridge Mountains section of the U.S. Appalachian-Cumberland highland.

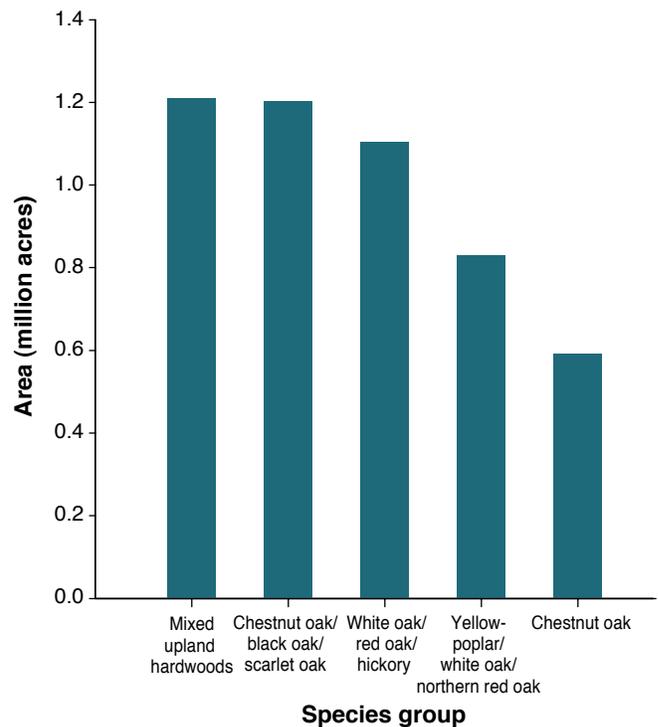


Figure 5—Area occupied by the five most common species and species groups (all falling into the upland hardwoods forest management type) in the Blue Ridge Mountains section of the U.S. Appalachian-Cumberland highland.

rare shade-intolerant plant species. Heath balds support rhododendron (*Rhododendron maximum*), mountain laurel (*Kalmia latifolia*), and sandmyrtle (*Leiophyllum buxifolium*), among other species (U.S. Department of Agriculture Natural Resources Conservation Service 2006). Also found at high elevations in this section are remnant spruce-fir (*Picea rubens*–*Abies fraseri*) forests, which cover about 21,200 acres in the Blue Ridge Mountains section. These relic forests are found at high elevations (>4,000 feet), and the majority are aged >81 years (USDA Forest Service 2012). Although climate certainly drives the range of spruce-fir forests, widespread logging in the early 20th century along with ownership patterns likely contributed to their limited extent.

Interior Low Plateau

The Interior Low Plateau section, located northwest of the Cumberland Plateau and Mountains section (fig. 1), is about evenly divided between Kentucky and Tennessee with a small part in northern Alabama. Its western border follows the Tennessee River north to the Ohio River; together the two rivers form its northern and western boundaries. The counties located on its eastern border are Mason, Fleming, Bath, Montgomery, Clark, Madison, Garrard, Lincoln, Pulaski, Russell, and Clinton Counties in Kentucky, and Pickett, Overton, Putnam, White, Warren, Coffee, Moore, and Lincoln Counties in Tennessee; the Alabama counties located on its southern boundary are Madison, Morgan, Lawrence, Lauderdale, and Limestone.

This section covers 28,135,680 acres, of which 25,377,870 acres are owned by non-Federal entities. In absolute acreage, it contains the most urban area in the Appalachian-Cumberland highland at 1.8 million acres. However, on a proportional basis, the amount of non-Federal land in urban uses amounts to only 7 percent—the second lowest in the subregion. Urban areas are concentrated in and around two Kentucky cities—Lexington, and Louisville—and the Nashville Basin in Tennessee. Rural areas are composed of small to medium-sized farms, with larger farms located in the northwestern parts. The gently rolling terrain in this section is particularly favorable to agricultural development, with 13.2 million acres classified as cropland or pastureland. Compared to the other sections of the Appalachian-Cumberland highland, the Interior Low Plateau has the highest percentage of non-Federal land base categorized as agriculture (52 percent) and the lowest percentage of land base categorized as forest (41 percent). As a proportion of total non-Federal land area, the Interior Low Plateau section contains the highest agricultural use (on an absolute and proportional basis) of the Appalachian-Cumberland highland, with 52 percent of the land classified as cropland and pastureland. Despite possessing about 10.3 million

acres of non-Federal forest land, the Interior Low Plateau section contains the smallest proportion of non-Federal land classified as forests.

Landform—The Interior Low Plateau section has a diversity of landforms and soils. The northeastern area—which includes the Kentucky cities of Louisville, Frankfort, and Lexington—is an area of gently rolling terrain with some isolated hills and ridges. Elevation ranges from 660 feet near the Ohio River to about 980 feet near Lexington (U.S. Department of Agriculture Natural Resources Conservation Service 2006).

The northwestern area—which includes the Kentucky towns of Henderson, Owensboro, and Madisonville—is characterized by gently sloping to steep slopes in the west with increasing steepness eastward. The steeper slopes have many bedrock escarpments and several levels of benches caused by alternating geologic beds of soft shale and hard sandstone. This area is dissected by numerous small and large tributaries of the Ohio River, ranging from well-defined valleys and broad floodplains of major streams to the narrow floodplains of smaller streams. Elevations range from 345 feet near the Ohio River to 950 feet on the highest ridges (U.S. Department of Agriculture Natural Resources Conservation Service 2006).

The southern area includes the basin surrounding Nashville, TN; beyond this is the Highland rim—a plateau consisting of low, rolling hills, upland flats, and narrow valleys with elevations ranging from 330 feet along the deepest valleys to 1,310 feet on the crests of isolated hills—that extends north to Bowling Green, KY and south to Clarksville, TN. Steep slopes occur where the Nashville basin cuts into the area and along the western edge that defines the Coastal Plain border. The Nashville basin is characterized by deep dissections on its edges and interior undulating and rolling hills; the land surface is deeply pitted with limestone sinks and limestone outcrops, and elevations average 650 feet—ranging from 450 feet in the most deeply cut stream channels to 1,325 feet on isolated hills (U.S. Department of Agriculture Natural Resources Conservation Service 2006).

The bedrock geology consists mostly of Ordovician to late Mississippian sedimentary rock formations. The banding plains are nearly flat across most of the section with alternating bands of shale, sandstone, and limestone of varying thicknesses. Loess deposits are common in northern areas. Karst topography and cave formations are common in all but the northwestern corner.

Soils—Soils in the Interior Low Plateau section are diverse. In the Nashville basin and the northwestern corner, soils are Udalfs. In other areas, soils are a mixture of Alfisols,

Inceptisols, Mollisols, and Ultisols. The Ultisols are found mainly in the Highland rim surrounding the Nashville basin. Common to all of the soils are mesic soil temperatures, udic soil regimes, and mixed mineralogy. Soil depth varies from very deep in lower slope positions to shallow on ridges or near bedrock outcrops. Most soils developed in residuum with the exception of those areas of loess deposits (U.S. Department of Agriculture Natural Resources Conservation Service 2006).

Forest composition—Like elsewhere throughout the Appalachian-Cumberland highland, upland hardwoods dominate the forested acreage in the Interior Low Plateau section, followed, distantly, by lowland hardwoods, oak-pine, natural pine, and planted pine (fig. 6). Overall, the age class distribution of upland hardwoods is skewed towards the older age classes. Lowland hardwoods, oak-pine, and natural pine age classes follow a normal distribution (fig. 6). Planting pine in this section appears to be a recent phenomenon.

The five most common species/species groups (fig. 7) across the Interior Low Plateau section are nested in the higher level “upland hardwoods” management type, which constitutes >75 percent of all the forest types. Overall, they are normally distributed with regard to age. In contrast, the oak-dominated forests are all skewed towards age classes that exceed the median age class.

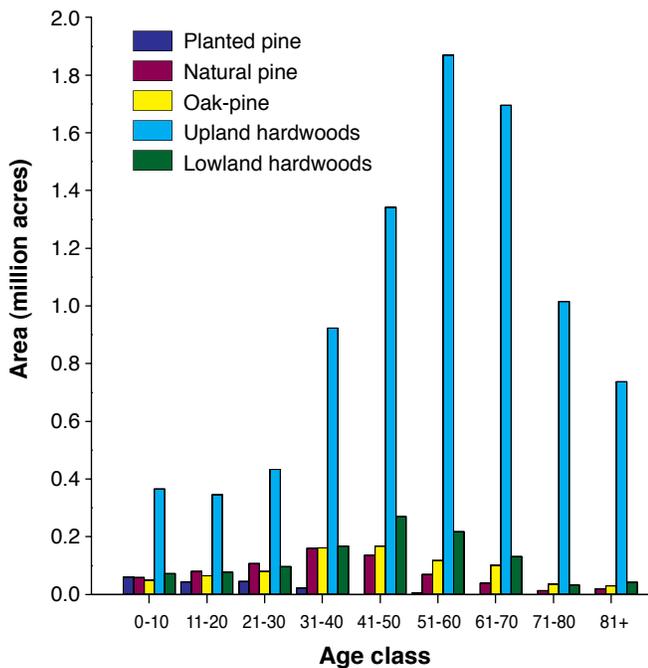


Figure 6—Age class distribution, 2010, of planted pine, natural pine, oak-pine, upland hardwoods, and lowland hardwoods forest management types in the Interior Low Plateau section of the U.S. Appalachian-Cumberland highland.

Northern Ridge and Valley

The Northern Ridge and Valley section is located east of the Appalachian Plateau and west of the Piedmont and the Blue Ridge Mountains section (fig. 1). Most of the land is located along the northwestern Virginia border with a smaller part occurring in northeastern Tennessee. Northern Ridge and Valley counties located in Virginia are Frederick, Clarke, Warren, Shenandoah, Page, Rockingham, Highland, Augusta, Bath, Rockbridge, Alleghany, Botetourt, Craig, Roanoke, Giles, Montgomery, Pulaski, Bland, Wythe, Tazewell, Smyth, Washington, Scott, and Russell; in Tennessee, they are Sullivan and Washington.

The section covers a total of 7,515,710 acres, of which 5,301,570 are held by non-Federal entities. Forests cover the largest proportion of the non-Federal land base, almost 2.3 million acres or 53 percent. Urban areas, which account for only 9 percent of the total non-Federal land base, are concentrated around Roanoke, VA, Bristol, TN, Kingsport, TN, and Johnson City, TN. Valley forests were cleared for agriculture long ago because of their fertile soils and lack of steep slopes. The association between more gentle terrain and agricultural uses can be observed by the increased agricultural uses in this section compared to some of the more rugged sections (such as the Blue Ridge Mountains). Currently, 37 percent of the non-Federal land base in the Northern Ridge and Valley section is classified as agricultural (cropland or pastureland).

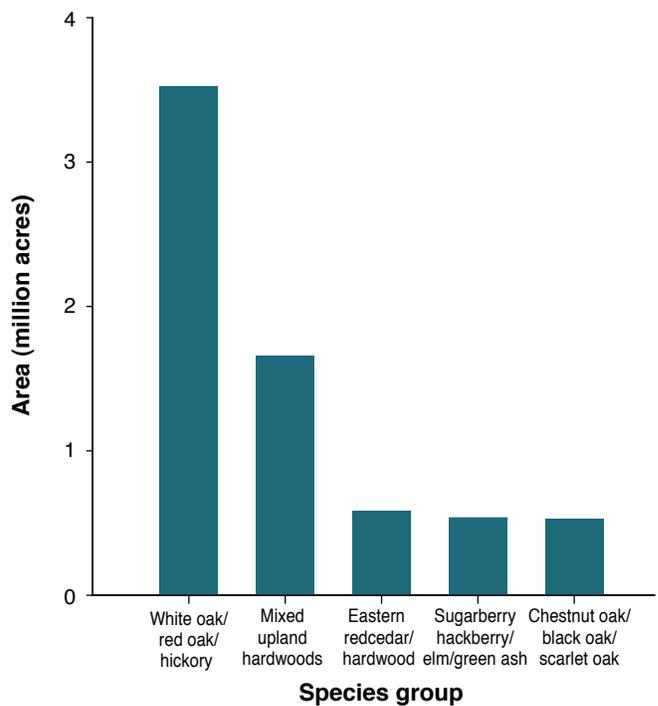


Figure 7—Area occupied by the five most common species groups (all falling into the upland hardwoods forest management type) in the Interior Low Plateau section of the U.S. Appalachian-Cumberland highland.

Landform—The Northern Ridge and Valley terrain is a nearly continuous band of parallel mountains and narrow valleys that trend northeast to southwest. The Great Valley is a significant landform in this section and contains the Shenandoah Valley and River. The bedrock geology is sedimentary and consists of alternating beds of limestone, dolomite, shale, and sandstone. The ridgetops are capped with more resistant carbonate and sandstone layers, and the valleys have eroded into less resistant shale or limestone (U.S. Department of Agriculture Natural Resources Conservation Service 2006). Rock outcrops are common and the rock strata are heavily folded, resulting in strongly inclined to almost-vertical bedrock (Smith 1994). Average elevation is 2,894 feet.

Soils—Soils in the section consist mostly of Ultisols and Inceptisols, with small areas of Alfisols and Spodosols. The dominant forest soils in the mountains are weathered from sandstone and shale; valley soils are weathered from shale, weathered from limestone, or have a limestone influence (Smith 1994). The mountain soils are excessively or somewhat excessively drained, low in natural fertility, and very-strongly to strongly acidic. Valley soils are well drained to moderately well drained, of moderate fertility, and medium to strongly acidic (Smith 1994). Soils are generally shallow and very rocky on sandstone ridges and sideslopes, and may be very deep in valleys and on large limestone formations (Smith 1994). On average, soil moisture is sufficient to meet plant needs throughout the year.

Forest composition—Upland hardwoods dominate the forested acreage in the Northern Ridge and Valley section followed distantly by oak-pine, natural pine, lowland hardwoods, and planted pine (fig. 8). Overall, the age distribution of upland hardwood forest management type is heavily skewed towards the older age classes. Excluding the oldest age class (>81), lowland hardwoods, oak-pine, and natural pine are approximately normally distributed (fig. 8). For oak-pine and natural pine, however, substantially more acreage is in the oldest age class than in any other single age class. The relatively small amount of planted pine in the ≤20-year age class suggests that little recent intensive pine management has occurred throughout the Northern Ridge and Valley section (fig. 8).

The five most abundant species/species groups (by acreage) across the Northern Ridge and Valley section are nested in the higher level “upland hardwoods” management type (fig. 9). Of these, the first four occur on fairly dry landscape positions, and the last one occurs most often on protected landscape positions, such as coves and north slopes, where moisture is higher. The prevalence of dry forest types reflects the drier climate found in this section. For the chestnut oak/black oak/scarlet oak, chestnut oak, and white oak/red oak/hickory, the age distribution is heavily skewed towards the older age classes (>70 years). In contrast, the age distribution for the mixed upland hardwoods includes a large acreage in young stands with a relatively small acreage in older stands.

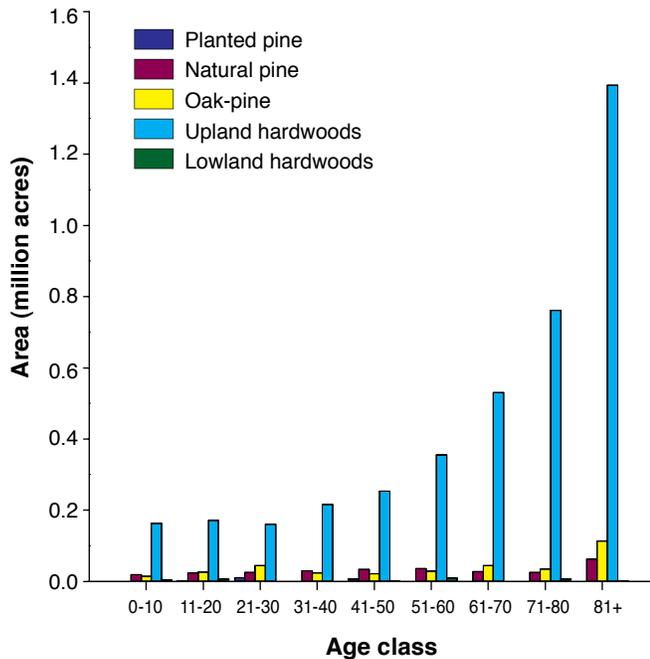


Figure 8—Age class distribution, 2010, of planted pine, natural pine, oak-pine, upland hardwoods, and lowland hardwoods forest management types in the Northern Ridge and Valley section of the U.S. Appalachian-Cumberland highland.

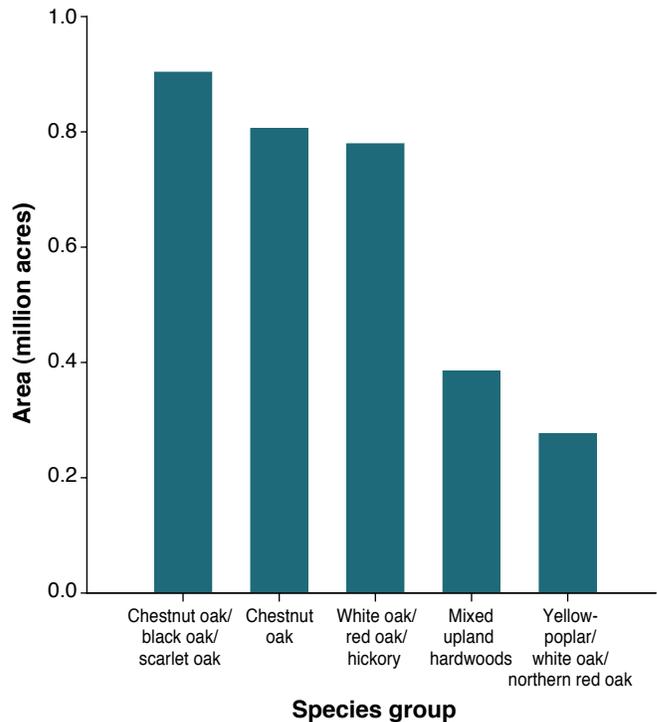


Figure 9—Area occupied by the five most common species and species groups (all falling into the upland hardwoods forest management type) in the Northern Ridge and Valley section of the U.S. Appalachian-Cumberland highland.

The age distribution of yellow-poplar/white oak/northern red oak is characterized by a moderate acreage in young stands (<20 years), small acreage in the middle of the age class (20 to 60 years), and a large acreage in older stands (>60 years).

Of particular conservation interest in this section are the relic spruce-fir forests found at high elevations (>4,000 feet). This forest type is old (>81 years), and covers only 6,200 acres in the Northern Ridge and Valley section (USDA Forest Service 2012). Although climate certainly drives the range of spruce-fir forests, widespread logging in the 20th century along with ownership patterns likely contributed to their limited extent.

Southern Ridge and Valley

The Southern Ridge and Valley section is located southeast of the Cumberland Plateau and Mountains section and northwest of the Blue Ridge Mountains section (fig. 1). It borders the Northern Ridge and Valley section to the northeast and the State of Georgia to the southwest. Most of the section is located in eastern Tennessee with a small area (Lee County) occurring in southwestern Virginia. Southern Ridge and Valley counties located in Tennessee are Hamilton, Bradley, McMinn, Meigs, Roane, Loudon, Blount, Knox, Union, Jefferson, Grainger, Hamblen, Greene, Hawkins, Claiborne, and Hancock.

The section covers 4,028,350 acres, of which 3,530,150 are held by non-Federal entities. Like elsewhere in the Appalachian-Cumberland highland, forest land is the predominant use in the Southern Ridge and Valley section, but the valleys widen southward, so other land uses, particularly agriculture, become more common. Although the section has the least acreage classified as urban uses, on a proportional basis, it also has the highest single concentration of urban uses, the area in and around Knoxville, TN. Agricultural land is an important land use in the Southern Ridge and Valley section. As of 1997, 36 percent of the total non-Federal land base in the section was classified as agricultural land (specifically cropland and pastureland).

Landform—The Southern Ridge and Valley terrain is a nearly continuous band of parallel mountains and valleys that trend northeast to southwest. In contrast to the Northern Ridge and Valley section, this section does not have as many ridges and the valleys' floors broaden and decrease in altitude toward the southwest. North of Knoxville, TN, the ridges are still numerous and the valley floors are high, at 2,500 feet (Fenneman 1938). Clinch Mountain is a significant landform that runs from the northern limit of the section to just south of Knoxville, TN. South of Knoxville, TN the landscape is composed of low ridges, knobs, and stream valleys (Fenneman 1938). Average elevation is 2,936

feet. The bedrock geology is sedimentary and consists of alternating beds of limestone, dolomite, shale, and sandstone. The ridgetops are capped with more resistant carbonate and sandstone layers, and the valleys have eroded into less resistant shale or limestone (U.S. Department of Agriculture Natural Resources Conservation Service 2006). The rock strata are heavily folded, which results in strongly inclined to almost vertical bedrock (Smith 1994).

Soils—Soils in the section consist mostly of Ultisols and Inceptisols. The dominant forest soils in the mountains are primarily weathered from sandstone and shale; valley soils are weathered from shale, weathered from limestone, or have a limestone influence (Smith 1994). The mountain soils are excessively or somewhat-excessively drained, low in natural fertility, and very strongly to strongly acidic. Valley soils are well drained to moderately well drained, of moderate fertility, and medium to strongly acidic (Smith 1994). Soils are generally shallow and very rocky on sandstone ridges and sideslopes, and may be very deep in valleys and on large limestone formations (Smith 1994). On average, soil moisture is sufficient to meet plant needs throughout the year.

Forest composition—Upland hardwoods dominate the forested acreage in the Southern Ridge and Valley section followed by the natural pine, oak-pine, lowland hardwoods, and planted pine (fig. 10). Overall, the age class distribution of the upland hardwood management types is skewed towards the older age classes. For natural pines, the distribution is skewed towards the younger age classes; however, the oak-pine distribution varies (fig. 10). For planted pine, all acreage occurs in age classes <30 years, emphasizing that planting is a relatively new phenomenon in the Southern Ridge and Valley section (fig. 10).

The five most abundant species/species groups across the section are nested in the higher level “upland hardwoods” management type (fig. 11). White oak/red oak/hickory, mixed upland hardwoods, chestnut oak/black oak/scarlet oak, and chestnut oak occur on fairly dry landscape positions. In contrast, yellow-poplar/white oak/northern red oak occurs most often on protected and moister landscape positions, such as coves and north slopes. For the oak-dominated forest types, the age distribution is skewed towards the older age classes (>50 years). This is especially true for the chestnut oak/black oak/scarlet oak, most of which are >70 years. Mixed upland hardwoods are evenly distributed among age classes. Chestnut oak is slightly skewed towards the older age classes (>50 years). Planted and natural pines—such as loblolly (*Pinus taeda*), shortleaf (*Pinus echinata*), and Virginia (*Pinus virginiana*)—are more common in this section than in the Northern Ridge and Valley section.

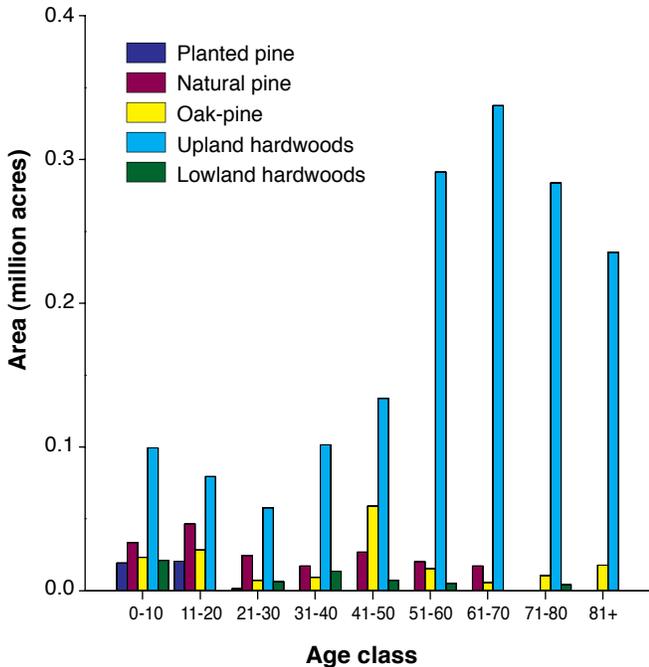


Figure 10—Age class distribution, 2010, of planted pine, natural pine, oak-pine, upland hardwoods, and lowland hardwoods forest management types in the Southern Ridge and Valley section of the U.S. Appalachian-Cumberland highland.

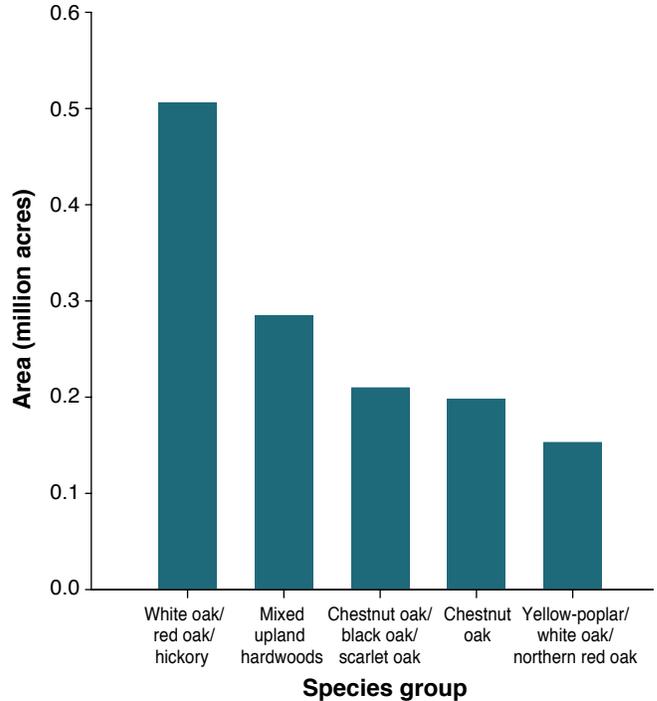


Figure 11—Area occupied by the five most common species and species groups (all falling into the upland hardwoods forest management type) in the Southern Ridge and Valley section of the U.S. Appalachian-Cumberland highland.

Cumberland Plateau and Mountains

The Cumberland Plateau is located northwest of the Northern and Southern Ridge and Valley sections and east of the Interior Low Plateau section (fig. 1). Most of this section is found in eastern Kentucky and eastern Tennessee, with the exception of a small area (Jackson County) in northern Alabama. Within the section, the Cumberland Mountains are located along the State borders of southeastern Kentucky, southwestern Virginia, and northeastern Tennessee. Cumberland Plateau and Mountains counties located in Virginia are Buchanan, Dickenson, Wise, and Norton; in eastern Tennessee they are Campbell, Scott, Fentress, Anderson, Morgan, Cumberland, Rhea, Bledsoe, Van Buren, Sequatchie, Grundy, Franklin, and Marion; and in Kentucky they are Lewis, Greenup, Boyd, Carter, Rowan, Elliott, Lawrence, Menifee, Morgan, Johnson, Martin, Powell, Wolfe, Magoffin, Floyd, Pike, Estill, Lee, Breathitt, Knott, Letcher, Perry, Owsley, Jackson, Rockcastle, Knox, Laurel, Harlan, Clay, Leslie, Bell, Whitley, McCreary, and Wayne.

This section covers a total of 12,839,230 acres—of which 11,315,970 acres are held by non-Federal entities—and contains both the largest proportion of non-Federal land in forests and the smallest (on a proportional basis) amount of area classified as urban. Flat land is not common, limiting agricultural uses; only 19 percent of the non-Federal land base is classified as agricultural land (cropland or pastureland).

Landform—The topography of the Cumberland Plateau varies according to location: rolling hills in the northern section, flat plateaus in the southern section, and highly dissected terrain covering most of the interior (Jones 2005). In the interior southeast and southwest parts, steep ridges and narrow valleys predominate (Jones 2005). The western border of the Cumberland Plateau, known as the Pottsville Escarpment, is highly dissected. A strip along the central part of the section’s eastern edge, known as the Cumberland Mountains, has the section’s highest elevations—4,145 feet at Black Mountain—dropping gradually to about 650 feet on the flood plain along the Ohio River (U.S. Department of Agriculture Natural Resources Conservation Service 2006). Average elevation for the section is 2,316 feet.

The plateau was formed by a broad uplift of strata, which created a level-bedded plateau. Over time, fluvial erosion and mass wasting have created a moderately dissected area of dendritic drainages (McNab and Avers 1994). The Cumberland Mountains were formed when the Cumberland overthrust block was pushed westward as a result of thin-skinned tectonics (McNab and Avers 1994). The thrust plate is delineated by prominent strike ridges—Pine Mountain to the northwest and Cumberland-Stone Mountain to the southeast (Smalley 1984). The bedrock of the Cumberland Plateau and Mountains section consists of sandstones, conglomerates, coals, siltstones, and shales of Pennsylvanian age. Resistant sandstone caps the ridges, and faster erosion

of lower strata results in rock houses, arches, and windows, particularly in northern areas. Limestones, shales, chert, and sandstones of Mississippian age may be exposed in entrenched streambeds, especially along the Pottsville Escarpment (Jones 2005).

Soils—Soils in the Cumberland Plateau and Mountains section consist mostly of Ultisols and Inceptisols. The soils found on the ridges and slopes are typically loamy to clayey, excessively drained, low in fertility, highly acidic, and often very rocky (Jones 2006). Soils containing higher organic matter and moisture content are less frequent, and may be found on lower slopes, terraces, and floodplains (Jones 2006). On average, soil moisture is sufficient to meet plant needs throughout the year.

Forest composition—Overall, the age classes for upland hardwoods represent a skewed distribution towards the older age classes. For natural pine, oak-pine, and lowland hardwoods, the age class distribution varies (fig. 12). Overall, the age classes of upland hardwoods represent an approximately skewed normal distribution, with more acreage in the older age classes than would occur if the age classes were normally distributed. For natural pine, oak-pine, and lowland hardwoods, the age classes represent a normal distribution with slightly more acreage occurring in the middle age classes than in the younger or older age classes (fig. 12). In the planted pines, substantially more acreage is in the <20

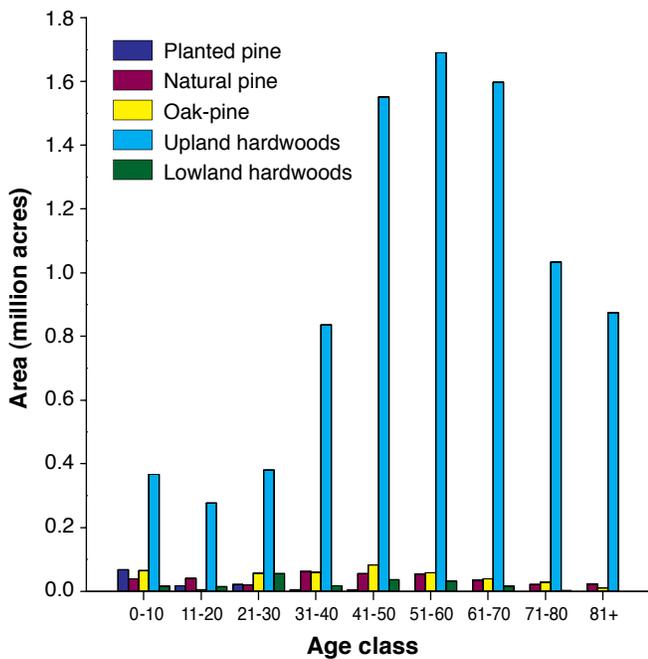


Figure 12—Age class distribution, 2010, of planted pine, natural pine, oak-pine, upland hardwoods, and lowland hardwoods forest management types in the Cumberland Plateau and Mountains section of the U.S. Appalachian-Cumberland highland.

age class than in the 21- to 50-year age classes, suggesting an increase in planting activity in the recent years (fig. 12).

The five most abundant species/species groups (by acreage) across the section are nested in the higher level “upland hardwoods” management type (fig. 13). The two oak-dominated types cover most of the acreage in this section; they—along with chestnut oak—are skewed towards the older age classes (>60 years). Mixed upland hardwoods are evenly distributed over all age classes except the >70 year class, where their numbers are lower.

The group associated with the highest levels of forest productivity is yellow-poplar/white oak/northern red oak. These forests are somewhat normally distributed across the age classes. The Cumberland Mountains have been cited as the heart of the historical mixed mesophytic association, which is known for its high diversity of plant species (Braun 1950). Braun (1950) identified three characteristics that described the mixed mesophytic forest: (1) three distinct strata of vegetation composed of understory, midstory, and overstory species; (2) shared overstory dominance by a multitude of hardwood species that may include yellow-poplar, basswood (*Tilia americana*), buckeye (*Aesculus* spp.), sugar maple (*Acer saccharum*), American chestnut (*Castanea dentata*), northern red oak, white oak, beech (*Fagus grandifolia*), and hemlock (*Tsuga* spp.); and (3) a preference for moist and well drained soils. The current forests of the Cumberland Plateau

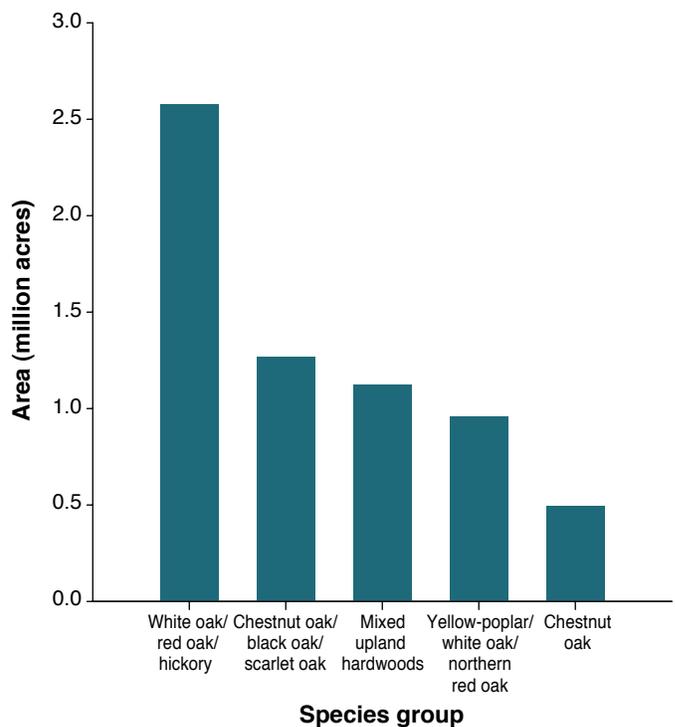


Figure 13—Area occupied by the five most common species and species groups (all falling into the upland hardwoods forest management type) across the Cumberland Plateau and Mountains section of the U.S. Appalachian-Cumberland highland.

and Mountains section are drier because of soil erosion resulting from cycles of harvesting and regeneration (Wharton and Barbour 1973). Nevertheless, plant diversity is still comparatively high in many areas, particularly in coves and on north-facing and east-facing aspects.

History of Disturbances and Recovery

The Appalachian-Cumberland highland has a history of human inhabitation that dates back to the Paleo-Indian period approximately 12,000 years ago (Yarnell 1998). Since that time, it has been continuously influenced by the various human populations that inhabited it, with the structure and composition of its forests shaped, in part, by patterns of land use. Until modern industrialization, activities associated with subsistence living were the primary uses of the Appalachian-Cumberland forests, providing fuel, building materials, and food. Below, we summarize the uses and disturbance events that, in part, shaped the attributes (such as structure and composition) of present-day Appalachian-Cumberland forests.

The disturbance history of the Appalachian-Cumberland highland is complex. A broad-scale view suggests that frequent small-scale gap dynamics (Lorimer 1980) coupled with debris landslides and wind and ice storms of intermediate scale and frequency were (and still are) the predominant natural disturbance agents acting on its forests (White and others 2011). Although lightning-caused wildfires did (and still do) occur, they were likely rare and primarily affected very specific parts of the landscape, such as low-elevation, dry ridge tops (Lafon and Grissino-Mayer 2007).

Evidence suggests purposeful burning conducted by Native Americans was prevalent across the Appalachian-Cumberland highland before European settlement; this served as an additional disturbance event controlling species composition and structural attributes of forests (Delcourt and Delcourt 1997, 1998). The extent of burning, as well as the direct and indirect effects of burning on vegetation, varied spatially and temporally across the topographically complex landscape (Flatley and others 2011, Guyette and others 2006, Yarnell 1998). In general, specifics about these fire regimes (such as extent, severity, behavior, and frequency) as they affect major forest types have not been fully quantified (Fesenmyer and Christensen 2010). However, the general consensus among scientists is that periodic, low-intensity fire was used by Native Americans (Abrams 1992, Brose and others 2001); also that the purpose and need for burning was related to subsistence living, with burning (along with tree girdling) used to clear land for agricultural purposes, attract game, and increase certain plant foods (Yarnell 1998). Burning was likely more frequent and more widespread before war and disease brought large reductions in Native populations (Guyette and others 2002, McEwan and others 2011).

Although the timing of widespread settlement varied across the Appalachian-Cumberland highland (Moore 2012, Yarnell 1998), settlement was always accompanied by increased use of forests. Some of the earlier activities that influenced forest structure and composition were similar to earlier activities conducted by Native Americans: widespread and open grazing (by hogs and other livestock), firewood collecting, harvesting of timber for subsistence living, burning (purposeful fires associated with settlement activities, such as land clearing and improving grazing habitat), and land clearing via tree girdling for agricultural uses (Spetich and others 2011, Yarnell 1998).

During the late 19th century and into the early 20th century, parts of the Appalachian-Cumberland highland began to experience the effects of modern industrialization. Although farming and subsistence living were the primary uses of forests in some areas (such as the Blue Ridge Mountains section), in other areas—such as eastern Kentucky, eastern Tennessee, and southwestern Virginia—forests began to be impacted by industrialization and subsequent land abandonment. As railroads were built, coal mining, widespread exploitive logging, and mining for other resources began to be the dominant forces shaping forests.

Although widespread exploitive logging was a prominent disturbance that shaped forests, another activity that has had a major impact—especially in the Cumberland Plateau and Mountains section and particularly in the northern part of the section—was coal mining. Hundreds of thousands of acres have been impacted by this activity. Coal has been extracted on a large scale since the early 1900s. Surface and contour mining remove the vegetation, soil, and rock (also known as overburden) that lie over the coal seam; the more recent practice of mountain top removal is becoming common. Coal mining affects the forest cover in three ways: (1) the forests are removed, along with the overburden, to get to the coal; (2) the overburden is often moved to a nearby valley, where it impacts existing vegetation and hydrology; and (3) the original forested area that was mined is often reclaimed to wildlife habitat, usually by planting grasses or forbs rather than regenerating back to forest cover.

So much forest land was impacted by disturbances that by 1908 an estimated 86 percent of the acreage in the Southern Appalachian Mountains (an area composed of northern Georgia, northern Alabama, eastern Tennessee, western North Carolina, eastern Kentucky, and southwestern Virginia) was classified as recently harvested or in young regrowth stages of development (Yarnell 1998). Also common during this period of intensive forest use were wildfires associated with the extraction of timber and flood events that resulted in widespread erosion on landscapes lacking vegetation (Yarnell 1998).

These disturbances shaped the structure and composition of the Appalachian-Cumberland forests. Another disturbance, however, that substantially affected forests was the loss of the American chestnut during the early part of the 20th century. The chestnut blight fungus (*Cryphonectria parasitica*) was introduced around 1901; by 1930, most of the American chestnut had disappeared. This keystone species—which fed, housed, and supported people and animals and was a dominant species in the canopy—is estimated to have occupied as much as 25 percent of the hardwood canopy cover in the forests of the Eastern United States (USDA Forest Service, Southern Region 2013). Over time, oaks—including chestnut oak, northern red oak, scarlet oak, and black oak—replaced the dominant position once held by the American chestnut.

Following the early years of land degradation, the intense cutting at the turn of the 20th century generally resulted in successful regeneration for most places. But in areas of less intensive cutting, high grading became the common practice. These partial harvests reduced the vigor of the forest over time, resulting in inadequate regeneration and the release of the inferior trees that were not worth harvesting. This multitude of interacting disturbances that essentially occurred within a period of decades shaped the present-day Appalachian-Cumberland forests. They are predominately even-aged hardwoods, more specifically mixed hardwoods, of which oak species are a prominent component. Forests went from periods where their use was primarily driven by subsistence living to periods of widespread exploitation of their vast resources to the current period of multiple uses including timber management, nontimber forest products, recreation, watershed management, and wildlife habitat.

CHAPTER 2.

Changes in the Physical Environment

CLIMATE

Blue Ridge Mountains

The average annual precipitation in the Blue Ridge Mountains section ranges from 1105 to 1928 mm, generally increasing with elevation. Locations in the southern part of the section receive up to about 2200 mm, one of the highest levels in the Eastern United States. Maximum precipitation occurs in midwinter and midsummer, and minimum precipitation occurs in early autumn. Snow and ice are common forms of winter precipitation, particularly at high elevations. The average annual temperature ranges from 11 °C to 15 °C, increasing to the south. Potential evapotranspiration averages 1954 mm and ranges from 1743 to 2127 mm. The growing season averages from 135 to 235 days (U.S. Department of Agriculture Natural Resources Conservation Service 2006). Aspect significantly affects the type and vigor of the plant communities. Southern and western facing slopes are warmer and drier than northern and eastern facing slopes and slopes shaded by higher mountains (U.S. Department of Agriculture Natural Resources Conservation Service 2006).

Interior Low Plateau

Average annual precipitation ranges from 1040 to 1600 mm, with the northeastern area receiving the least amount of annual rainfall and the Highland rim receiving the most. Maximum precipitation occurs in midwinter and early spring, and minimum precipitation occurs in early autumn. Rainfall mostly occurs as high-intensity, convective thunderstorms. Snow and ice are common forms of winter precipitation, but are variable in frequency and intensity. Snowfall is common in northern areas and fairly uncommon in the Nashville basin. The average annual temperature ranges from 11 °C to 16 °C. The growing season averages 210 days and ranges from 190 to 230 days (U.S. Department of Agriculture Natural Resources Conservation Service 2006).

Northern Ridge and Valley

The average annual precipitation in the Northern Ridge and Valley section ranges from 963 to 1210 mm, increasing to the southwest into Tennessee. The section receives, on average, less precipitation than its neighbors, attributable to a rain shadow produced by its northeast and southwest trending ridges. Maximum precipitation occurs in midwinter and midsummer, and minimum precipitation occurs in early autumn. Most of the rainfall occurs as high-intensity, convective thunderstorms. Snow and ice are common forms of winter precipitation. The average annual temperature ranges from 9 °C to 14 °C, increasing to the south. Potential evapotranspiration averages 1854 mm, and ranges from 1643 to 2046 mm, highest in the summer months and increasing to the southwest. The growing season averages from 150 to 210 days (McNab and Avers 1994)—longest in the south and shortest at high elevations and at the northern edge.

Southern Ridge and Valley

The average annual precipitation in the Southern Ridge and Valley section ranges from 1134 to 1424 mm, increasing to the southwest. Aspect significantly affects the type and vigor of the plant communities. Southern and western facing slopes are warmer and drier than northern and eastern facing slopes and slopes shaded by higher mountains (U.S. Department of Agriculture Natural Resources Conservation Service 2006). Maximum precipitation occurs in midwinter and midsummer, and minimum precipitation occurs in early autumn. Most of the rainfall occurs as high-intensity, convective thunderstorms. Snow may occur in the winter, especially at higher elevations. The average annual temperature ranges from 13 °C to 15 °C, increasing to the south. Potential evapotranspiration averages 2071 mm, and ranges from 1931 to 2144 mm. It is highest in the summer months and increases to the southwest. The growing season averages from 170 to 210 days (McNab and Avers 1994)—longest in the southern part of the section and shortest at high elevations and at the northern edge.

Cumberland Plateau and Mountains

The average annual precipitation in the Cumberland Plateau and Mountains section ranges from 1116 to 1501 mm, increasing with elevation. It can be as much as 1905 mm in the Cumberland Mountains (U.S. Department of Agriculture Natural Resources Conservation Service 2006). Almost half of the annual precipitation falls during the growing season, with rainfall occurring as high-intensity, convective thunderstorms during summer (U.S. Department of Agriculture Natural Resources Conservation Service 2006). Snow occurs in the winter, particularly at higher elevations. The average annual temperature ranges from 12 °C to 15 °C. Potential evapotranspiration averages 1983 mm, and ranges from 1780 to 2175 mm. The growing season averages 200 days and can range from 170 to 225 days.

CLIMATE CHANGE FORECASTS

Climate was projected under two emissions storylines developed by the Intergovernmental Panel on Climate Change (2007b). The A1B storyline is characterized by low population growth, high energy use, and economic growth. The B2 storyline is characterized by moderate population growth, energy use, and economic growth. These storylines represent two levels of global carbon dioxide emissions by 2100 (Intergovernmental Panel on Climate Change 2007a, Solomon and others 2007): 60 Gt of carbon-dioxide equivalents in the A1B storyline, resulting in an atmospheric concentration of about 700 parts per million; and 65 Gt of carbon-dioxide equivalents in the B2 storyline, resulting in an atmospheric concentration of about 600 parts per million. They were combined with four general circulation models to form four Cornerstone Futures—(A) MIROC3.2+A1B, (B) CSIROMK3.5+A1B, (C) CSIROMK2+B2, and (D) HadCM3+B2—each of which compared forecasts of the next 50 years (2010 to 2060) in decadal increments with 10-year historical (1997 to 2006) averages (Wear and others 2013).

Cornerstone A

Characterized by high population growth and high energy use/economic growth (MIROC3.2+A1B), Cornerstone A forecasts the Appalachian-Cumberland highland to be dry and hot when compared to historical trends (table 1). Surface temperature is expected to increase slowly and steadily, albeit with some variability (fig. 14). By 2060, average annual temperature is predicted to be an average of 3.4 °C higher than the historical average (table 1), with the largest increases occurring in the Northern Ridge and Valley (28 percent), Interior Low Plateau (27 percent), and Cumberland Plateau and Mountains (26 percent) sections. Although predicted trends in precipitation are more variable than temperature (fig. 14), all five Appalachian-Cumberland sections are

Table 1—Historical (1997 to 2006) trends in average annual precipitation and temperature by section in the U.S. Appalachian-Cumberland highland

Section	Average annual precipitation (mm)	Average annual temperature (°C)
Blue Ridge Mountains	1409	12.6
Northern Ridge and Valley	1095	11.8
Southern Ridge and Valley	1285	14.1
Cumberland Plateau and Mountains	1263	13.2
Interior Low Plateau	1291	14.0

expected to experience significant reductions in average annual precipitation with some of the largest reductions occurring in the Interior Low Plateau and Northern Ridge and Valley sections.

Cornerstone B

Characterized by high population growth and high energy-use/economic-growth (CSIROM-K3.5+A1B), Cornerstone B forecasts the Appalachian-Cumberland highland to be relatively wet and warm when compared to historical trends (table 1). Surface temperature is expected to increase slowly and steadily, albeit with some variability (fig. 15). By 2060, average annual temperature is predicted to be an average of 1.6 °C higher than the historical average (table 1), with the largest increases occurring in the Northern Ridge and Valley (16 percent), Interior Low Plateau (13 percent), and the Cumberland Plateau and Mountains (13 percent) sections. Although predicted trends in precipitation are more variable than temperature (fig. 15), all five sections are forecasted to either approximate or be wetter than the historical average with the Blue Ridge Mountains section experiencing some of the largest increases. All sections, with the exception of the Blue Ridge Mountains, are still expected to experience periods of decreased precipitation; however, these decreases are expected to be smaller than under Cornerstone A.

Cornerstone C

Characterized by low population/income-growth and energy use (CSIROMK2+B2), Cornerstone C forecasts the Appalachian-Cumberland highland to be moderate and warm when compared to historical trends (table 1). Surface temperature is expected to increase slowly and steadily, albeit with some variability (fig. 16). By 2060, average annual temperature is predicted to be an average of 2.5 °C higher than the historical average (table 1), with the largest increases occurring in the Northern Ridge and Valley (15 percent),

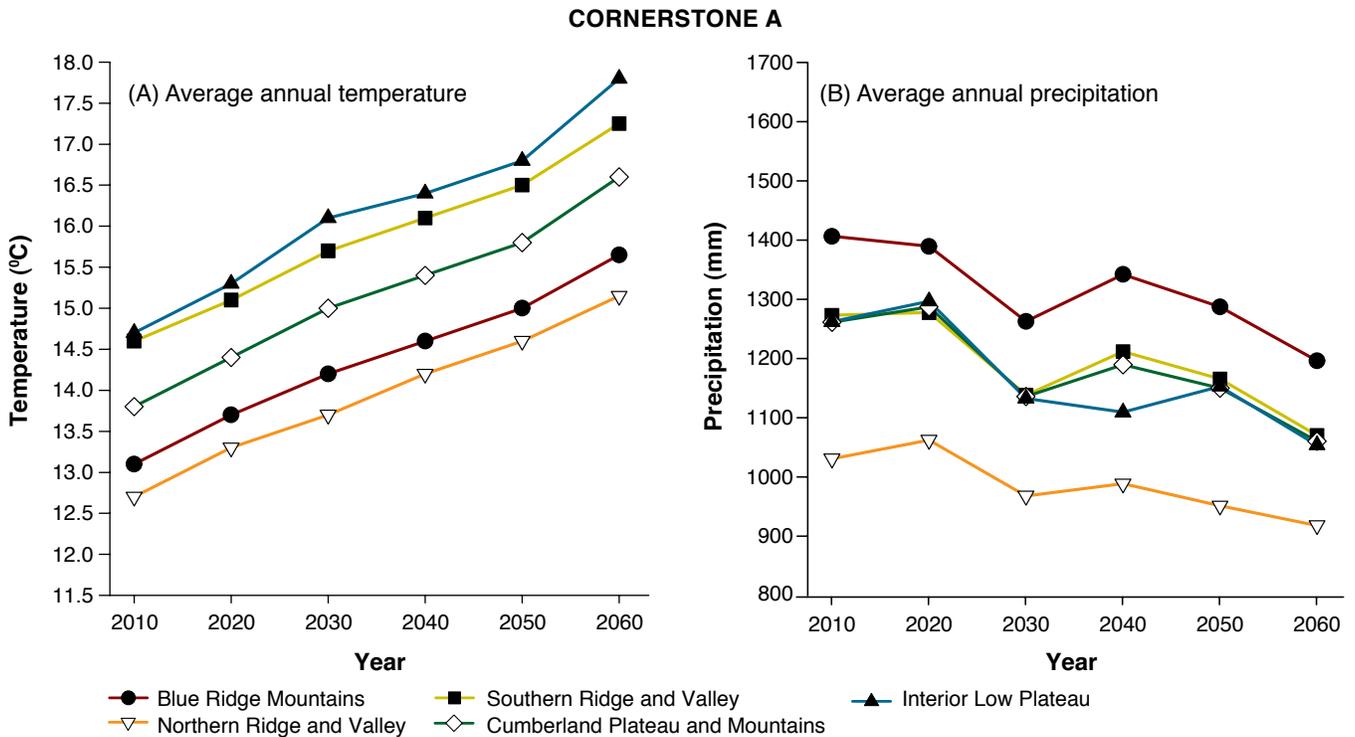


Figure 14—Climate changes, 2010 to 2060, under Cornerstone A for the five sections of the U.S. Appalachian-Cumberland highland—(A) average annual temperature and (B) average annual precipitation; each of the four primary Cornerstone Futures represents a general circulation model (MIROC3.2, CSIROMK3.5, CSIROMK2, or HadCM3) paired with one of two emission scenarios (A1B representing low-population/high-economic growth, high energy use; B2 representing moderate growth and use). Cornerstone A is MIROC3.2+A1B (McNulty and others 2013).

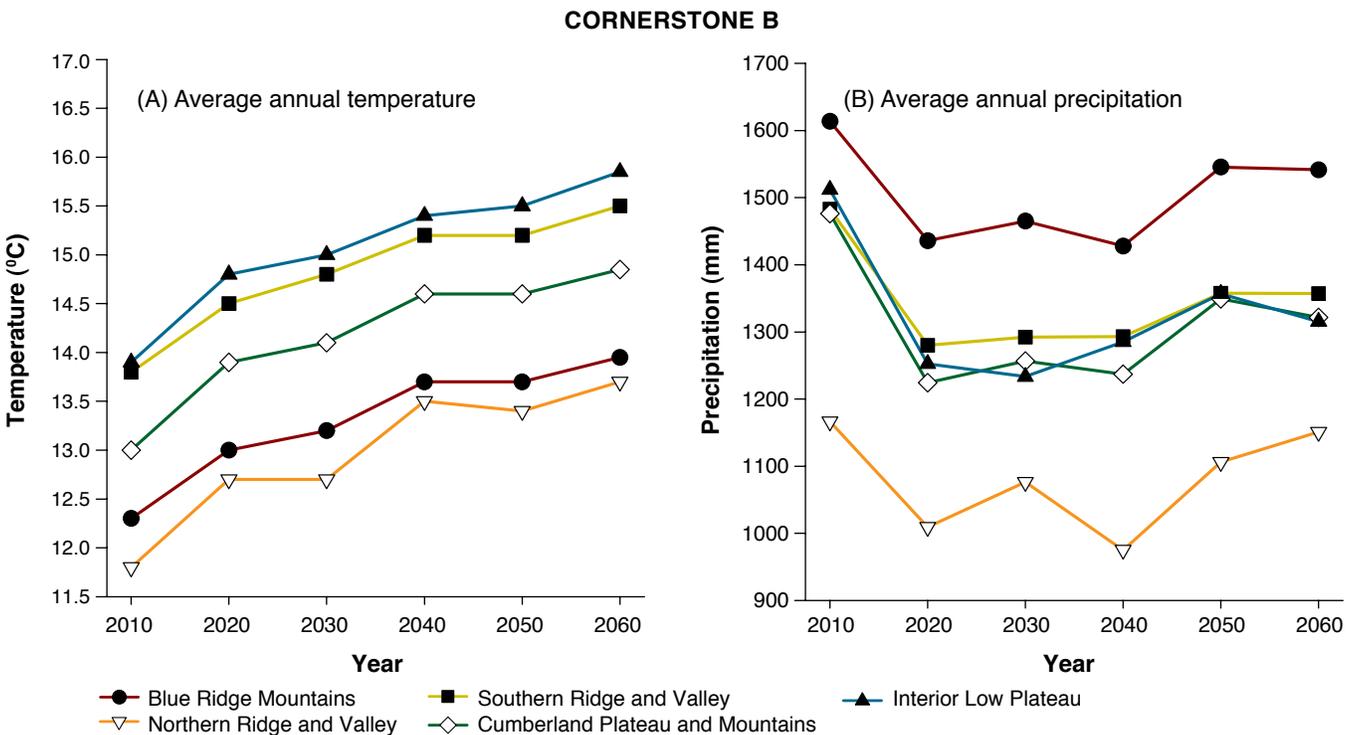


Figure 15—Climate changes, 2010 to 2060, under Cornerstone B for the five sections of the U.S. Appalachian-Cumberland highland—(A) average annual temperature and (B) average annual precipitation; each of the four primary Cornerstone Futures represents a general circulation model (MIROC3.2, CSIROMK3.5, CSIROMK2, or HadCM3) paired with one of two emission scenarios (A1B representing low-population/high-economic growth, high energy use; B2 representing moderate growth and use). Cornerstone B is CSIROMK3.5+A1B (McNulty and others 2013).

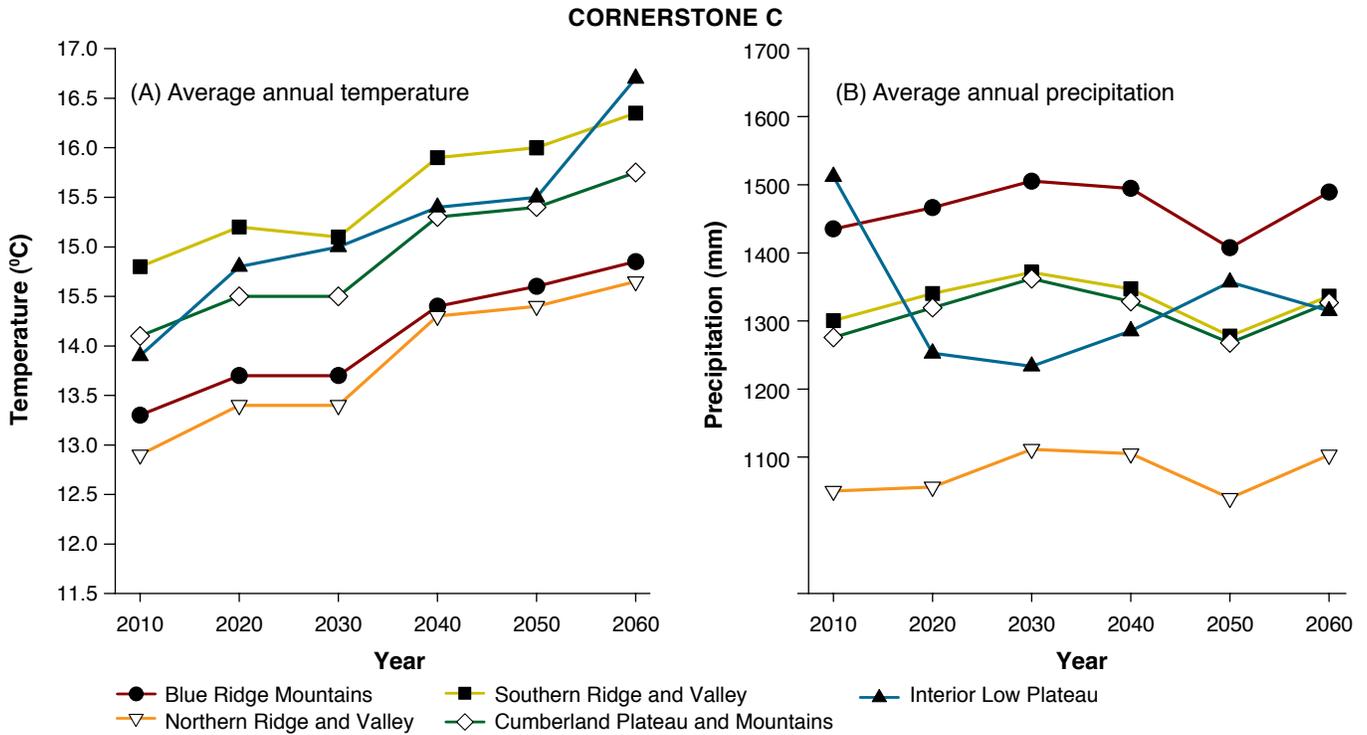


Figure 16—Climate changes, 2010 to 2060, under Cornerstone C for the five sections of the U.S. Appalachian-Cumberland highland—(A) average annual temperature and (B) average annual precipitation; each of the four primary Cornerstone Futures represents a general circulation model (MIROC3.2, CSIROMK3.5, CSIROMK2, or HadCM3) paired with one of two emission scenarios (A1B representing low-population/high-economic growth, high energy use; B2 representing moderate growth and use). Cornerstone C is CSIROMK2+B2 (McNulty and others 2013).

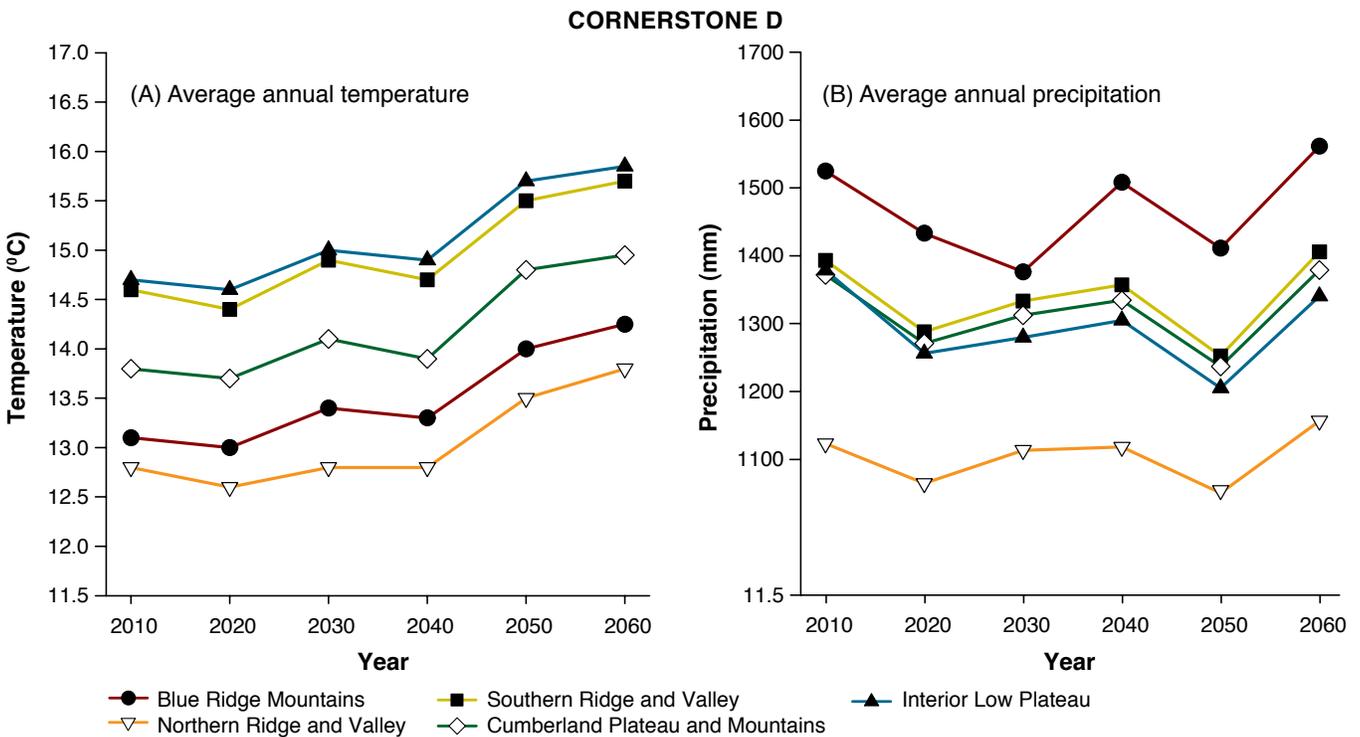


Figure 17—Climate changes, 2010 to 2060, under Cornerstone D for the five sections of the U.S. Appalachian-Cumberland highland—(A) average annual temperature and (B) average annual precipitation; each of the four primary Cornerstone Futures represents a general circulation model (MIROC3.2, CSIROMK3.5, CSIROMK2, or HadCM3) paired with one of two emission scenarios (A1B representing low-population/high-economic growth, high energy use; B2 representing moderate growth and use). Cornerstone D is HadCM3+B2 (McNulty and others 2013).

Interior Low Plateau (12 percent), and Cumberland Plateau and Mountains (12 percent) sections. Although the predicted trends in precipitation are more variable than temperature (fig. 16), the Appalachian-Cumberland highland is expected to be slightly wetter than the historical average. Although annual precipitation is likely to fall below the historical average occasionally, no single decadal average is forecasted to be <10 percent of historical precipitation levels.

Cornerstone D

Characterized by low population/income-growth and energy use (HadCM3+B2), Cornerstone D forecasts the Appalachian-Cumberland highland to be moderate and warm when compared to historical trends (table 1). Surface temperature is expected to increase slowly and steadily, albeit with some variability (fig. 17). By 2060, average annual temperature is predicted to be an average of 1.8 °C higher than the historical average (table 1), with large increases occurring in the Northern Ridge and Valley (16 percent), Interior Low Plateau (13 percent), Cumberland Plateau and Mountains (13 percent), Blue Ridge Mountains (13 percent), and Southern Ridge and Valley (12 percent). Although the predicted trends in precipitation are more variable than temperature (fig. 17), the Appalachian-Cumberland highland is expected to be slightly wetter than the historical average. Although annual precipitation is likely to fall below the 10-year historical average occasionally, no single decadal average is forecasted to be <10 percent of historical precipitation levels.

Summary

A gradual change in climate is forecasted to occur under all Cornerstone Futures across the Appalachian-Cumberland highland over the next 50 years compared to the 10-year historical average (1997 to 2006). The forecasted increase in average decadal temperature ranges from 1.6 °C (Cornerstone B) to 3.4 °C (Cornerstone A). The Interior Low Plateau section will likely continue to be the warmest of the five Appalachian-Cumberland sections and the Northern Ridge and Valley section will likely remain the coolest.

Unlike temperature, where a steady increase is forecasted regardless of Cornerstone Future, predictions for precipitation are less consistent. In general, Cornerstone A forecasts the largest change; although high levels of decadal variability are likely, the average decadal precipitation is forecasted to be 8 percent less than the historical average. In comparison, average decadal precipitation under Cornerstones B, C, and D is forecasted to be 2 to 3 percent greater than the historical average.

For a broader discussion of climate in the South, see McNulty and others (2013).

FIRE

Wildfire reports compiled for a State-by-State assessment of wildfire risks in the South (Buckley and others 2006) revealed that the Cumberland Plateau and Mountains section of the Appalachian-Cumberland highland—which includes the eastern parts of Tennessee and Kentucky and several counties in western Virginia—were a primary area of wildfire activity from 1997 to 2002 (fig. 18). Some wildfire activity was reported in the Blue Ridge Mountains, Northern Ridge and Valley, and Southern Ridge and Valley sections; only minor levels were reported in the Interior Low Plateau section.

Figure 19 shows the total acres burned by season for the Appalachian-Cumberland highland. Wildfire activity is lowest in the summer (June through August) and highest in the autumn (September through November), with spring (March through May) providing a secondary peak. The winter wildfire season was largely tied to either an extended autumn wildfire season or an early spring wildfire season.

The use of prescribed burning as a means to meet management objectives is increasing on public lands throughout southern forests. In the Appalachian-Cumberland highland, prescribed burning is used to reduce fuel loads and subsequent wildfire hazard, improve forest health, manage wildlife habitat (including habitat for threatened and endangered species), and meet other ecosystem restoration goals. Limitations on prescribed burning as a forest management tool include safety and liability risks (Achtmeier and others 1998, Wade and Brenner 1995) and smoke management issues (Macie and Hermansen 2002).

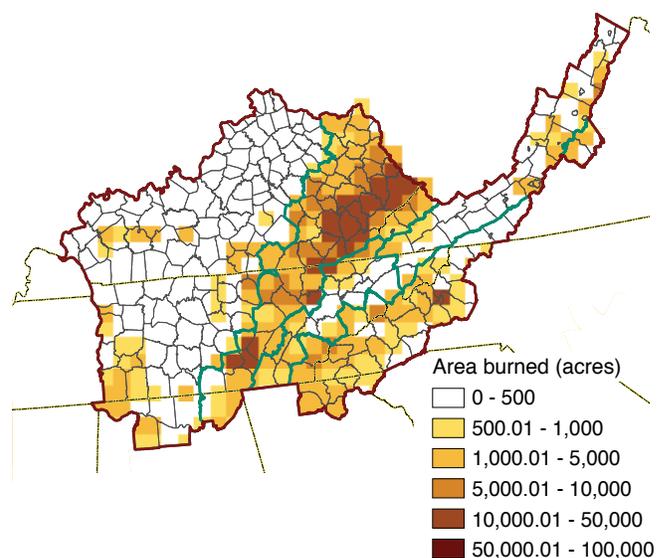


Figure 18—Area burned by wildfires, 1997 to 2002, in the U.S. Appalachian-Cumberland highland; data compiled for a State-by-State assessment of wildfire risks in the South (Buckley and others 2006).

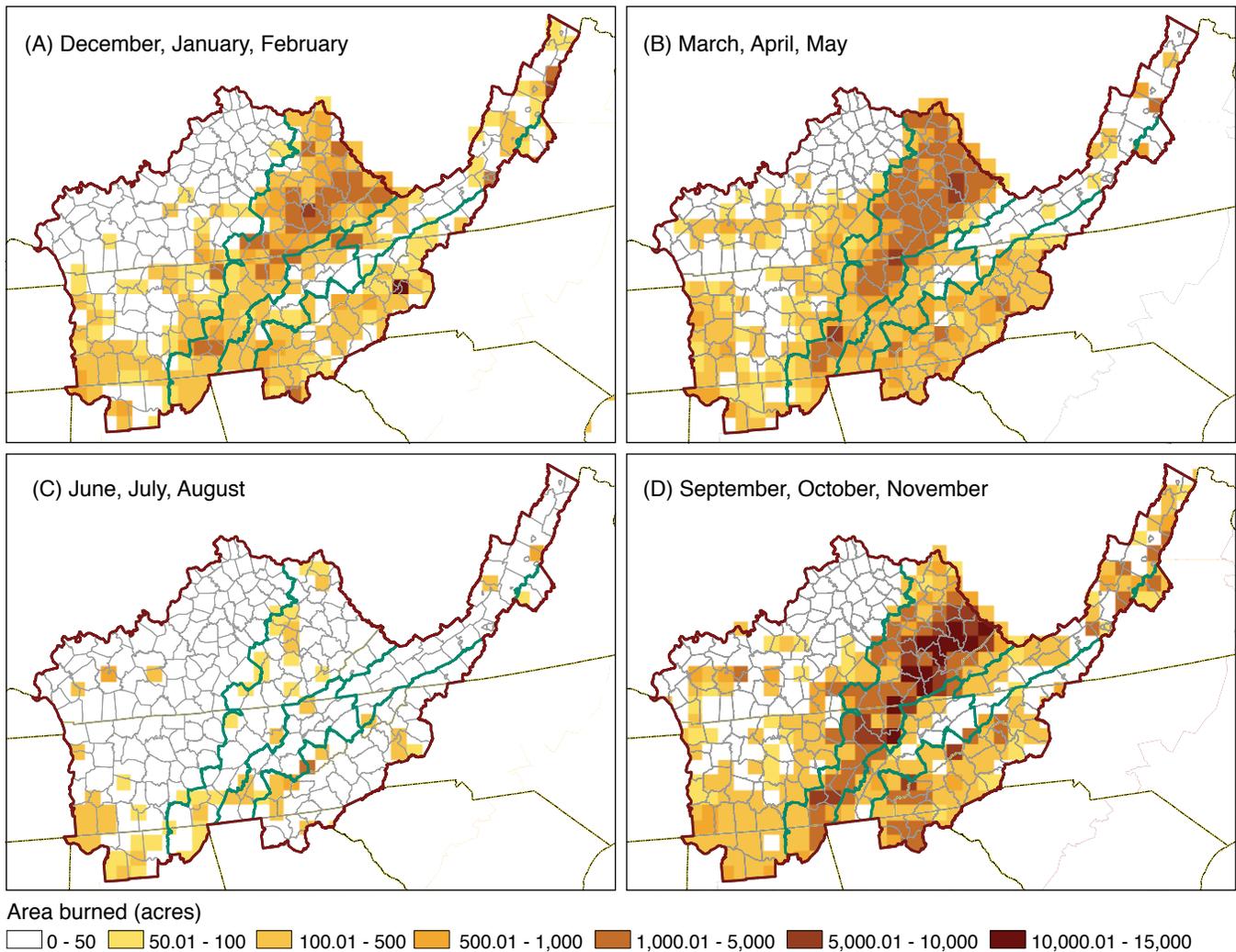


Figure 19—Area burned by wildfire, 1997 to 2002, in the U.S. Appalachian-Cumberland highland during (A) winter months of December through February, (B) spring months of March through May, (C) summer months of June through August, and (D) autumn months of September through November; data compiled for a State-by-State assessment of wildfire risks in the South (Buckley and others 2006).

General Outlook for Wildfire Risk

Under the future conditions forecasted by the four Cornerstone Futures (A through D), fire would continue to have a substantial role in the ecology and management of southern forests throughout the Appalachian-Cumberland highland. Wildfire will likely continue to threaten life and property, but would be exacerbated by continued population growth, associated expansion of the wildland-urban interface, and climate change. As is true for the rest of the Central Hardwood region of the United States (Guyette and Spetich 2003), humans are the main factor influencing the frequency of wildfire ignitions in the Appalachian-Cumberland highland.

As population increases in and around forested landscapes (especially in the wildland-urban interface) and as recreation

pressure increases, wildfire ignitions generally increase (Romero-Calcerrada and others 2008). Given this association between population and wildfire starts, the forecasted increase in population and urbanization-driven changes in land use (chapter 3) along with increased recreation pressure (chapter 5) on forests would mean that fire suppression, active management to reduce wildfire risk and hazard (hazardous fuels reduction projects), and public outreach and education (establishing safe zones around private property in the wildland-urban interface) will continue to be immediate concerns for land managers.

As population growth and urbanization increases the issues, surrounding wildfire risk and the use of prescribed burning in and around populated areas to achieve a multitude of forest management objectives—including hazardous fuels reduction—should be expected to increase.

Stanturf and Goodrick (2013) simulated wildfire hazard for 2010 and developed projections through 2060 under Cornerstone Futures A through D, using a potential drought index (PDI). For a complete explanation of PDI, we refer readers to the fire chapter of the Southern Forest Futures technical report (Stanturf and Goodrick 2013). Readers of this report on the Appalachian-Cumberland highland should be aware that PDI accentuates drought conditions and thus highlights areas of potential increases in wildfire potential. Positive values of the PDI indicate drought conditions, which serve as a surrogate for potential increases in wildfire potential.

Comparing 2010 PDI values under the four Cornerstone Futures (fig. 20) with data on actual acres burned (fig.

18) shows that low annual PDI values do not necessarily correspond to low wildfire potential; for example, the western Appalachian Mountains experienced a high level of acres burned despite having the lowest annual PDI values.

By 2060, despite all Cornerstones predicting drier conditions overall, annual PDI in the Appalachian-Cumberland highland is forecasted to continue at near zero (fig. 21). Cornerstone A depicts the most severe conditions, but little change in PDI is forecasted under Cornerstones B, C, and D. The relatively low PDI values suggest that the potential for wildfire would remain low. However, as noted above, the relationship between annual PDI and acres burned by wildfire in the Cumberland Plateau section is not strong.

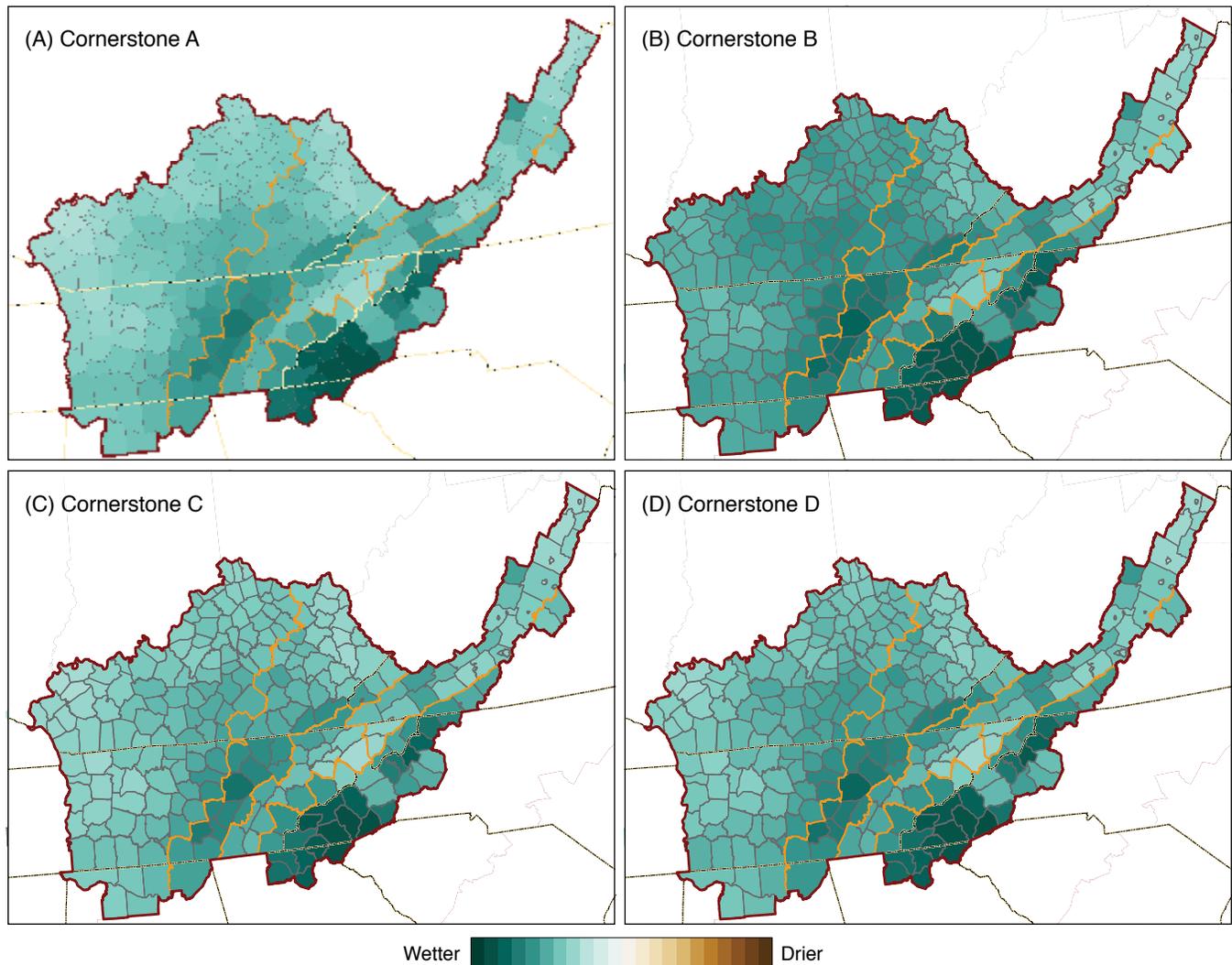


Figure 20—Annual fire potential in the U.S. Appalachian-Cumberland highland for current conditions, 2010, as simulated by Cornerstone Futures A through D; each of the Cornerstone Futures represents a general circulation model—MIROC3.2, CSIROMK3.5, CSIROMK2, or HadCM3—paired with one of two emission scenarios—A1B representing low-population/high-economic growth, high energy use; B2 representing moderate growth and use: (A) MIROC3.2+A1B, (B) CSIROMK3.5+A1B, (C) CSIROMK2+B2, and (D) HadCM3+B2 (McNulty and others 2013).

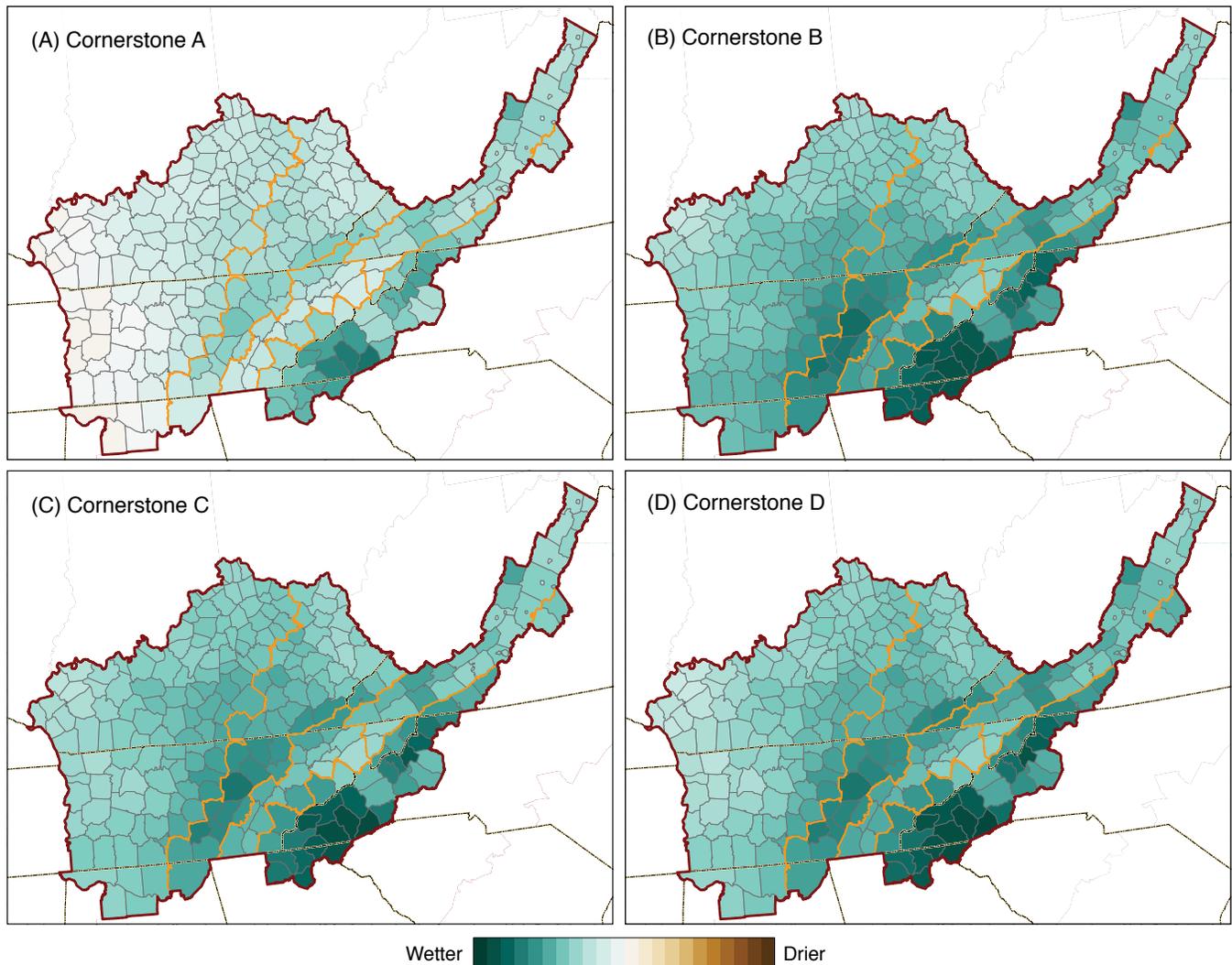


Figure 21—Predicted annual fire potential in the U.S. Appalachian-Cumberland highland, 2060, under Cornerstone Futures A through D; each of the Cornerstone Futures represents a general circulation model—MIROC3.2, CSIROMK3.5, CSIROMK2, or HadCM3—paired with one of two emission scenarios—A1B representing low-population/high-economic growth, high energy use; B2 representing moderate growth and use; (A) MIROC3.2+A1B, (B) CSIROMK3.5+A1B, (C) CSIROMK2+B2, and (D) HadCM3+B2 (McNulty and others 2013).

Seasonality of Wildfire in a Changing Climate

Examining forecasted PDI by season suggests only slight changes over the next 50 years. Cornerstone A forecasts the largest increase in dryness, as indicated by an increase in PDI. By 2060, this cornerstone predicts substantial drying across the Appalachian-Cumberland highland, with the largest increase in PDI occurring in the summer months (fig. 22). By 2060, substantial drying is expected across the Appalachian-Cumberland highland, with the largest increase in PDI occurring in the summer months. This increase in PDI during the summer months could result in prolonged spring and earlier autumn wildfire seasons.

Cornerstone B forecasts more subtle changes in PDI over the next 50 years, the result being longer drying periods in winter and summer months (fig. 23). This could translate into a more active winter wildfire season, an earlier onset of the spring wildfire season, or both. Given the majority of prescribed burning in the Appalachian-Cumberland highland is conducted during the dormant season, wintertime drying could result in escaped prescribed fires, thereby reducing the usefulness of the practice. The change in the PDI during the autumn wildfire season, which is predicted to be slightly lower than under Cornerstone A, could shorten the autumn wildfire season.

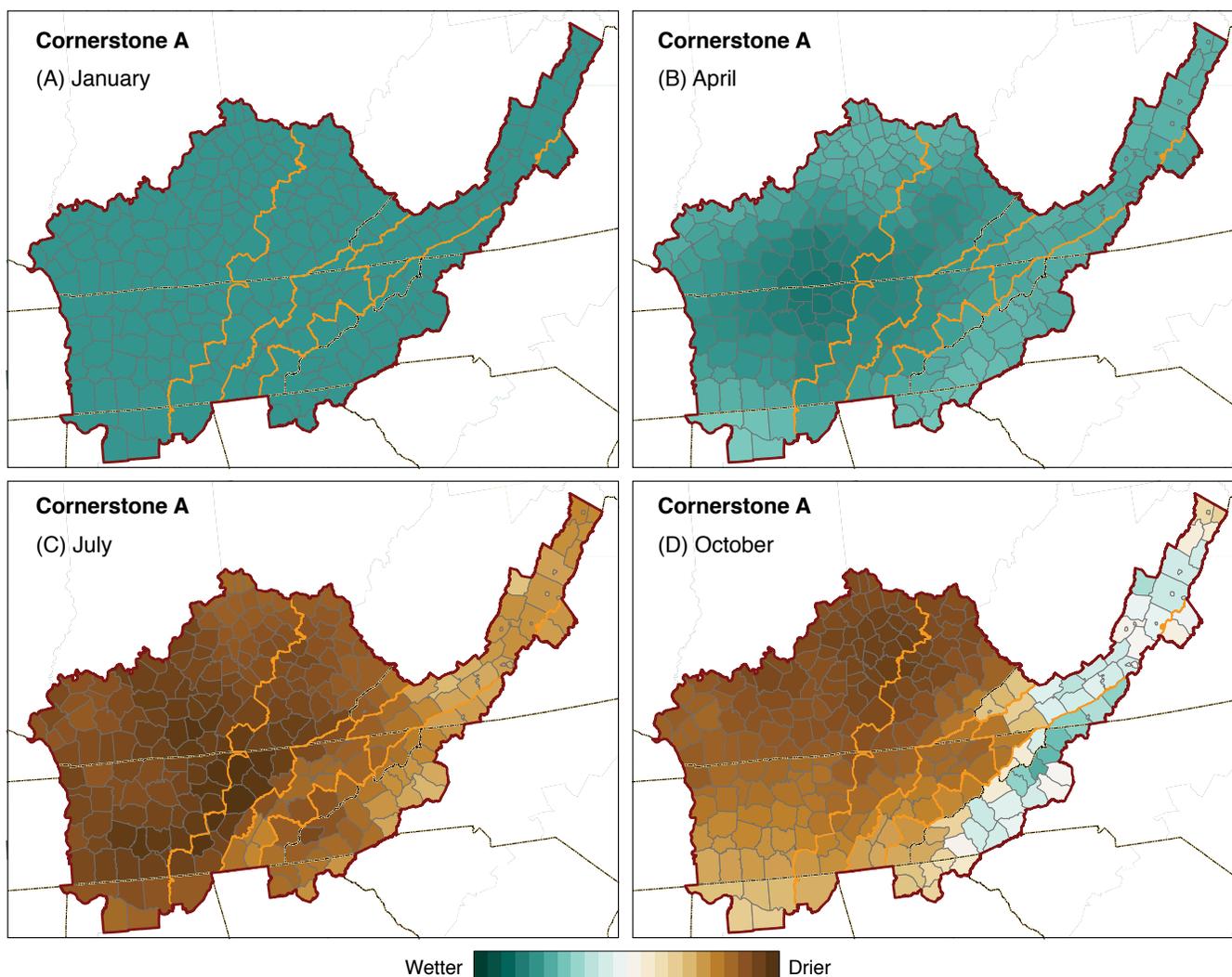


Figure 22—Seasonal fire potential, 2060, predicted under Cornerstone A for the U.S. Appalachian-Cumberland highland during (A) January, (B) April, (C) July, and (D) October; each of the four primary Cornerstone Futures represents a general circulation model (MIROC3.2, CSIROMK3.5, CSIROMK2, or HadCM3) paired with one of two emission scenarios (A1B representing low-population/high-economic growth, high energy use; B2 representing moderate growth and use). Cornerstone A is MIROC3.2+A1B (McNulty and others 2013).

Across the South, Cornerstones C and D predictions are only slightly different from Cornerstone B in terms of seasonality of wildfire. The gradual transition from winter rainy season to summer dry season in Cornerstone B is largely erased, which brings the 2060 conditions into much closer alignment with Cornerstone C and D.

Outlook for Prescribed Burning

Increasing urbanization and fragmentation are expected to be of concern for prescribed burning and smoke management across the Southern United States. These concerns apply to the Appalachian-Cumberland highland as well. An extended wildfire season would magnify the importance of effective

fuels management. However the same drying that could extend the wildfire season could also limit the ability to use prescribed fire. Forecasted increases in dryness could shorten burn windows, increase the potential for escaped fires, and/or have more severe fire effects than intended.

The challenges surrounding prescribed burning—threat of escape, smoke management, and air quality—will likely continue. These issues are expected to increase as populations and transportation systems continue to grow and spread out across the Appalachian-Cumberland highland. Some States—Alabama, Kentucky, North Carolina, and Virginia—have passed laws to address prescribed fire liability related to escaped prescribed burns.

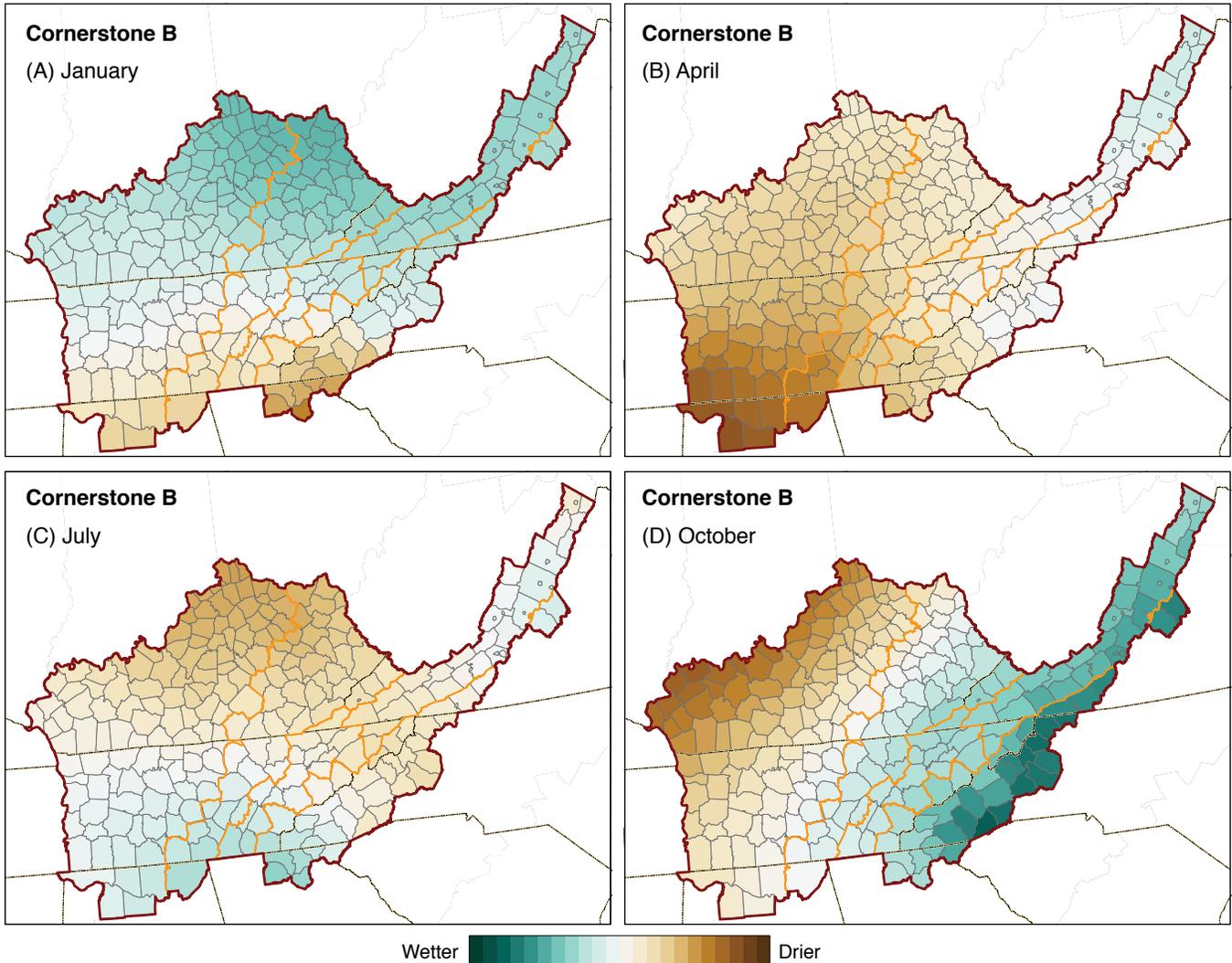


Figure 23—Seasonal fire potential, 2060, predicted under Cornerstone B for the U.S. Appalachian-Cumberland highland during (A) January, (B) April, (C) July, and (D) October; each of the four primary Cornerstone Futures represents a general circulation model (MIROC3.2, CSIROMK3.5, CSIROMK2, or HadCM3) paired with one of two emission scenarios (A1B representing low-population/high-economic growth, high energy use; B2 representing moderate growth and use). Cornerstone B is CSIROMK3.5+A1B (McNulty and others 2013).

Summary

Over the long-term and factoring in the effects of climate change, prescribed burning programs will likely grow, at the same time that urbanization and fragmentation of the forests are increasing. The complexity and cost of prescribed burning are expected to increase as these factors become more pronounced. Restrictions on the use of prescribed burning to manage fuels would exacerbate potential climate change effects, particularly in the western Appalachian Mountains where wildfire potential is expected to increase. Fuel buildups combined with more intense wildfires under a changed climate potentially would have drastic consequences for fire-dependent or fire-adapted forest communities.

Wildfire activity in the southern Appalachian Mountains is lowest in the summer and highest in the autumn, with spring providing a secondary peak. Winter wildfire activity is more than in the summer, but is largely tied to either an extended autumn wildfire season or an early spring season. Cornerstone A represents the highest degree of change over the next 50 years, with much more drying expected, particularly in the summer and autumn months. Cornerstone B is closer to current conditions. Under this cornerstone, the western Appalachian Mountains would experience drier summers, resulting in a prolonged spring and earlier autumn wildfire season.

For a broader discussion of wildfire in the South, see Stanturf and Goodrick (2013).

CHAPTER 3.

The Human Footprint

POPULATION, DEMOGRAPHY, AND ECONOMIC ACTIVITY

From 1990 to 2008, the South grew considerably faster (32.5 percent) than the U.S. average of 22.2 percent (table 2), with all demographic groups experiencing an increase in growth. The South is one of the two regions that outpaced the national rate for all race/ethnic groups.

All Appalachian-Cumberland sections experienced increases in population, income per capita, and gross regional product from 1970 to 2000. Although the sections had similar average income per capita, they varied substantially in population and gross regional product, with the Interior Low Plateau section highest in both metrics. In 2000 income per capita (in 2004 dollars) in the Appalachian-Cumberland highland averaged \$25,388 compared to \$26,892 for the

other four subregions. Differences in gross regional product were more distinct (likely reflecting inherent differences in the size of the various subregions, with the Appalachian-Cumberland being one of the smallest); the Appalachian-Cumberland averaged \$66,325 million compared to \$157,317 million for the other subregions.

Blue Ridge Mountains

The population, income per capita, and gross regional product increased in the Blue Ridge Mountains section from 1970 to 2000 (fig. 24). By 2000, the population was 1.3 million, with the largest increase reported in the counties closest to Asheville, NC. Income per capita (in 2004 dollars) increased about \$5,000 for every 10 years from 1980 to 2000, reaching \$24,561.25 by 2000. Gross regional product increased from 1970 to 2000, approximating \$31.3 billion by 2000.

Table 2—U.S. population in 2008 by race/ethnicity and region with increase (or decrease) since 1990

Race/ethnicity	North		South		Rocky Mountains		Pacific Coast		United States	
	Million persons	Percent increase (decrease)								
Caucasian	92.2	(0.2)	63.5	14.0	19.5	25.3	24.3	(1.4)	199.5	5.9
African American	14.8	18.7	18.9	35.4	0.9	69.4	2.6	8.9	37.2	26.8
American Indian	0.4	23.2	0.7	36.4	0.8	38.3	0.4	13.7	2.3	29.6
Asian/Pacific Islander	4.7	116.4	2.5	170.6	0.7	171.1	5.8	59.0	13.7	95.4
Two or more ^a	1.5	–	1.3	–	0.4	–	1.3	–	4.5	–
Hispanic ^b	10.8	94.6	16.0	143.2	5.5	157.8	14.7	80.4	46.9	109.8
Total	124.4	10.1	102.8	32.5	27.8	46.0	49.1	25.2	304.1	22.2

^aPercent change for two or more races is missing because U.S. citizens could not select more than one race until 2000.

^bHispanics of any race are included in this category.

Source: U.S. Census Bureau (1990, 2008a).

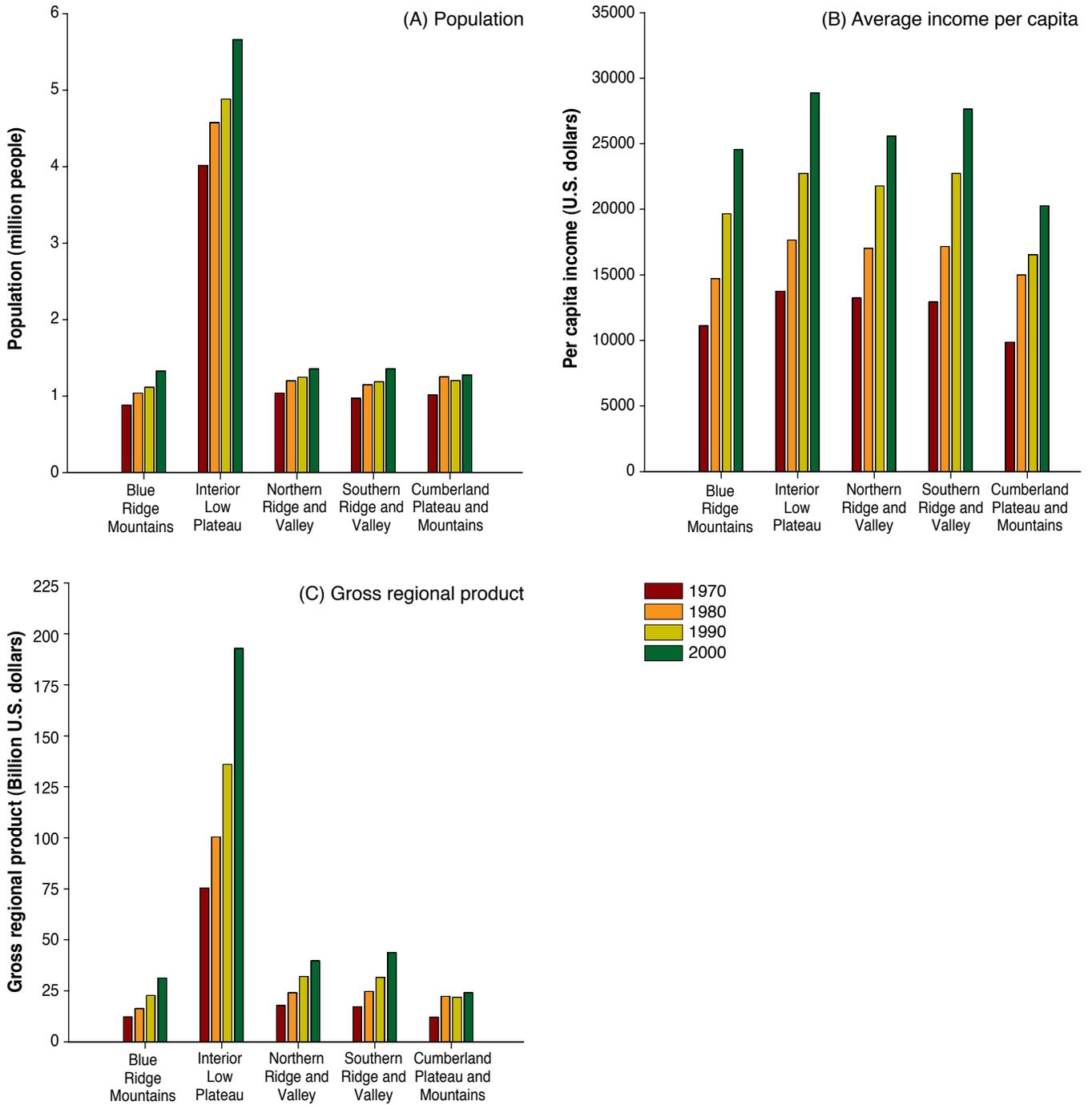


Figure 24—From 1970 to 2000, demographic changes by section of the U.S. Appalachian-Cumberland highland: (A) population, (B) average income per capita, and (C) gross regional product.

Interior Low Plateau

The population, income per capita, and gross regional product increased in the Interior Low Plateau section from 1970 to 2000 (fig. 24). By 2000, the population was 5.7 million. Income per capita (in 2004 dollars) increased about \$5,000 for every 10 years from 1980 to 2000, reaching \$28,883 by 2000. From 1970 to 2000, the gross regional product increased from 75.3 billion to \$192.8 billion.

Northern Ridge and Valley

The population, income per capita, and gross regional product increased in the Northern Ridge and Valley section from 1970 to 2000 (fig. 24). By 2000, the population was 1.3 million, with the largest increase reported in the counties closest to metropolitan Washington, Roanoke, VA, and Knoxville, TN. Income per capita (in 2004 dollars) increased about \$4,000 for every 10 years, reaching \$25,590 by 2000. Gross regional product increased steadily from 1970 to 2000, approximating \$39.7 billion by 2000.

Southern Ridge and Valley

The population, income per capita, and gross regional product increased in the Southern Ridge and Valley section from 1970 to 2000 (fig. 24). By 2000, the population was 1.4 million, with the largest increase reported in the counties closest to the Tennessee cities of Johnson City, Bristol, Kingsport, and Knoxville. Income per capita (in 2004 dollars) steadily increased as well, by about \$5,000 for every 10 years, reaching \$27,639 by 2000. Gross regional product increased from 1970 to 2000, approximating \$43.7 billion by 2000.

Cumberland Plateau and Mountains

By 2000, the population of the section was 1.3 million (fig. 24), with the largest increase reported in Laurel County, KY; conversely, Harlan County, KY, experienced one of the largest decreases in population over 30 years in the entire Appalachian-Cumberland highland. Income per capita (in 2004 dollars) increased by \$6,800 from 1970 to 1980 (fig. 24) but only by \$1,500 from 1980 to 1990; by 2000 it reached \$20,265. Gross regional product fluctuated from 1970 to 2000 (fig. 24), with minor increases observed from 1970 to 1980 followed by a slight increase from 1980 to 1990. By 2000, gross regional product approximated \$24.1 billion.

THE SHIFTING SOCIETAL LANDSCAPE

With moderate growth, the total population of the United States is expected to increase by >47 percent, nearly 60 percent for the South (table 3). Of the States with land in the Appalachian-Cumberland highland, only Virginia (62.0 percent) is projected to grow faster than the southwide average. The remaining States—including Alabama (44.6 percent), Georgia (52.9 percent), Kentucky (35.3 percent), North Carolina (55.3 percent), and Tennessee (51.9 percent)—are expected to grow slower than the southwide average. These percentages reflect State totals and have not been scaled to the Appalachian-Cumberland portion of each State.

Figure 25 shows the population density for the Appalachian-Cumberland highland. Population densities are generally highest near current metropolitan areas such as Huntsville (Alabama); Nashville and Knoxville (Tennessee); Bowling Green, Louisville, and Lexington (Kentucky); Cincinnati suburbs (northern Kentucky); Blacksburg and Roanoke (Virginia); and Henderson County, Caldwell County, Burke County, and the city of Asheville (North Carolina).

From 1990 to 2008 (fig. 26), population density growth decreased in some western Virginia and eastern Kentucky counties, while the highest increases in population density growth occurred in northern Alabama and Georgia, the Nashville and Knoxville area in Tennessee, the Lexington-Louisville corridor in Kentucky, greater Cincinnati, several counties in western North Carolina, and the Harrisonburg area in Virginia.

As shown in table 2, about 63 percent of the southern population is Caucasian, about 18 percent is African American, and 16 percent is Hispanic. No other race/ethnic group represents >3 percent of the population: <1 percent for American Indians, ~2 percent for Asian/Pacific Islanders, and about 1 percent for two or more races. From 1990 to 2008, the lowest percentage of increase was for non-Hispanic Caucasians, although the rate of growth for this group was more than double the national rate. The Asian/Pacific Islander population had the highest growth rate (170.6 percent), followed by the Hispanic population (143.2 percent) with growth being especially high in North Carolina and Georgia.

Figure 27 indicates that the Hispanic population grew in all counties of the Appalachian-Cumberland highlands, with the exception of Hancock County in Tennessee, and Buchanan and Bath Counties in Virginia, between 1990 and 2008.

Table 3—Estimated U.S. population (millions of people) for 2008 and projections to 2060 by region and Southern State for three levels of population growth

State(s)	Population (2008)	Projected population (2060)			Increase ^a (percent)
		Low growth	Moderate growth	High growth	
-----million persons-----					
All U.S. States	304.4	397.3	447.3	505.3	47.1
All Pacific Coast States	49.1	67.8	76.3	86.2	55.6
All Rocky Mountain States	27.8	44.1	49.7	56.1	79.0
All Northern States	124.4	139.9	157.6	178.0	26.7
All Southern States	102.8	145.4	163.7	184.9	59.2
Alabama	4.7	6.0	6.7	7.6	44.6
Arkansas	2.9	3.9	4.4	4.9	52.6
Florida	18.3	30.5	34.3	38.8	87.4
Georgia	9.7	13.2	14.8	16.7	52.9
Kentucky	4.3	5.1	5.8	6.5	35.3
Louisiana	4.4	5.3	5.9	6.7	34.5
Mississippi	2.9	3.8	4.3	4.8	44.6
North Carolina	9.2	12.7	14.3	16.2	55.3
Oklahoma	3.6	4.4	5.0	5.7	37.5
South Carolina	4.5	6.3	7.0	8.0	57.3
Tennessee	6.2	8.4	9.4	10.7	51.9
Texas	24.3	34.7	39.1	44.1	60.6
Virginia	7.8	11.2	12.6	14.2	62.0

^aUnder the assumption that growth will be moderate.
Sources: Cordell and others (2013); U.S. Census Bureau (2008a).

Population density by county, 2008
(persons per square mile)

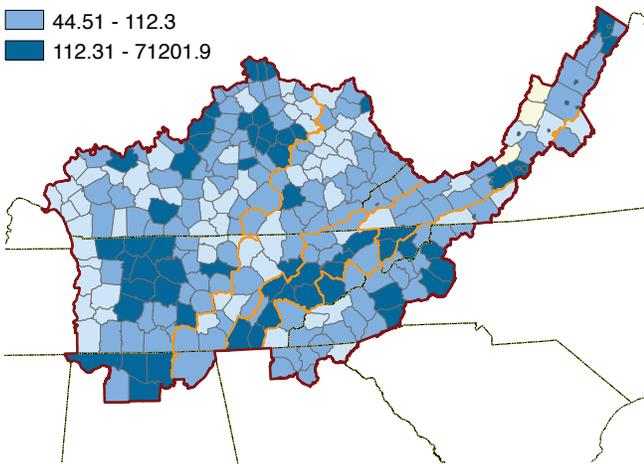
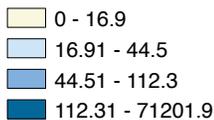


Figure 25—Population density by county, 2008, in the U.S. Appalachian-Cumberland highland (Source: U.S. Census Bureau 2008b).

Population density growth, 1990-2008
(persons per square mile)

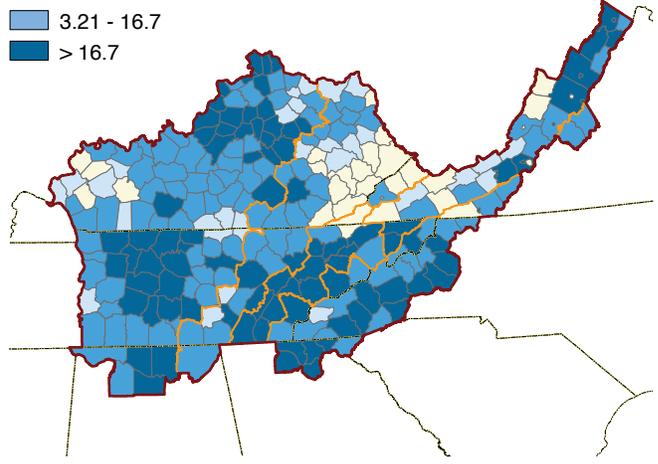
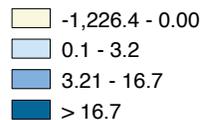


Figure 26—Change in population density by county, 1990 to 2008, in the U.S. Appalachian-Cumberland highland (Source: U.S. Census Bureau 2008b).

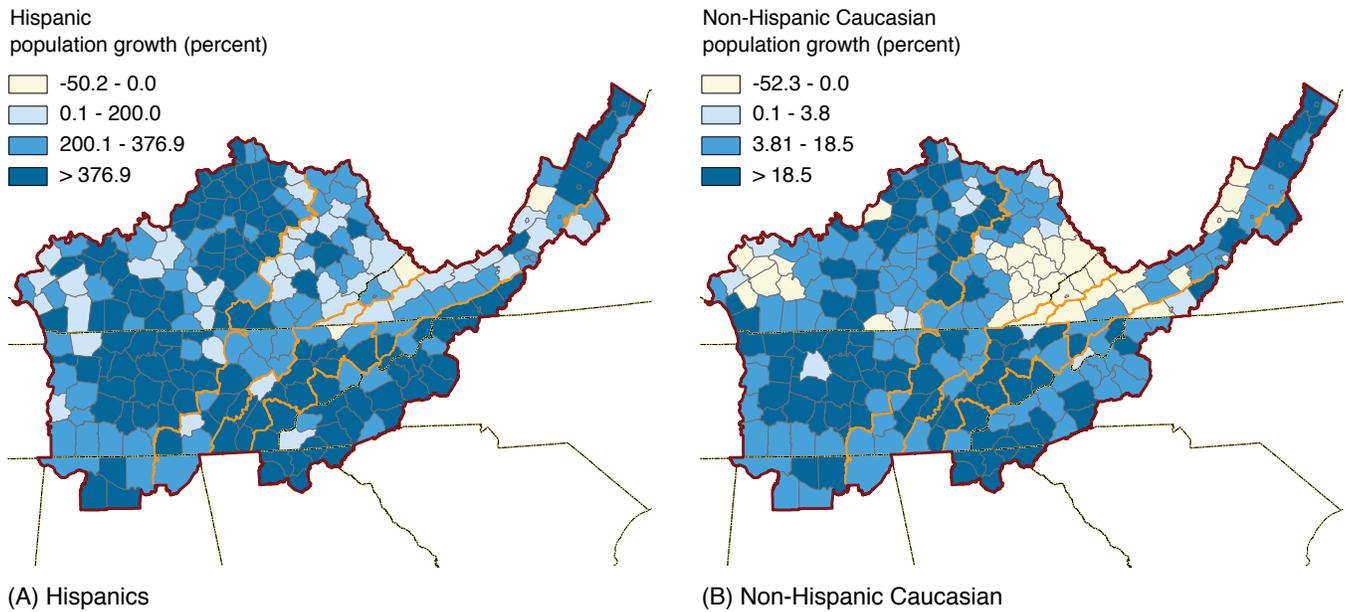


Figure 27—Change in population by county, 1990 to 2008, in the U.S. Appalachian-Cumberland highland for (A) Hispanics and (B) non-Hispanic Caucasians (Source: U.S. Census Bureau 2008b).

Regarding non-Hispanic Caucasian population growth, numerous counties in the Cumberland Plateau and Mountains section of eastern Kentucky and western Virginia saw either decreases or no growth, as did a handful of counties in the Northern Ridge and Valley section of Virginia and the westernmost parts of the Interior Low Plateau section.

Expected patterns of growth (persons per square mile) are depicted in Figure 28. This parameter is described in three ways: under a low growth population projection, a moderate growth population projection, and a high growth population projection from 2008 to 2060. Under the low growth projection, the highest growth is expected in counties and in areas surrounding current urban centers such as Louisville and Lexington in Kentucky; and Nashville, Knoxville, and several northern counties in Tennessee. Counties with lower density growth would be scattered around the Appalachian-Cumberland landscapes, although some would be concentrated in the Northern and Southern Ridge and Valley sections, the Cumberland Plateau and Mountains section, and the western edges of the Interior Low Plateau section.

Under the moderate growth population projection (fig. 28), growth areas would increase most in the counties surrounding Nashville and Knoxville in Tennessee; Louisville, Lexington, and Cincinnati suburbs in Kentucky; and the Asheville area in North Carolina. Again, counties with lower growth in population density would be scattered

around the Appalachian-Cumberland highland, although some would be concentrated in the Northern Ridge and Valley section, the Cumberland Plateau and Mountains, and the western edges of the Interior Low Plateau section.

Under the high growth projection (fig. 28), the special distribution of population density growth would be similar to the moderate growth projection. With high growth, fewer counties would have low expected growth; these would be scattered in the Northern Ridge and Valley and the Interior Low Plateau sections.

Summary

With regard to racial composition, population distribution, and population growth, the South has been and continues to be a very dynamic region of the country. It is characterized by rapid population growth, dramatic changes in demographics, and shifting uses of land and water resources. In the last two decades the South's population grew at a considerably faster rate (over 30 percent) than the U.S. average (just above 20 percent). Over the next 50 years or so, projected growth for the South is expected to be nearly 60 percent, approaching 105 million.

For a broader discussion of demographics in the South, see Cordell and others (2013).

Population density change
(persons per square mile)

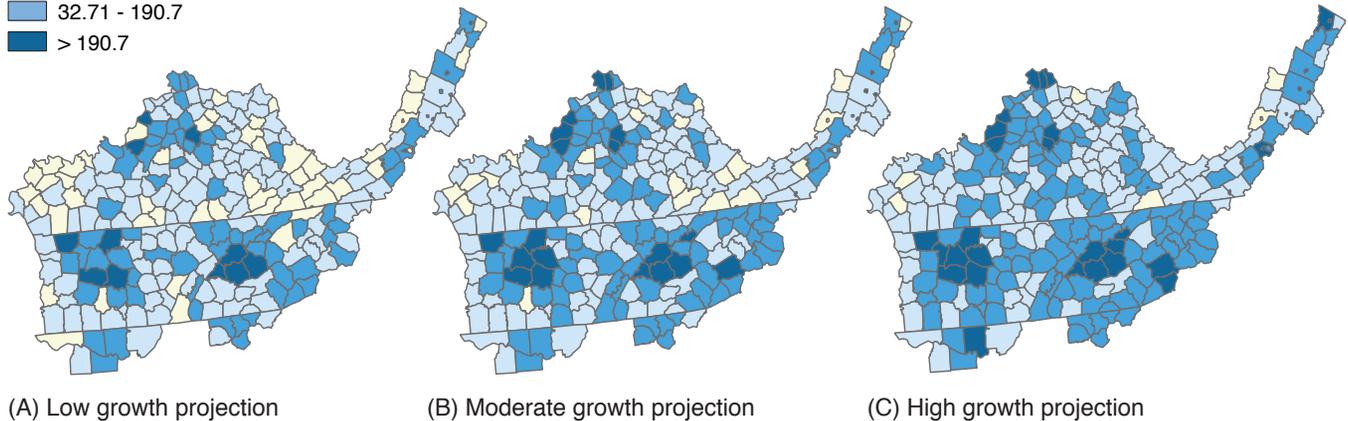
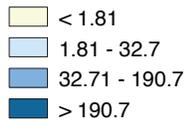


Figure 28—Change in population density by county, 2008 to 2060, in the U.S. Appalachian-Cumberland highland under a (A) low growth projection, (B) moderate growth projection, and (C) high growth projection (Sources: Cordell and others 2011, U.S. Census Bureau 2008b).

For the purposes of this publication, land in the Appalachian-Cumberland highland is classified into four categories that are based on definitions used in by the National Resources Inventory:

Forests—A land cover/use category that is at least 10 percent stocked by single stemmed forest trees—of any size—that will be at least 13 feet tall at maturity. When viewed vertically, canopy cover is ≥ 25 percent. Also included are areas bearing evidence of natural regeneration of tree cover (cutover forest or abandoned farmland) and not currently developed for nonforest use. For classification as forest land, the area must be at least 1 acre and 100 feet wide.

Cropland—A land cover/use category that includes areas used for the production of crops that are adapted for harvest. Two subcategories of cropland are recognized: cultivated and noncultivated. Cultivated cropland is defined as land in row crops or close-grown crops and other types of cultivated cropland, such as hayland or pastureland that is in a rotation with row or close-grown crops. Examples of noncultivated cropland are permanent hayland and horticultural cropland.

Pastureland—A land cover/use category of land managed primarily for the production of introduced or native forage plants for livestock grazing. Pastureland may consist of a single species in a pure stand, a grass mixture, or a grass-legume mixture. Management usually consists of cultural treatments—fertilization, weed control, reseeding, or renovation and control of grazing. (For the National Resources Inventory, this category includes land that has a vegetative cover of grasses, legumes, forbs, or all three—regardless of whether or not it is being grazed by livestock.)

Urban—A land cover/use category consisting of residential, industrial, commercial, and institutional land; construction sites; public administrative sites; railroad yards; cemeteries; airports; golf courses; sanitary landfills; sewage treatment plants; water control structures and spillways; other land used for the purposes described above; small parks (<10 acres) in urban and built-up areas; and highways, railroads, and other transportation facilities if they are surrounded by urban areas. Also included are tracts of <10 acres that do not meet the above definition but are completely surrounded by urban and built-up land. Two size categories are recognized in the National Resources Inventory: areas 0.25 to 10 acres, and areas >10 acres.

LAND USES

Forest land is the dominant land use across all five sections in the Appalachian-Cumberland highland. Land-use patterns and the degree of development across the Appalachian-Cumberland highland are, in part, likely limited by the topography of the landscape, the availability and access to water resources, and the patterns of public and private ownership (Turner and others 1996, Verburg and others 1999). Overall the Appalachian-Cumberland highland has the highest growth rate (on a proportional basis) of urban land use compared to the rest of the South. Fastest growing areas are central-northern Kentucky (an area bordered by Lexington, Louisville, and Cincinnati) and around the Tennessee cities of Nashville and Knoxville.

According to the 1997 National Resources Inventory (fig. 29), the predominant uses of non-Federal land in the sections of Appalachian-Cumberland highland are:

- **Blue Ridge Mountains**—4,312,160 acres in forests (67 percent), 1,041,040 acres in pastureland (16 percent), 386,650 acres in cropland (6 percent), and 682,210 acres urban (11 percent)
- **Interior Low Plateau**—10,309,890 acres in forests (41 percent), 7,158,050 acres in pastureland (28 percent), 6,087,660 acres in cropland (24 percent), and 1,822,280 acres urban (7 percent)
- **Northern Ridge and Valley**—2,283,010 acres in forests (53 percent), 1,404,920 acres in pastureland (27 percent), 601,830 acres in cropland (11 percent), and 471,810 acres urban (9 percent)
- **Southern Ridge and Valley**—1,836,390 acres in forests (52 percent), 916,080 acres in pastureland (26 percent), 321,050 acres in cropland (9 percent), and 456,630 acres urban (13 percent)
- **Cumberland Plateau and Mountains**—8,637,990 acres in forests (76 percent), 1,610,990 acres in pastureland (14 percent), 597,460 acres in cropland (5 percent), and 469,550 acres urban (4 percent)

Forecasts (2010 to 2060)

Urban—Under Cornerstones A and B (high population and economic growth), the forecasted area of non-Federal urban land is expected to increase from the 1997 base of about 3.9 million acres to >10.6 million acres by 2060, an increase of about 172 percent (table 4). The highest percentage of growth is expected to occur in the Interior Low Plateau section (198 percent) followed by the Cumberland Plateau and Mountains section (186 percent).

Under Cornerstones C and D (moderate population and low economic growth), the highest percentage of growth in urban land use (table 5) is expected to occur in the Interior

Low Plateau section (about 131 percent), followed by the Cumberland Plateau and Mountains section (113 percent).

Forest land—In contrast to urban land uses, forest use forecasts for the South depend on timber prices in addition to the drivers of urbanization. Under Cornerstone B (high urbanization and decreasing timber prices), the Appalachian-Cumberland highland is projected to lose about 3.7 million acres of forest by 2060, about 13 percent from the 1997 base (table 6). The largest percentage loss of forest land use would be in the Blue Ridge Mountains section (18 percent), followed closely by the Southern Ridge and Valley section (17.8 percent). As shown in figure 30, the largest proportional losses of forest land would occur in Boone County in Kentucky; Buncombe County, Clay County, and Graham County in North Carolina; Knox County and Unicoi County in Tennessee; and Towns County and Rabun County in Georgia.

Under Cornerstone C (low urbanization and increasing timber prices), the Appalachian-Cumberland highland is projected to lose about 1.4 million acres, about 5.1 percent of the 1997 base (table 7). The largest percentage loss is projected to be in the Southern Ridge and Valley section, (about 10 percent), followed closely by the Blue Ridge Mountains section (about 9.9 percent). As shown in figure 30, the largest loss of forest land use for Cornerstone C is in the Cincinnati metropolitan area to Louisville in Kentucky; Nashville and Knoxville in Tennessee; Buncombe County, Henderson County, Clay County, Graham County, and Swain County in western North Carolina; and all of the Appalachian-Cumberland counties in northern Georgia—the exception being Gilmer County which would have a lower percentage change.

Cropland—In contrast to forest area, which is more heavily influenced by urbanization patterns, cropland change is more heavily influenced by the timber prices. Across the Appalachian-Cumberland highland, little change (-3 percent to +3 percent) is forecasted to occur from the 1997 base acreage under Cornerstone D, which has an expectation of moderate urbanization gains and decreasing timber prices. Exceptions would occur in around the urban areas of Nashville and Knoxville in Tennessee, and areas around Louisville and Lexington in Kentucky. In these areas, cropland uses could decrease 3 to 25 percent by 2060.

Under Cornerstone B, which again has an expectation of decreasing timber prices, but large urbanization gains, the decrease is forecasted to be in the 15 percent range. Assuming the high timber prices under Cornerstone A (large urbanization gains) and Cornerstone C (moderate urbanization gains), the decrease in cropland use is forecasted to be more widespread. Much of the Appalachian-Cumberland highland is forecasted to lose 3 to 10 percent by 2060, with more substantial decreases (10 to 25 percent)

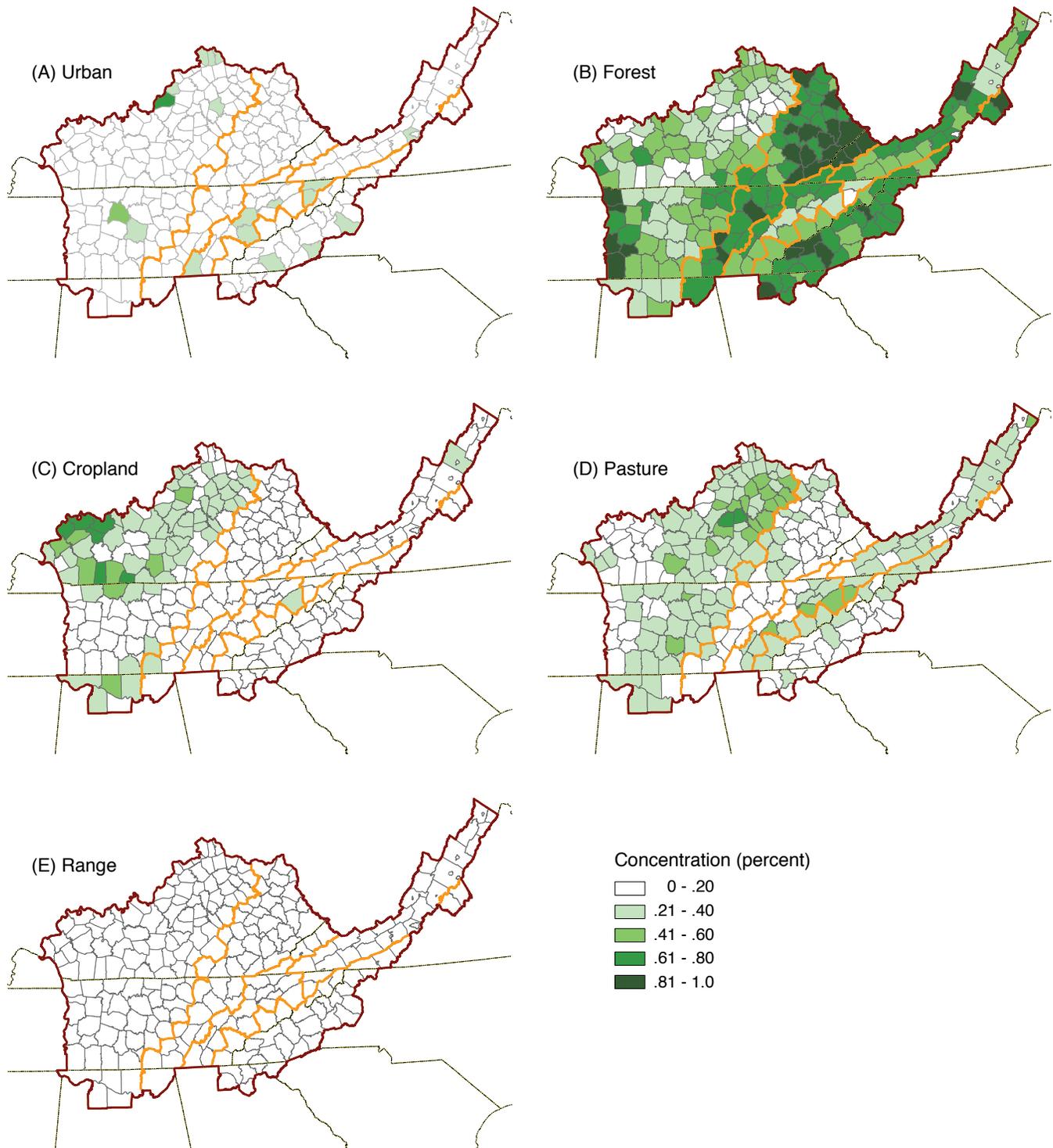


Figure 29—Concentrations of five land uses, 1997, in the U.S. Appalachian-Cumberland highland—(A) urban, (B) non-Federal forest land, (C) cropland, (D) pastureland, and (E) rangeland (Source: National Resources Inventory).

Table 4—Forecasted area of urban land in the five sections of the U.S. Appalachian-Cumberland highland, 1997 to 2060, based on an expectation of high population and income growth

Section	Area in urban use					Increase (1997 to 2060)	
	1997	2010	2020	2040	2060	Area	Percent
-----million acres-----							
Blue Ridge Mountains	0.68	0.85	1.02	1.35	1.81	1.13	164.9
Cumberland Plateau and Mountains	0.47	0.60	0.73	0.98	1.34	0.87	186.0
Interior Low Plateau	1.82	2.45	2.99	4.08	5.44	3.62	197.7
Northern Ridge and Valley	0.47	0.54	0.61	0.73	0.91	0.43	92.6
Southern Ridge and Valley	0.46	0.57	0.74	0.88	1.13	0.67	147.4
Total for all sections	3.90	5.01	6.03	8.03	10.63	6.73	172.4

Source: Huggett and others (2013).

Table 5—Forecasted area of urban land in the five sections of the U.S. Appalachian-Cumberland highland, 1997 to 2060, based on an expectation of low population and income growth

Section	Area in urban use					Increase (1997 to 2060)	
	1997	2010	2020	2040	2060	Area	Percent
-----million acres-----							
Blue Ridge Mountains	0.68	0.90	1.03	1.19	1.42	0.73	107.60
Cumberland Plateau and Mountains	0.47	0.64	0.73	0.84	1.00	0.53	113.30
Interior Low Plateau	0.82	2.56	2.98	3.54	4.20	2.39	131.30
Northern Ridge and Valley	0.47	0.57	0.61	0.66	0.73	0.25	54.00
Southern Ridge and Valley	0.46	0.59	0.67	0.78	0.91	0.45	98.70
Total for all sections	3.90	5.25	6.04	7.02	8.27	4.36	111.80

Source: Huggett and others (2013).

Table 6—Forecasted area of non-Federal forest land in the five sections of the U.S. Appalachian-Cumberland highland, 1997 to 2060, based on an expectation of high population and income growth coupled with decreasing timber prices

Section	Area in forest use					Decrease (1997 to 2060)	
	1997	2010	2020	2040	2060	Area	Percent
-----million acres-----							
Blue Ridge Mountains	4.31	4.19	4.08	3.85	3.54	0.78	18.00
Cumberland Plateau and Mountains	8.64	8.53	8.42	8.21	7.94	0.70	8.10
Interior Low Plateau	10.31	10.01	9.75	9.25	8.66	1.65	16.00
Northern Ridge and Valley	2.82	2.78	2.75	2.68	2.59	0.23	8.30
Southern Ridge and Valley	1.84	1.78	1.73	1.63	1.51	0.33	17.80
Total for all sections	27.92	27.30	26.73	25.62	24.23	3.69	13.20

Non-Federal land includes land held by private organizations, individuals, families, local governments, Indian reservations, and U.S. States but does not include U.S. military bases or lands managed by the U.S. Department of Agriculture and the U.S. Department of the Interior.
Source: Huggett and others (2013).

Table 7—Forecasted area of non-Federal forest land in the five sections of the U.S. Appalachian-Cumberland highland, 1997 to 2060, based on an expectation of low population and income growth coupled with increasing timber prices

Section	Area in forest use					Decrease (1997 to 2060)	
	1997	2010	2020	2040	2060	Area	Percent
-----million acres-----							
Blue Ridge Mountains	4.31	4.18	4.11	4.02	3.88	0.43	9.90
Cumberland Plateau and Mountain	8.64	8.54	8.49	8.45	8.35	0.29	3.30
Interior Low Plateau	10.31	10.09	10.00	9.95	9.87	0.44	4.20
Northern Ridge and Valley	2.82	2.78	2.77	2.76	2.74	0.08	2.90
Southern Ridge and Valley	1.84	1.78	1.75	1.70	1.65	0.18	10.00
Total for all sections	27.92	27.38	27.12	26.88	26.50	1.42	5.10

Non-Federal land includes land held by private organizations, individuals, families, local governments, Indian reservations, and U.S. States but does not include U.S. military bases or lands managed by the U.S. Department of Agriculture and the U.S. Department of the Interior.
Source: Huggett and others (2013)

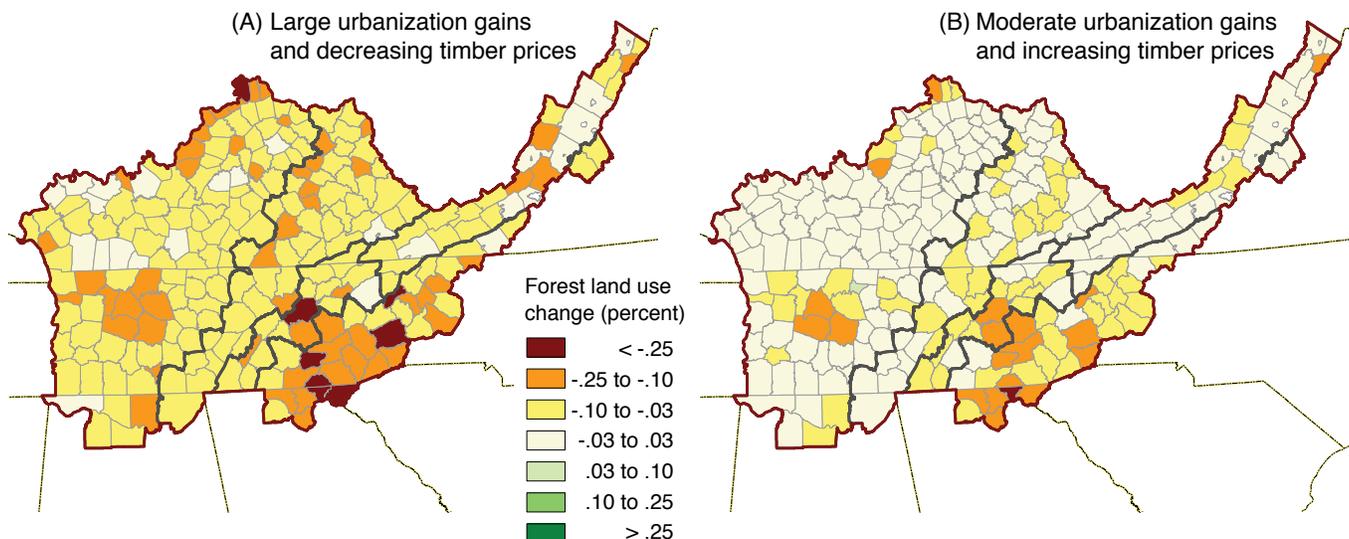


Figure 30—Predicted percentage of land remaining in forest use by 2060 (from the 1997 baseline) in the U.S. Appalachian-Cumberland highland under assumptions of (A) large urbanization gains and decreasing timber prices, and (B) of moderate urbanization gains and increasing timber prices (Source: Wear and others 2013).

forecasted for areas near Nashville in Tennessee and the Lexington and Louisville areas in Kentucky.

Pastureland—Cornerstone B forecasts the highest loss of pastureland—about 15 percent of the 1997 base acreage. Pasture losses for all the Cornerstone Futures would be concentrated in broad zones, one stretching from northern Georgia to northern Kentucky and including a large area in Tennessee.

Summary

Over the 50-year horizon, dramatic changes in land uses are predicted in the Appalachian-Cumberland highland, regardless of the Cornerstone Future applied. Urban land use is expected to increase from about 4.3 million acres under Cornerstones C and D, to about 6.7 million acres under Cornerstones A and B. Loss of forest, cropland, and pastureland is expected in all Cornerstone Futures. About 3.7 million acres of forest land use is projected under Cornerstone A, and 1.4 million acres under Cornerstone C.

These forecasts are in line with predictions for the other subregions in the South—all are expected to lose some forest acreage under all Cornerstone Futures, with nearly all of the area expected to be converted to urban uses. The forecasts indicate that strong future timber markets could ameliorate forest losses somewhat, but only at the expense of cropland uses.

For a broader discussion of land use in the South, see Wear (2013).

Forest Ownership

Of its 35.5 million forested acres in the Appalachian-Cumberland highland, roughly 29.3 million are owned by non-Federal entities. Consistent with overall land ownership patterns in the Eastern United States, the vast majority of Appalachian-Cumberland forest land is privately held, with ownership varying from as low as 60 percent in the Northern Ridge and Valley section to as high as 91 percent in the Interior Low Plateau section. State and local government ownership represents the lowest percentage of land ownership. Federal ownership (including large Federal holdings, such as the land owned by the Tennessee Valley Authority along water concourses) varies from as low as 6 percent in the Interior Low Plateau section to as high as 37 percent in the Northern Ridge and Valley section.

Blue Ridge Mountains—Based on the 2010 projections, as shown in figure 31, 35.1 percent of forest land in the Blue Ridge Mountains is under Federal management. Significant Federal forests include land in Great Smoky Mountains

National Park and the Nantahala, Pisgah, Cherokee, and Chattahoochee National Forests. Sixty three percent of forest land is privately owned, and the remainder (2.3 percent) is held by State and local governments (U.S. Department of Agriculture Natural Resources Conservation Service 2006).

Interior Low Plateau—As shown in figure 31, only 6.4 percent of forest land in the Interior Low Plateau section is under Federal management. Federal holdings include Land Between the Lakes, Mammoth Cave National Park, Fort Knox, and Fort Campbell. The remaining forests in the Interior Low Plateau section are privately owned (91.0 percent), with some small holdings (2.5 percent) in State parks and other public lands (U.S. Department of Agriculture Natural Resources Conservation Service 2006).

Northern Ridge and Valley—As shown in figure 31, 36.7 percent of the forest land in the Northern Ridge and Valley section is under Federal management. Federal holdings include land in Shenandoah National Park, the George Washington National Forest, and Jefferson National Forest. About 3.6 percent of forest land is under State and local government management, and the remainder (59.9 percent) is privately owned (U.S. Department of Agriculture Natural Resources Conservation Service 2006).

Southern Ridge and Valley—As shown in figure 31, 11.2 percent of forest land in the Southern Ridge and Valley section is under Federal management. Federal holdings include the Great Smoky Mountains National Park and the Cherokee National Forest. Approximately 4.3 percent of the forest is held by State and local municipalities, and the remainder (84.5 percent) is privately owned (U.S. Department of Agriculture Natural Resources Conservation Service 2006).

Cumberland Plateau and Mountains—As shown in figure 31, about 9.1 percent of forest land in the Cumberland Plateau and Mountains section is under Federal management, about 85.6 percent is privately owned, and the remaining 5.3 percent is held by State and local governments (U.S. Department of Agriculture Natural Resources Conservation Service 2006). The only national forest in the Cumberland Plateau and Mountains section is the Daniel Boone in eastern Kentucky. Although the proclamation boundary of the Daniel Boone encompasses 2.1 million acres, only about 708,000 acres are in Federal management (USDA Forest Service, Southern Region, Daniel Boone National Forest 2013). Also within the proclamation boundary are State and private lands in a dissected landscape of ownerships. The Big South Fork National River and Recreation Area is another Federally owned area that covers 125,000 acres in southern Kentucky and northern Tennessee.

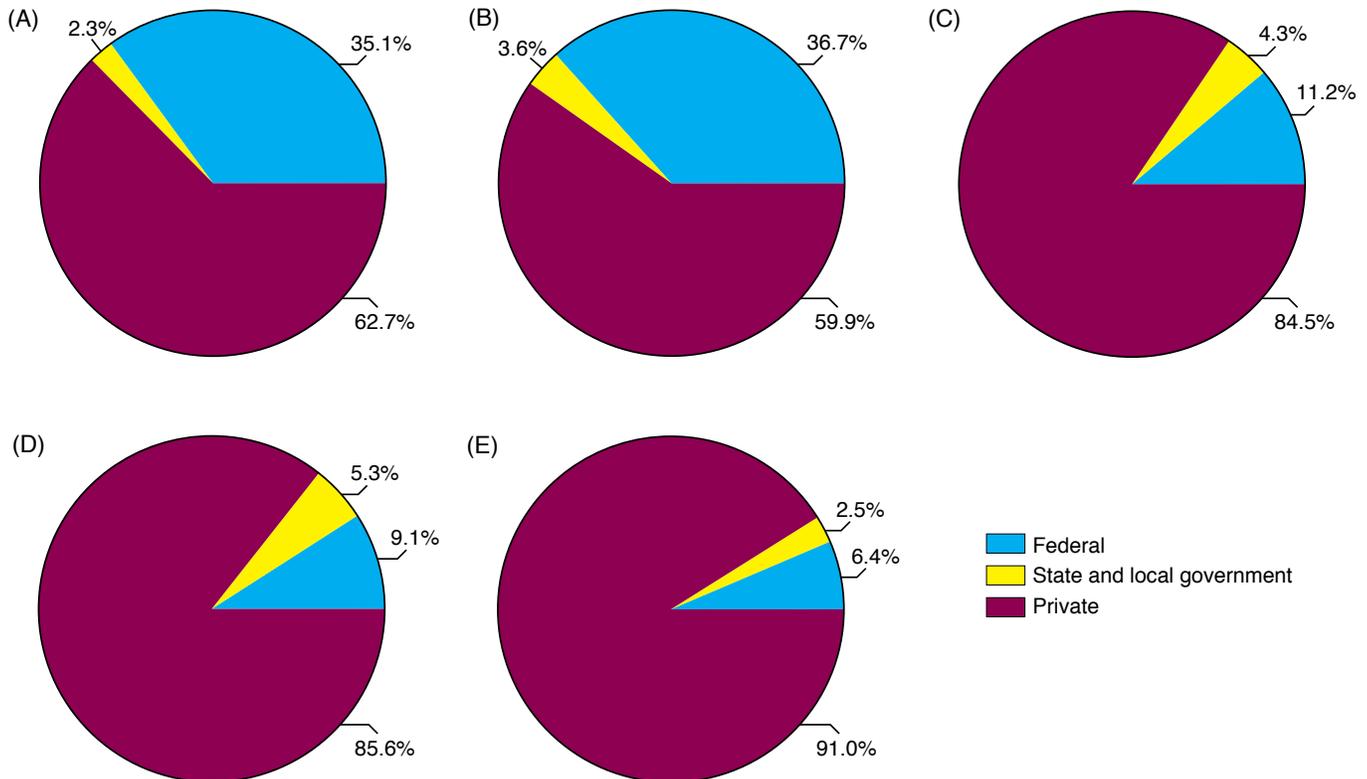


Figure 31—Forest ownership patterns, 2010 projections, in the U.S. Appalachian-Cumberland highland, by section: (A) Blue Ridge Mountains, (B) Northern Ridge and Valley, (C) Southern Ridge and Valley, (D) Cumberland Plateau and Mountains, and (E) Interior Low Plateau.

Forest Ownership Dynamics

In broad terms, forest ownership falls into two categories, private and public ownership. For the South as a whole, ownership of forest area is largely in private ownership, with 86 percent being in some form of private ownership and 5 million private owners holding 200 million acres.

Private forest ownership may be divided into corporate and family categories. On average in the South, families and individuals own two-thirds of the total private forest acreage, or about 134 million acres, the remaining third (or 66 million acres) held by corporations, conservation organizations, partnerships, and tribes. Corporate ownership includes the forest products industry, real estate investment trusts, timber investment management organizations, and other corporations. The largest ownership transition in the last century occurred from 1998 to 2008, when the forest products industry divested about three-fourths of its holdings. The largest gain in ownership was realized by timber investment management organizations and real estate investment trusts.

Exact numbers of acreage transfer in the Appalachian-Cumberland highland have not been determined, but a review of data and maps developed by Butler and Wear

(2013) revealed movement of acreage from the forest products industry to timber investment management organizations or real estate investment trusts. As shown in table 8, total corporate acre ownership has fallen in all six States from 1998 to 2008. As forest products industry ownership has decreased in all States, the largest gain in the corporate ownership type has been in timber investment management organizations, with five of the Appalachian-Cumberland States increasing from zero acres in 1998 to several hundred thousand acres in 2008. During that period, two States—Alabama and Georgia—experienced an increase in real estate investment trust acreage, and the remaining four States experienced a decrease. Three States—Kentucky, Tennessee, and Virginia—reported no acres in real estate investment trust holdings in 2008.

A review of maps for the entire subregion (fig. 32) shows that the forest product industry ownership is minimal, limited to small concentrations in a few counties of the Interior Low Plateau and Cumberland Plateau and Mountains sections of Alabama and the Northern Ridge and Valley and Blue Ridge Mountains sections of Virginia. For timber investment management organizations, the concentration in the Appalachian-Cumberland highland is more widespread (fig. 32)—with low concentrations in the Interior Low Plateau section in Alabama, Kentucky, and Tennessee; the

Table 8—Corporate forest ownership groups by State, 1998 and 2008, for States with land in the U.S. Appalachian-Cumberland highland

State	Total corporate		Forest products industry		Timber investment management organizations		Real estate investment trusts		Other corporate	
	1998	2008	1998	2008	1998	2008	1998	2008	1998	2008
-----thousand acres-----										
Alabama	4,360	4,160	3,240	1,264	772	2,115	348	555	0	227
Georgia	4,348	3,889	2,478	518	0	827	1,707	2,272	163	272
Kentucky	440	334	220	0	0	333	8	0	212	1
North Carolina	1,589	1,343	1,581	560	0	749	17	9	0	25
Tennessee	1,109	625	1,053	0	0	614	8	0	48	10
Virginia	931	787	687	163	0	521	24	0	220	103
Total	12,777	11,138	9,259	2,505	772	5,159	2112	2,836	643	638

Sources: Lanworth Inc. Unpublished report. On file with: David Wear, U.S. Department of Agriculture, Forest Service, North Carolina State University, P.O. Box 8008, Raleigh NC, 27695; Butler and Wear (2013).

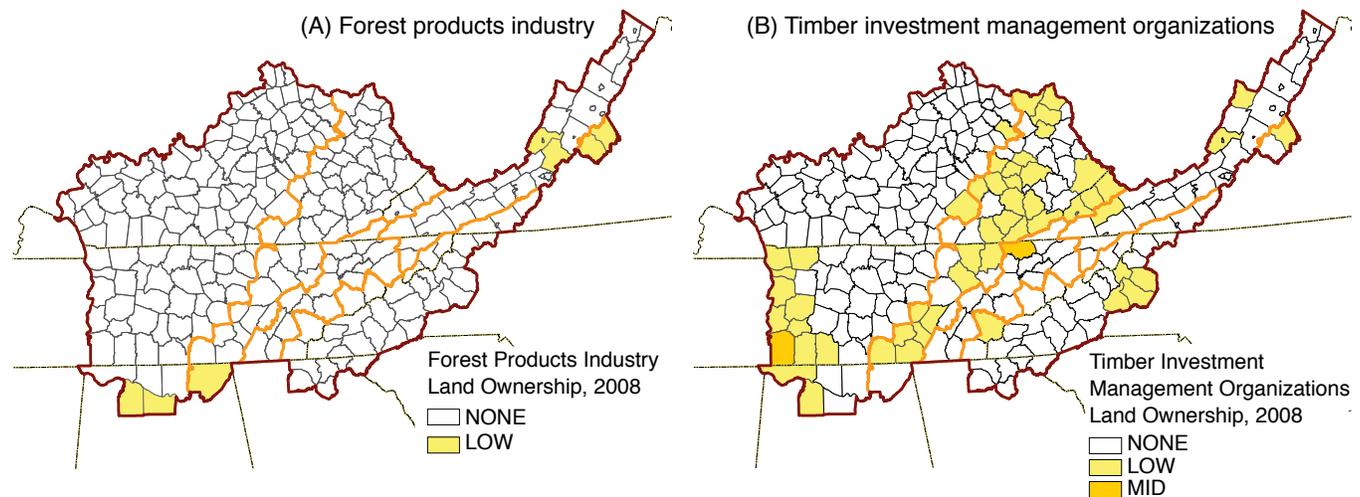


Figure 32—U.S. Appalachian-Cumberland highland concentration of forest land, 2008, owned by (A) the forest products industry, and (B) timber investment management organizations (Source: Lanworth, Inc.)

Cumberland Plateau and Mountains section of Kentucky, Tennessee, and Virginia; the Northern Ridge and Valley section of Virginia; and the Blue Ridge Mountains section of Tennessee and North Carolina. Mid-level concentrations are located in Wayne and Claiborne Counties in Tennessee.

Family forest owners are a more diverse group than corporate owners, both in the amount of acreage they own and their motivations for management and ownership. Butler and Wear (2013) defined family owners to include families, individuals, trusts, estates, family partnerships, and other unincorporated groupings of individuals who own forests. Nearly 60 percent of family forest owners hold ≤ 9 acres; at the same time, about 60 percent of family forest acreage is in holdings of ≥ 100 . Few family forest owners have a written management plan for their forest holdings. Although a larger number of owners received management advice, less than half of all family forest land is owned by an individual or family who has sought advice.

Family forest owners cite a variety of reasons for keeping their holdings, including legacy, aesthetics, and land investments. The future of family forests depends on personal, familial, social, and market forces that will unfold as land transfers from one owner to the next. Although many family forest owners want to keep their land intact for future generations, they are not certain they will be able to do so. Losses in forest acreage in conjunction with anticipated ownership turnover could only lead to an ongoing parcelization and fragmentation of private forests.

The Southern United States contains about 32 million acres of publically owned forests. This represents about 14 percent of the total forest land area. Large holdings of public forest in the Appalachian-Cumberland section include the William B. Bankhead National Forest in Alabama; the Chattahoochee National Forest in Georgia; the Daniel Boone National Forest and Land Between the Lakes National Recreation Area in Kentucky and Tennessee; the Nantahala National Forest, Pisgah National Forest and Great Smoky Mountains National Park in North Carolina; the Cherokee National Forest and

the Great Smoky Mountains National Park in Tennessee; and the George Washington National Forest, Jefferson National Forest, and parts of the Shenandoah National Park in Virginia. Other large forest holdings in the section include land managed by two U.S. Department of the Interior units—Fish and Wildlife Service and Bureau of Indian Affairs—as well as numerous State and local parks and forests.

Outlook for Forest Ownership

For corporate owners, the traditional model of large land ownership by forest products industry shifted dramatically from 1998 to 2008 as industry lands shifted to investment groups, either timber investment management organizations or real estate investment trusts. A shift back to forest products industry ownership is not expected in future years; nor is a reversal in the fragmentation of ownership expected. The implications for forest management and forest conditions over the long run are unclear, but the ownership change signals a change in management objectives and the potential for ongoing ownership transitions. Butler and Wear (2013) concluded that this shift in ownership will likely increase the frequency of forest land transactions in response to changing economic conditions. For example, as land increases in value for developed uses, investment group managers would be somewhat more likely to sell their holdings for development than would forest industry owners. The result might not be that more land is developed in the long run, but rather that development would occur more rapidly. This new ownership dynamic would also accelerate the fragmentation of ownerships that were once stable. Fragmentation and parcelization of family and individually owned forests is expected to continue even without the pressure of development. Increased parcelization and urbanization of private forests could lead to future challenges such as difficulties in implementing traditional forestry practices on small acreages and reductions in prescribed burning to address health and safety concerns and ordinances.

For a broader discussion of forest ownership in the South, see Butler and Wear (2013).

CHAPTER 4.

Biological Threats

INVASIVE PLANTS

Invasive species as defined under Executive Order 13112 are (1) a species that is nonnative (or alien) to the ecosystem under consideration, and (2) whose introduction causes or is likely to cause economic or environmental harm or harm to humans. Across the South, invasive plant species pose a significant threat to overall forest health, and will likely be of increasing concern over the next 50 years. They can alter forest structure and function (Fox and others 2011, Hartman and McCarthy 2008, Weidenhamer and Callaway 2010), and they can modify forest composition by limiting regeneration opportunities for native species and reducing habitat quality for a variety of vertebrate and invertebrate species. The continued invasions that are expected would further alter forest ecosystem structure and function resulting in a decrease in overall forest health, forest productivity, and ecosystem resistance and resilience to disturbances, including climate change. The decrease in forest productivity coupled with the high costs associated with the control of invasive plants makes them an economic as well as an ecological issue for southern forests (Holmes and others 2009).

Miller and others (2013) identified 33 of the most common invasive plants in the Southern United States from five functional groups: (1) trees, (2) woody shrubs, (3) grasses and bamboos, (4) vines, and (5) forbs. About 4.4 million acres of the Appalachian-Cumberland highland are currently affected. In terms of absolute acres affected, the Interior Low Plateau section contains the highest levels of invasive-plant coverage in the Appalachian-Cumberland highland, with about 2,272,100 acres affected, followed by the Cumberland Plateau and Mountains section (783,145 acres), Southern Ridge and Valley section (452,521 acres), Northern Ridge and Valley section (266,605 acres), and Blue Ridge Mountains section (217,832 acres).

Regardless of the specific species, invasion of forest communities by nonnative plants is driven largely by habitat fragmentation, parcelization, increasing population, recreational use, and forest disturbance, all of which are forecasted to increase under the Cornerstone Futures. In addition, climate change will not only accelerate the rate of invasion of invasive plants in a given area, but also facilitate movement of specific species into new ecosystems.

Invasive Trees

Of the high priority invasive trees identified by Miller and others (2013), tree-of-heaven (*Ailanthus altissima*) covers the largest amount of land area in the five Appalachian-Cumberland sections, with the highest concentrations found in the Cumberland Plateau around Nashville, TN, and along the Shenandoah Valley in the Northern Ridge and Valley section (fig. 33). This species is most commonly located along forest roads, but readily invades forest sites that have been recently harvested or otherwise disturbed. Because it is highly competitive and capable of outgrowing most native tree species, tree-of-heaven can dramatically alter forest structure, composition, and function.

Because mechanical site preparation before and after harvesting can aggravate infestation, in areas of high infestation, herbicide treatments are recommended to eliminate extant individuals as well as the sprouting potential

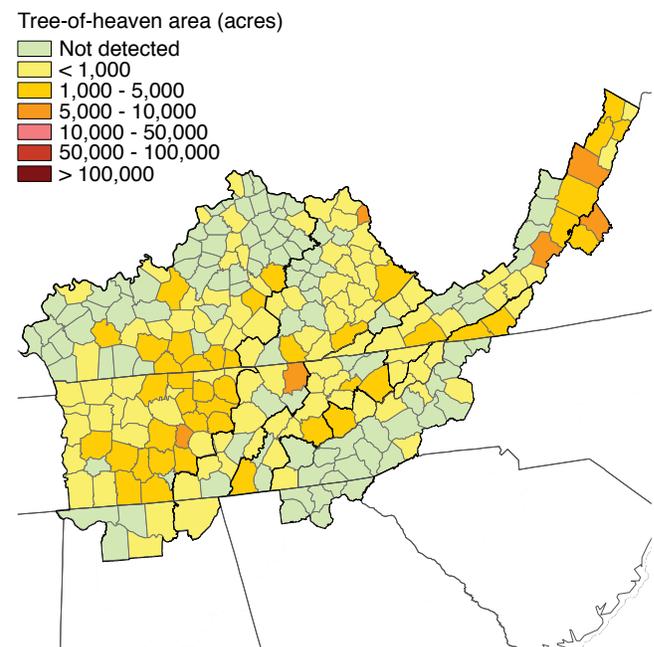


Figure 33—Extent of infestations by tree-of-heaven, 2010, in the U.S. Appalachian-Cumberland highland (Source: Forest Inventory and Analysis, Southern Research Station, U.S. Forest Service).

of top-killed trees. Total elimination of this species at a stand or site-specific level requires long-term surveillance, both for new germinants that appear the year after seed fall (no viability in the soil seed bank) and for root fragments that can readily sprout anytime. The abundance of this species is expected to increase over the next 50 years (Miller and others 2013).

Invasive Vines

Of the high priority invasive vines identified by Miller and others (2013), Japanese honeysuckle (*Lonicera japonica*) covers the largest amount of land area in the Appalachian-Cumberland highland and its five sections. Concentrations of Japanese honeysuckle are particularly high throughout the Cumberland Plateau and Mountains and Interior Low Plateau sections (fig. 34). It is a particular problem on forested sites because of its high tolerance to shade, meaning that it can persist in the understory of mature forests for long periods of time. In high-light environments that result from disturbances, Japanese honeysuckle can grow extremely rapidly. Its spread is from the rooting of litter-covered vines, which twine around small-diameter woody plants and eventually block sunlight to regenerating trees and shrubs—thereby changing forest structure and composition. It is not uncommon for Japanese honeysuckle to become a prominent species following canopy-reducing disturbances in many forest types across the Southeastern United States (Hull and Scott 1982, Schierenbeck 2004, Webster and others 2006).

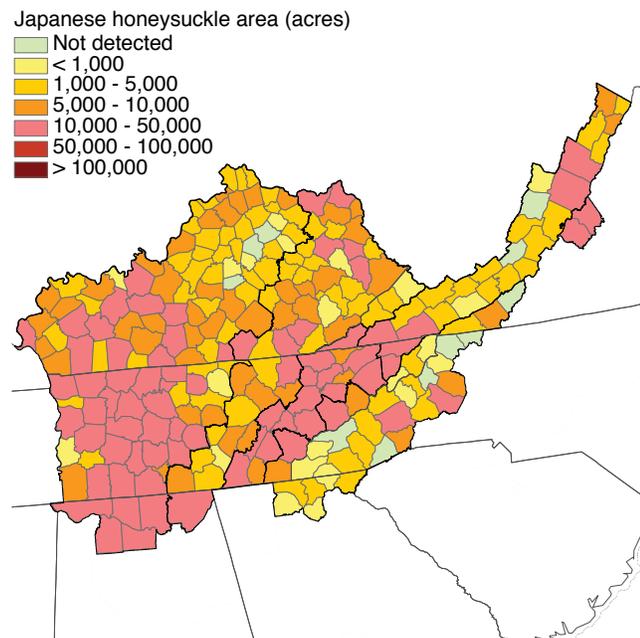


Figure 34—Extent of infestations by Japanese honeysuckle, 2010, in the U.S. Appalachian-Cumberland highland (Source: Forest Inventory and Analysis, Southern Research Station, U.S. Forest Service).

Control methods are centered on herbicide application before any planned disturbances and in the immediate years afterward. Winter treatments are possible because it is evergreen, and appropriate in areas where safeguarding deciduous plants is a goal. As with any control method, long-term surveillance is required for successful eradication. Over the next 50 years, this species is expected to continue to spread and affect forest health throughout all areas of the South (Miller and others 2013). Because of the high levels of occupation, it can only be treated on high priority sites.

Invasive Shrubs

Of the high threat invasive shrubs identified by Miller and others (2013), invasive roses (*Rosa* spp.) cover the largest amount of land area in the Appalachian-Cumberland highland. Invasive roses have the highest cover relative to the other high priority invasive shrubs in all sections, with the exception of invasive privets (*Ligustrum* spp.) in the Southern Ridge and Valley section and bush honeysuckles (*Lonicera* spp.) in the Interior Low Plateau section. Concentrations of invasive roses, and multiflora rose (*Rosa multiflora*), in particular, are highest in Kentucky and Virginia in the Cumberland Plateau and Mountains section and Appalachian Mountains (fig. 35).

Although all invasive shrubs in the Appalachian-Cumberland highland are shade tolerant and capable of surviving in interior forest conditions, most are found along forest roads,

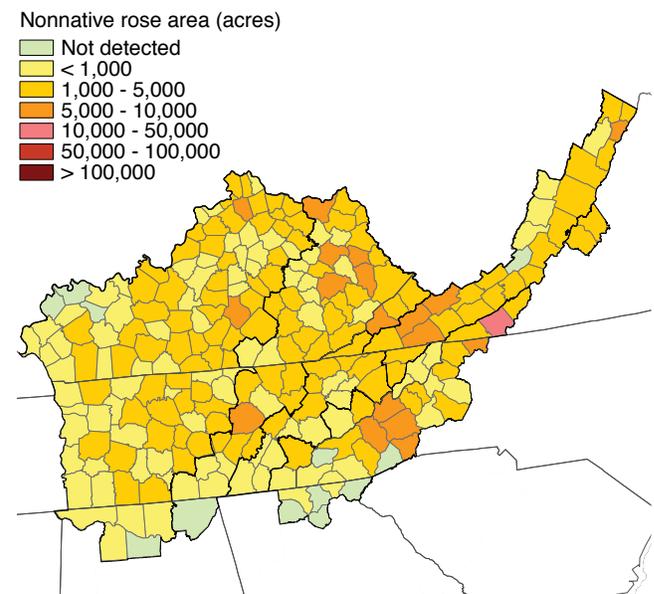


Figure 35—Extent of infestations by invasive roses, 2010, in the U.S. Appalachian-Cumberland highland (Source: Forest Inventory and Analysis, Southern Research Station, U.S. Forest Service).

often extending into open forest habitats. Regeneration and spread of these invasive shrubs is the result of fruit consumption by birds (Greenberg and Walter 2010) and prolific sprouting. Under the current climate, the potential habitat for invasive roses, in particular, in the Appalachian-Cumberland highland is extremely high. Potential habitat for invasive roses is lower under Cornerstones A and C, but remains high under Cornerstones B and D (Miller and others 2013). When infestations occur, natural regeneration of native tree species is greatly hindered. Control options include foliar herbicide application as well as cut-surface application of herbicide. As with any control method, long-term surveillance is required for successful eradication.

Invasive Grasses

Of the high priority invasive grasses identified by Miller and others (2013), tall fescue (*Schedonorus phoenix*) has the highest relative cover in the Northern Ridge and Valley, Cumberland Plateau and Mountains, and Interior Low Plateau sections; and Japanese stiltgrass (*Microstegium vimineum*) has the highest relative cover in the Blue Ridge Mountains and Southern Ridge and Valley sections. Tall fescue is most heavily concentrated in the forests of Kentucky, Virginia, and central Tennessee (fig. 36) whereas Japanese stiltgrass is most heavily concentrated around population centers, such as Asheville, NC, in the Blue Ridge Mountains section and Knoxville, TN, in the Southern Ridge and Valley section (fig. 37). Although tall fescue is important

forage for domestic livestock, infestations of this grass reduce wildlife habitat quality, especially for ground-nesting birds (Barnes and others 1995). Japanese stiltgrass is most common along roadsides, forest edges, and streamsides; its seeds are easily spread by water and indirectly by hiking and other recreational activities.

Potential habitat for Japanese stiltgrass would remain constant under Cornerstone B and increase by 91 percent under Cornerstone D (Miller and others 2013). In contrast, under Cornerstones A and C, potential habitat would be greatly reduced because of increased temperatures (Miller and others 2013). As with any invasive grass, control efforts for both Japanese stiltgrass and tall fescue are centered on herbicide application followed by the establishment of natural grasses or shade-producing shrubs and trees. Long-term surveillance is required for successful eradication.

Invasive Forbs

Garlic mustard (*Alliaria petiolata*), the only high priority invasive forbs identified by Miller and others (2013), is virtually undetected in the Blue Ridge Mountains, Northern Ridge and Valley, and Southern Ridge and Valley sections. High infestations are found in scattered counties of the Cumberland Plateau and Mountains and Interior Low Plateau sections (fig. 38). The main impact of garlic mustard infestations is the loss of herbaceous vegetation, resulting in a decrease in understory diversity and richness.

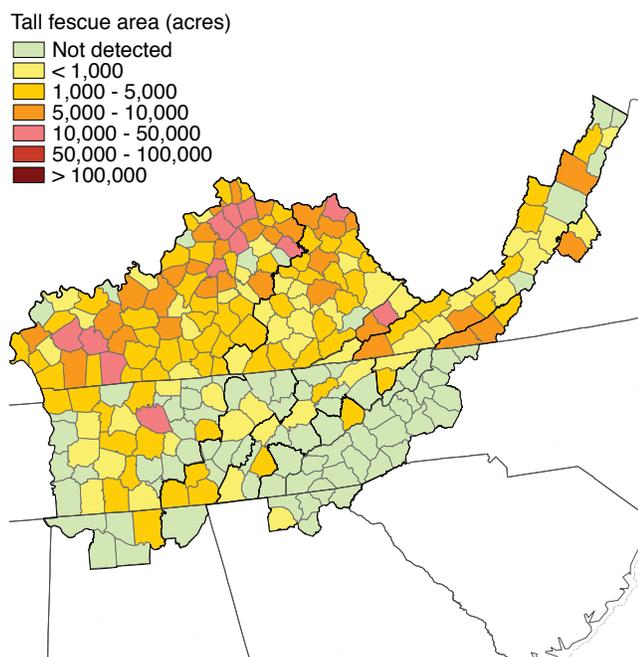


Figure 36—Extent of infestations by tall fescue, 2010, in the U.S. Appalachian-Cumberland highland (Source: Forest Inventory and Analysis, Southern Research Station, U.S. Forest Service).

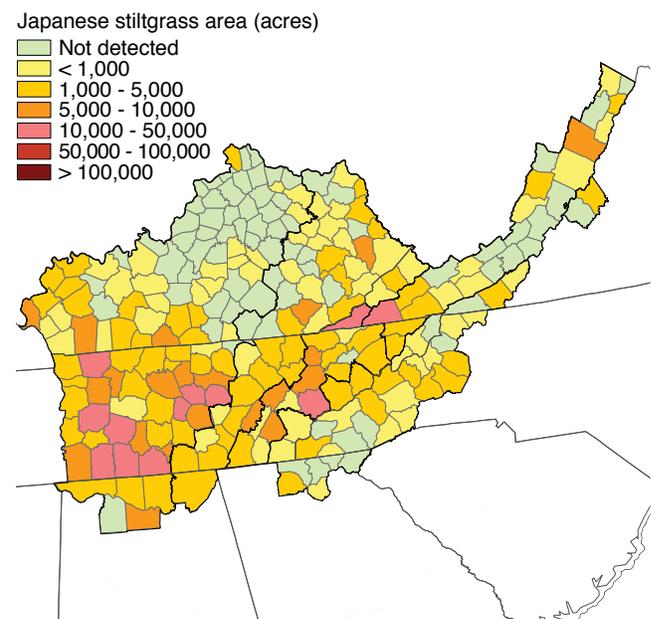


Figure 37—Extent of infestations by Japanese stiltgrass, 2010, in the U.S. Appalachian-Cumberland highland (Source: Forest Inventory and Analysis, Southern Research Station, U.S. Forest Service).

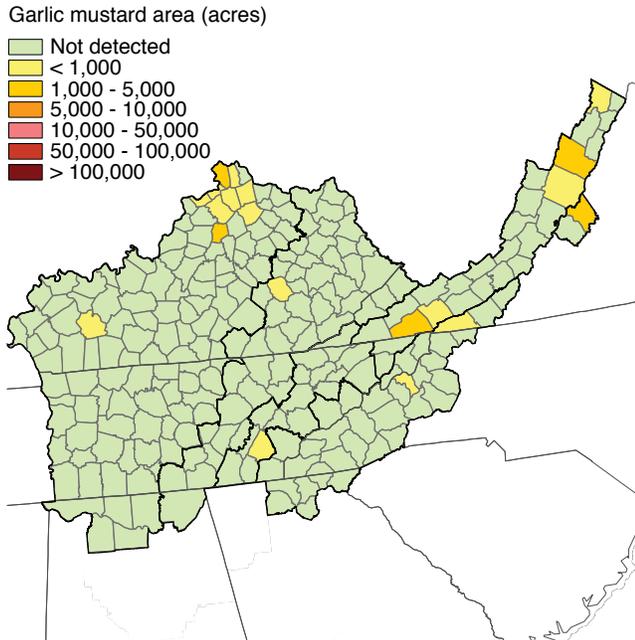


Figure 38—Extent of infestations by garlic mustard, 2010, in the U.S. Appalachian-Cumberland highland (Source: Forest Inventory and Analysis, Southern Research Station, U.S. Forest Service).

Over the next 50 years, the cover of garlic mustard is forecasted to increase by 45 percent (Miller and others 2013). Control and eradication efforts are centered on foliar herbicide applications and long-term surveillance.

Summary

The continued spread of invasive plants will modify species composition, habitat quality, and overall forest productivity as well as greatly limit forest management opportunities in affected stands and forests. The resulting alteration of ecosystem structure and function could ultimately decrease resistance and resilience to future disturbances, including climate change. Loss of forest productivity coupled with the negative effects that invasive plants have on other ecosystem services (such as wildlife habitat quality, overall forest health, and biodiversity), makes their control an important ecological as well as economic concern. Although eradication may only be possible at a local scale, slowing the rate of spread may be possible through increased awareness and knowledge. Education will be particularly important in and around areas forecasted to experience dramatic increases in population (such as existing population centers).

For a broader discussion of invasive plants in the South, see Miller and others (2013).

INSECT AND DISEASE PESTS

Forests pest and disease outbreaks act as disturbance events that exert an enormous influence on the overall structure and function of southern forests. They not only affect overall ecosystem health, but their presence or potential threat to a particular system can also influence management decisions. Therefore, understanding the effect that forest insects and diseases have on forest resources is critical to maintaining ecosystem services provided by southern forests currently as well as into the future. A mixture of native and nonnative species comprise the 30 most important insect and disease agents identified by Duerr and Mistretta (2013).

Forest Insects

Numerous insect species currently affect or will likely affect the forests of the Appalachian-Cumberland highland. Although all forests pests can be problematic and all have the potential to impact vast areas of forest land, a few species are of particular importance because of their current or potential effects on forest structure, function, and composition. The four insects identified by Duerr and Mistretta (2013) that are of particular importance in the Appalachian-Cumberland highland are described below.

Balsam woolly adelgid—Balsam woolly adelgid (*Adelges piceae*) was introduced from Europe around 1900 (Ragenovich and Mitchell 2006). It poses a continued threat to the structure, composition, and function of spruce-fir forests, which are restricted to high elevations in the southern Appalachian Mountains. Although Fraser fir is the only species directly affected by the adelgid, indirect effects of infestations are numerous, given the numerous plant and animal species that require mature spruce-fir forests for survival (Trani Griep and Collins 2013). All five major areas of high-elevation spruce-fir forests—including parts of North Carolina, Tennessee, and Virginia—are infested, and about 95 percent of the mature (>40 years of age) Fraser fir component of the spruce-fir ecosystem has been directly killed by the adelgid. The loss of mature trees has left the fir component in the spruce-fir ecosystem primarily comprised of younger (<40 year) trees, which may not provide the same benefits that older, more mature trees provide. Predicted levels of climate change would mean a reduction in the area suitable to spruce-fir forests but would not have any direct effect on the adelgid itself.

Insecticides are the only method of control for the adelgid, but application of insecticides is only practical as a targeted effort in high-value populations, such as Christmas tree plantations, not on landscape level in natural, forest settings.

Increased temperature and decreased precipitation will likely have the effect of both shrinking the range of spruce-fir forests now isolated on mountaintops and increasing adelgid activity and damage. If these trends continue unabated, natural populations of southern Fraser fir could disappear over the next 50 years.

Hemlock woolly adelgid—Hemlock woolly adelgid (*Adelges tsugae*) is an aphid-like insect native to Japan, that was first observed in or around the Richmond, VA area in the 1950s (McClure and others 2001). Susceptible host species include eastern (*Tsuga canadensis*) and Carolina hemlock (*Tsuga caroliniana*). Since its introduction, the adelgid has infested about half of the range of eastern hemlock—from Georgia to Maine—although winter temperatures $\leq 20^\circ\text{C}$ diminish population densities (Trotter and Shields 2009). Consequently, although warming temperatures associated with climate change would have little impact on its southern extent, the extent of and mortality caused by hemlock woolly adelgid infestations in more northerly latitudes could increase. The rate of spread ranges from 12.5 km/year (Evans and Gregoire 2007) to between 20 and 30 km/year, with dispersal primarily through wildlife (McClure 1990). Following infestation, hemlock trees, both eastern and Carolina hemlock species, die in as little as 2 to 6 years (McClure and others 2001, Ragenovich and Mitchell 2006).

The vast majority of the native range of hemlock in the Appalachian-Cumberland highland is infested by hemlock woolly adelgid (fig. 39). A variety of methods are being examined for control or treatment (or both). For individual trees (such as ornamentals and highly valued trees), systemic insecticides are effective, although treatments are short lived

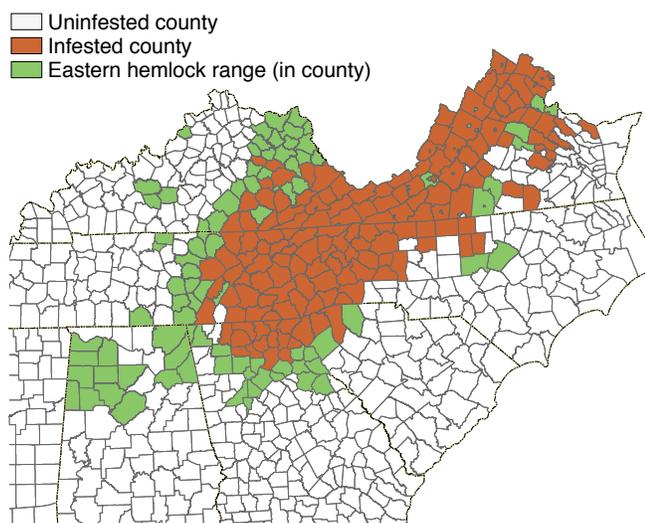


Figure 39—Native range of eastern hemlock and extent of infestation by hemlock woolly adelgid in the Eastern United States in 2012 (Source: United States Department of Agriculture, Forest Service: <http://na.fs.fed.us/fhp/hwa/maps/2012.pdf>. [Date accessed: August 22, 2013]).

and must be repeated. Because these chemical treatments applied at the individual-tree level are not practical at the landscape level or even at the stand level, other efforts such as biological control are being investigated.

The loss of hemlock from the landscape has numerous ecological consequences. Eastern hemlock is a primary component of riparian and acidic and moist cove forests in the Appalachian-Cumberland highland, and Carolina hemlock grows in low elevation ridgetop locations and dry rocky outcrops. Considered a foundational species (Ellison and others 2005), eastern hemlock is long-lived and the most shade-tolerant of the Appalachian-Cumberland conifers. Eastern hemlock forests support a vast array of wildlife species not found in companion mixed-hardwood forests (Snyder and others 2002), exert a large influence over the hydrological cycle (Jenkins and others 1999), and are a critical component of the nutrient cycle and stream chemistry (Ford and Vose 2007). As they succumb to infestations by the adelgid, the composition of the regeneration layer is largely rhododendron. In places where rhododendron is not available for regeneration, mixed-hardwood species—such as oak, sweet birch (*Betula lenta*), red maple (*Acer rubrum*), beech, and yellow-poplar—will dominate (Ford and others 2012, Spaulding and Rieske 2010). The replacement of eastern hemlock by these species will ultimately alter ecosystem structure and function and could alter ecosystems by changing the physical structure of streams, increasing canopy openness, light, and stream temperatures—all of which would have substantial impacts on wildlife habitat (Vose and others 2013, Webster and others 2012) and hydrologic processes (Ford and Vose 2007). To avoid these cascading ecological consequences, restoration activities that mitigate the negative effects of eastern hemlock losses have become a primary management concern.

Emerald ash borer—In North America, emerald ash borer (*Agrilus planipennis*) was first identified in six counties in southeastern Michigan and the Canadian Province of Ontario in 2002. This wood-boring insect is native to Asia and was likely introduced in solid-wood packing material. Susceptible hosts in the eastern landscapes of North America include all 16 species of ash (*Fraxinus* spp.). Tree decline and subsequent death are caused by the disruption of nutrient and water transport by larvae (McCullough and others 2008). Despite strict Federal and State quarantine and control efforts, emerald ash borer has spread to 17 States, including three—Kentucky, Tennessee, and Virginia—in the Appalachian-Cumberland highland. Its rapid movement across the forests of the Eastern United States is thought to have occurred from the transportation of ash nursery stock, harvested logs, and firewood (McCullough and others 2008).

Ash is a relatively minor component of Appalachian-Cumberland forest ecosystems, with green ash (*Fraxinus*

pennsylvanica) and white ash (*Fraxinus americana*) being the most common species. Green ash is primarily located in riparian areas, and white ash is a component of upland hardwood forests. Outside the forests, ash is most prevalent in urban areas, used for residential and commercial landscaping and in parks and other public places in the 1970s and 1980s to replace American elm (*Ulmus americana*), which died after the introduction of Dutch elm disease.

In the next 50 years (2010 to 2060), emerald ash borer will likely kill most rural and urban ash trees in the Appalachian-Cumberland highland, costing millions of dollars and producing unknown ecological consequences. Although, control can be achieved through chemical treatments that are only feasible on select individual, high-value trees. Given that all ash trees are susceptible and that chemical control on a landscape-level is not practical, the creation of “ash conservation areas” where small pockets of ash are treated and maintained is recommended (Duerr and Mistretta 2013).

Several larval and egg parasitoids are being investigated for use as biological control agents (U.S. Department of Agriculture Animal and Plant Health Inspection Service 2010). Although results are preliminary, these biological control agents would likely mitigate populations but would not control or completely stop the spread and impacts of this insect invader.

Gypsy moth—Gypsy moth (*Lymantria dispar*) is a defoliating insect introduced into the United States from Europe in 1869. Individual gypsy moths, mostly males, are located throughout the Appalachian-Cumberland highland, but these isolated individuals are either eradicated or do not cause damage—as it is only in the larval stages that gypsy moths feed and cause damage. In the Appalachian-Cumberland highland, established gypsy moth populations are currently limited to Virginia. However, if infestations continue to spread at a rate of 7 to 10 miles per year (Sharov and others 2002), much of the Appalachian-Cumberland highland will contain gypsy moth populations in the next 50 years (2010 to 2060). Hosts favored by the gypsy moth include some of the most prominent Appalachian-Cumberland forest species, including most oaks as well as basswood. Some of the prominent species of limited favorability to gypsy moth include yellow-poplar, red maple, American beech, sweet birch, yellow birch (*Betula alleghaniensis*), black cherry (*Prunus serotina*), pines, sugar maple, cucumber tree (*Magnolia accuminata*), and most hickories.

Gypsy moth outbreaks generally last 1 to 5 years (Kauffman and Clatterbuck 2006). After outbreaks, populations decrease and remain relatively low for 4 to 12 years (McCullough and others 1995). In general, single-year defoliation results in only a slight reduction in growth. If defoliation exceeds 50

percent or occurs over multiple years, trees become stressed and can eventually die (Kauffman and Clatterbuck 2006).

Unlike efforts to control many other nonnative insects (such as emerald ash borer and hemlock woolly adelgid), management activities exist that can suppress gypsy moth outbreaks on a landscape level. Mitigation efforts are especially important in the Appalachian-Cumberland highland where preferred oak species dominate the landscape. Many of these management actions revolve around silvicultural manipulation of forest structure or composition (or both), but the biological control agent Bt (*Bacillus thuringiensis*) and chemical controls such as insecticides and pheromones are also used to eradicate advancing populations and suppress active infestations.

Silvicultural treatments that increase resilience to gypsy moth outbreaks are centered on timber harvests and intermediate management activities. In mature stands, harvesting species favored by the gypsy moth can yield financial return along with reducing the susceptibility of the regenerating stand. Thinning and other intermediate stand-density management activities can enlarge crowns, reduce competition for resources, and improve overall health—all of which are useful in reducing mortality following defoliation (Muzika and others 1998).

Managing for trees that are not preferred by gypsy moth can increase resistance to an outbreak. However, this approach could conflict with other forest management goals in the Appalachian-Cumberland highland (Muzika and Liebhold 2000) because it would mean substantially reducing the component of mixed-hardwood or oak-dominated stands—oak—that is of high ecological and economic importance (Kauffman and Clatterbuck 2006, McCullough and others 1995).

Pathogens/Disease Complexes

The list of pathogens that affect forests in the Appalachian-Cumberland highland is extensive and includes notable diseases, such as chestnut blight (which eliminated American chestnut as a canopy tree species in the early 20th century), Dutch elm disease, butternut canker, dogwood anthracnose, and beech bark disease. These diseases continue to shape forest structure and composition, but their effects have already been realized or will be limited to a small number of Appalachian-Cumberland species—unlike the three diseases described below.

Two of the diseases described below are particularly important to the Appalachian-Cumberland highland because they impact primarily oaks, which occupy >50 percent of the forested land base throughout the Central Hardwood Region (Johnson and others 2002) and are often considered

a keystone species because of their value to ecosystem structure and function and their economic importance. The third—thousand cankers disease—threatens walnuts, a small component of Appalachian-Cumberland forests that has high societal and economic values.

Oak decline—Oak decline is a disease complex in which a slow progression of crown dieback eventually results in tree mortality. Oak decline begins with an environmental stress—such as drought, late spring frosts, or defoliation—that weakens trees and increases susceptibility to secondary pests and pathogens. These secondary hosts—including the two-lined chestnut borer (*Agrilus bilineatus*), hypoxylon cankers (*Xylaria hypoxylon*), and armillaria root rot (*Armillaria mellea*)—contribute to the further decline and eventual mortality of oak trees. Although all the predominant Appalachian-Cumberland oak species are susceptible to oak decline, species in the red oak subgenera—particularly black oak, and scarlet oak—are most vulnerable. Other attributes that predispose oaks to decline are advanced age (>70 years), high oak basal area, poor site quality, and poor soil conditions such as shallow, rocky soils or soils with high clay content (Oak and others 1996). Oak decline can act at both the individual-tree (Greenberg and others 2011) and landscape scales (Haavik and others 2012).

Over the next 50 years (2010 to 2060), the occurrence and spatial extent of oak decline events could increase in Appalachian-Cumberland forests. Warming temperatures and more frequent and longer episodic drought events coupled with continued aging of existing stands would further predispose these forests to oak decline. Mitigation measures that could promote resilience to future oak decline events include preferentially favoring species—such as white oak and chestnut oak—that are less susceptible to oak decline, increasing overall tree diversity, and increasing individual tree vigor by thinning and implementing other intermediate stand-management activities (Haavik and others 2012).

Sudden oak death—Sudden oak death, caused by a fungus (*Phytophthora ramorum*) is a disease that kills many oak species; symptoms begin with stem cankers and crown dieback followed by eventual tree death. First identified in 1995, sudden oak death is currently limited to California and southwestern Oregon where it has devastating effects on tanoaks (*Lithocarpus densiflorus*), coast live oaks (*Q. agrifolia*), and California black oaks (*Q. kelloggii*). Although a wide variety of other hosts exist in the Western United States, the pathogen generally does not cause mortality in these species (O'Brien and others 2002).

Although currently confined to the West Coast, the pathogen is known to infect nursery stock that is widely traded across the United States. According to the U.S. Department of Agriculture Animal and Plant Health

Inspection Service (2010), all Appalachian-Cumberland States except Kentucky have had nursery stock test positive for the sudden oak death fungus.

The forests of the Eastern United States are home to a wide variety of confirmed and potential host species (Rizzo and others 2002, U.S. Department of Agriculture Animal and Plant Health Inspection Service 2010), including oaks (in particular northern red oak), mountain laurel, rhododendron species, and arrowwood (*Viburnum dentatum*). The consequences of the introduction of sudden oak death to eastern forests would be profound. With oak comprising as much as 60 to 80 percent of the basal area of Appalachian-Cumberland forests (fig. 40), the role that these oak forests play in ecology and economics is pivotal. Widespread mortality of oak would alter ecosystem structure and function, reduce biodiversity, and modify the habitat of numerous plants and animals, including species of conservation concern (Kliejunas 2003).

The introduction of sudden oak death into upland oak ecosystems of the Appalachian-Cumberland highland during the next 50 years (2010 to 2060) is not a certainty. Although quarantine efforts and regulations, testing programs for the fungus, educational outreach, and improved nursery practices do not guarantee the pathogen will not establish, these control efforts appear to be effective to date. However, the abundance of host species coupled with continued trade of nursery stock from infected areas guarantees that sudden oak death will continue to be a high priority forest health issue.

Thousand cankers disease—Thousand cankers disease, first recognized in 2008 in the Western United States, causes branch dieback and eventual tree death of walnut trees (*Juglans* spp.). The disease is caused by a fungus (*Geosmithia morbida*) of unknown origin, which is vectored by the walnut twig beetle (*Pityophthorus juglandis*). The walnut twig beetle is native to North America (primarily the Southwestern United States), but its presence alone (without the fungus) does not cause significant mortality (Seybold and others 2011). It is only when the walnut twig beetle is associated with the fungus that symptoms occur. These include branch mortality, small cankers on the branches and bole, and entrance and exit holes used by the walnut twig beetle on dead and dying branches (Seybold and others 2011). Mortality is ultimately caused by numerous coalescing cankers that develop around individual beetle wounds and that ultimately girdle the tree (Cranshaw and Tisserat 2012).

In the Appalachian-Cumberland highland, hosts include black walnut (*Juglans nigra*), a source of high-quality lumber and veneer, and butternut (*Juglans cinerea*), of interest because of its rarity. Although rarely found in pure stands, black walnut occurs as scattered individuals in upland

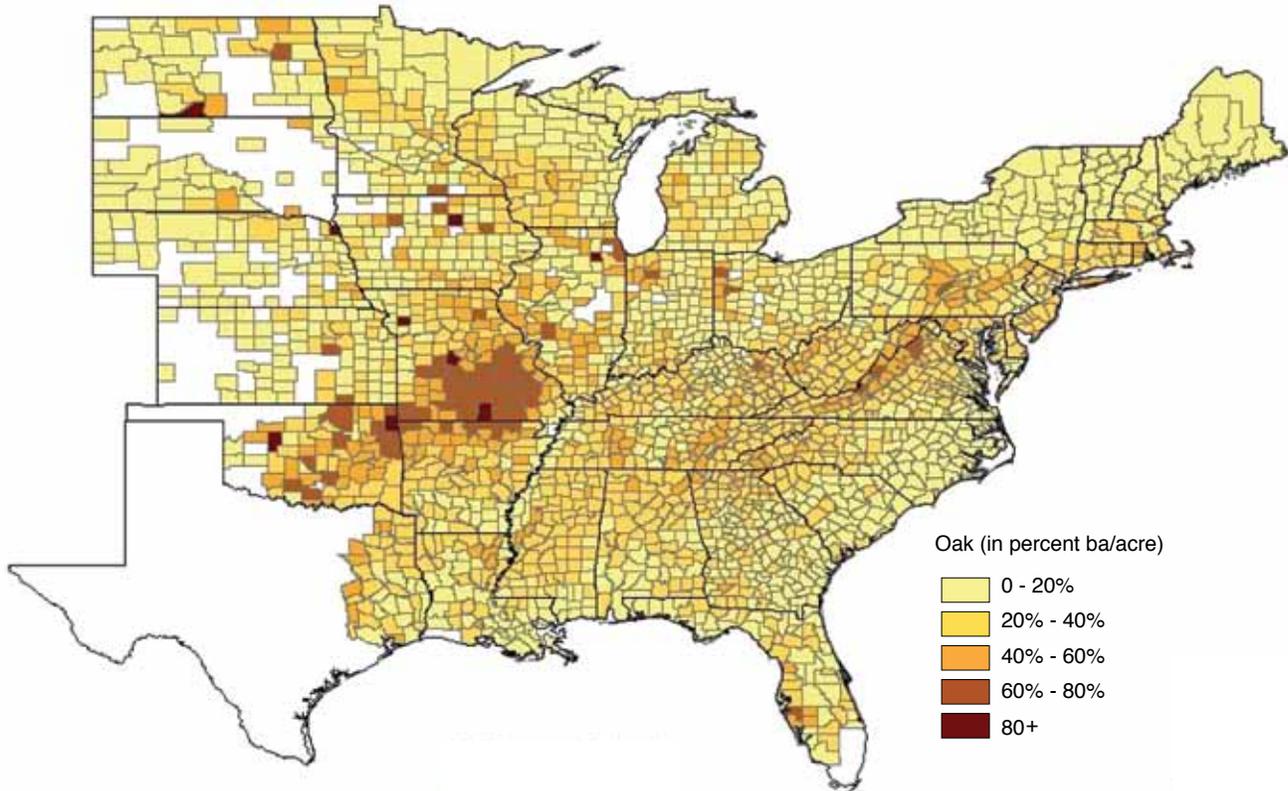


Figure 40—Oak abundance (expressed as a percent of basal area/acre) in the U.S. Appalachian-Cumberland highland (Source: Moser and others 2006).

oak-hickory forests. Throughout Appalachian-Cumberland landscapes, the most recently summarized survey data estimate the live tree volume of black walnut to be about 594.8 million cubic feet (USDA Forest Service 2012).

Confirmed detection of thousand cankers disease is limited to urban settings in four Tennessee counties, with suspected infections occurring in 10 additional counties (Duerr and Mistretta 2013). Additionally, a positive identification of thousand cankers disease recently (2013) occurred in western North Carolina (Haywood County) resulting in wood products quarantine. In the absence of recognized methods for alleviating symptoms or stopping the disease, the only recommended controls are quarantines on the movement of wood in and around known areas of infestations and quick and intense sanitation once the disease has been detected (Cranshaw and Tisserat 2012). In the next 50 years (2010 to 2060), thousand cankers disease will likely be found throughout the range of walnut in the Appalachian-Cumberland highland given that few barriers, including climate, exist to stop the movement of walnut twig beetles and infected wood.

Summary

In the Appalachian-Cumberland highland, the relationships among insects, pathogens, and other drivers of future forest conditions are complex and, for the most part, unknown. However, climate change is likely to exacerbate the impact or increase the aggressiveness (or both) of some insects and pathogens. Given past trends, future importation of additional invasive insects and pathogens through international and domestic commerce and travel is also likely. This means that forest pests, either known or as yet unknown, will continue to be a primary disturbance, and directly and indirectly drive structural and compositional changes in forests (Lovett and others 2006).

For a broader discussion of insects and diseases in the South, see Duerr and Mistretta (2013).

CHAPTER 5.

Effects on Forests and their Values

FOREST CONDITIONS

Across the Appalachian-Cumberland highland, terrain, geology, climate, and soils combine in many ways to produce a highly complex landscape where site quality and productive capacity vary. Most of the variation in productivity is driven by variation in moisture available within as well as among the sections comprising the Appalachian-Cumberland highland.

The structure and composition of southern forests have also been shaped by past patterns of land use. During the early part of the 20th century, widespread exploitive logging, resource extraction (such as coal mining), land clearing for agriculture, and subsequent land abandonment followed by forest reestablishment were the dominant forces shaping the structure and function of southern forests (chapter 1). In more recent history, however, the condition of forests across the South has been more heavily influenced by rates of urbanization coupled with fluctuating timber markets. In 2006, an estimated 62 percent (or 9.7 billion cubic feet) of all growing stock removals in the United States occurred in southern forests, with 70 percent softwoods and 30 percent hardwoods (Smith and others 2009).

Forest Area

In 2010, forest land accounted for 35.4 million acres (table 9), or 57 percent of the about 62.3 million total acres in the Appalachian-Cumberland highland. Of the 35.4 million acres 81 percent was classified as upland hardwoods

Table 9—Forest area, 2010, in the five sections of the U.S. Appalachian-Cumberland highland

Section	Area
	<i>million acres</i>
Blue Ridge Mountains	7.35
Northern Ridge and Valley	4.69
Southern Ridge and Valley	2.09
Cumberland Plateau and Mountains	9.73
Interior Low Plateau	11.54

Oak Regeneration—A Special Challenge in the Appalachian-Cumberland Highland

In all five sections of the Appalachian-Cumberland highland, oak-dominated forests and mixed-hardwood forests that have oaks as a substantial component are an important resource, both economically and ecologically. Failure of successful oak regeneration has long been identified as a high-priority management issue, and is a particularly large problem on mid- to high-quality sites (for example, submesic to mesic sites with high site index values) following forest management activities (such as regeneration harvesting). This failure is ultimately the result if large oak seedlings (seedlings >4 feet tall) or saplings are absent from the understory at the time of harvesting; the cause is a multitude of interacting factors, including a change in climate from frequent multi-year droughts to a period of increased moisture, land use changes, changes in fire regimes from relatively frequent low-intensity fires to a period of fire suppression, the loss of American chestnut, fluctuating herbivore populations, changing forest structure, fewer canopy-gap creating disturbances, and extirpation or elimination of species such as passenger pigeon, woodland bison, and elk (Buchanan and Hart 2012, McEwan and others 2011, Spetich and others 2011, Yarnell 1998). In general, management activities that dramatically reduce the forest canopy without the presence of large oak seedlings or small oak saplings in the understory often result in oak regeneration failure because competitors that include species such as yellow-poplar and red maple quickly outcompete the small, slower growing oak seedlings. Ultimately it is this failure of oak to regenerate following stand-replacing disturbances that is the primary factor leading to an underrepresentation of the oak-dominated and mixed-oak forest types in the younger age classes.

(fig. 41) followed by oak-pine (7 percent), natural pine (6 percent), lowland hardwoods (4 percent), and planted pine (1 percent). Continued changes in the societal forces that shape forest conditions, including urbanization, parcelization, and current and future timber markets, have the potential to alter forest conditions in the Appalachian-Cumberland highland.

Growing Stock

Blue Ridge Mountains section—Growing stock volume increased 24 percent over the past 10 years. Currently (2010), the hardwood growing stock volume in the section is 12.28 billion cubic feet, an increase of about 2.34 billion cubic feet. Softwood growing stock volume is currently at 3.26 billion cubic feet, an increase of 0.17 billion cubic feet.

Interior Low Plateau section—Growing stock volume has increased slightly over the past 10 years. Currently (2010), hardwood growing stock is 16.33 billion cubic feet, an increase of about 3.92 billion cubic feet or 32 percent. Currently (2010), softwood growing stock volume is about 1.17 billion cubic feet, an increase of 0.15 billion cubic feet; although not substantial in absolute terms, this represents a 15 percent increase in softwood growing stock volume. The Interior Low Plateau section has the largest amount of hardwood growing stock volume, reflecting the size of this section relative to the other Appalachian-Cumberland sections.

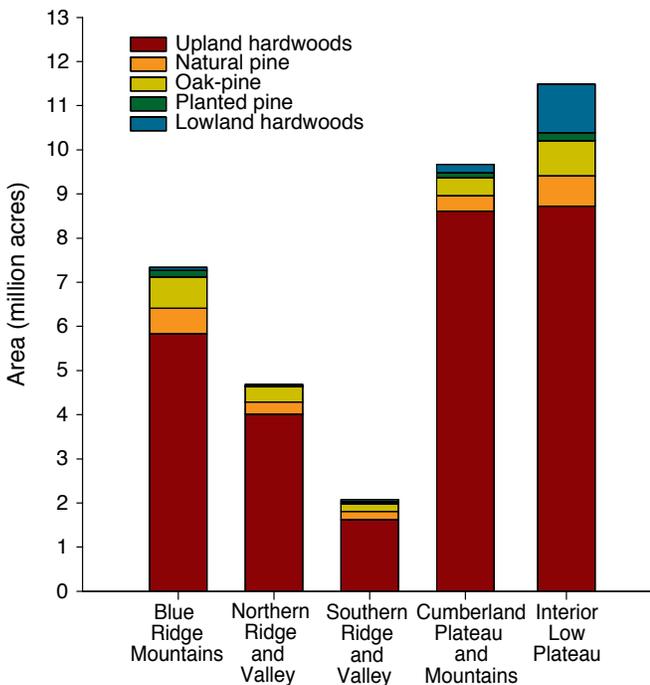


Figure 41—Forest area, 2010, by forest management type and section of the U.S. Appalachian-Cumberland highland.

Northern Ridge and Valley section—Both hardwood and softwood growing stock volumes have decreased slightly over the past 10 years. Currently (2010), the volume of hardwood growing stock is 6.64 billion cubic feet, a decrease of about 0.09 billion cubic feet or 1 percent. Softwood growing stock volume is currently at 1.03 billion cubic feet, a decrease of 0.01 billion cubic feet or 1 percent.

Southern Ridge and Valley section—The Southern Ridge and Valley section has experienced the largest proportional change in both hardwood and softwood growing stock volume of the Appalachian-Cumberland sections over the past 10 years. Currently (2010), the hardwood growing stock volume in the section is 3.07 billion cubic feet, an increase of about 1.01 billion cubic feet, or 50 percent. Softwood growing stock volume is currently at 0.39 billion cubic feet, a decrease of 0.25 billion cubic feet or 40 percent.

Cumberland Plateau and Mountains section—Currently (2010), hardwood growing stock volume is 15.19 billion cubic feet, an increase of about 3.59 billion cubic feet or 31 percent higher than 10 years ago. Softwood growing stock volume is currently at 1.24 billion cubic feet, a decrease of 0.42 billion cubic feet or 25 percent.

Projections of forest conditions were based on the four Cornerstone Futures (A through D) discussed above, plus two others that assume alternative levels of tree planting: Cornerstone E represents Cornerstone A (low population growth and high energy use/economic growth) with an increase from current planting levels, and Cornerstone F represents Cornerstone D (moderate population/income growth and energy use) with a decrease in planting (Wear and others 2013).

Forest Area Projections

Under all six Cornerstone Futures, forests across the Appalachian-Cumberland highland are forecasted to decrease over the next 50 years (fig. 42). Unlike areas of the South where changes in forest conditions are more heavily influenced by harvesting and future timber markets (primarily areas that are dominated by softwood forest types), in the Appalachian-Cumberland highland, where hardwood forest types dominate the landscape, the condition and status of forests are most heavily influenced by urbanization-driven land use changes, which are closely linked with changes in population and income.

Because future changes in forested acreage in the Appalachian-Cumberland highland are primarily driven by urbanization, the proportion of forest land forecasted to

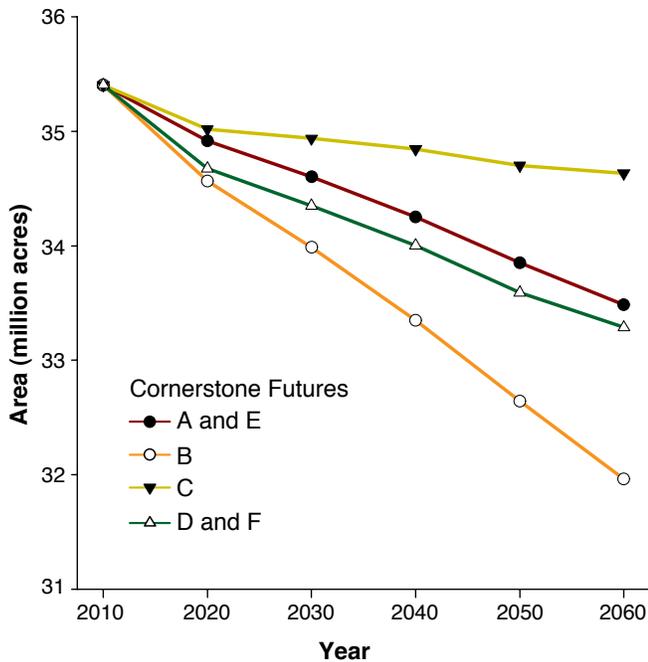


Figure 42—Forecasted change in forest area, 2010 to 2060, in the U.S. Appalachian-Cumberland highland under six alternative scenarios (Wear and others 2013): moderate urbanization/increasing timber prices (Cornerstone A), moderate urbanization/decreasing timber prices (Cornerstone B), low urbanization/increasing timber prices (Cornerstone C), low urbanization/decreasing timber prices (Cornerstone D), moderate urbanization/increasing timber prices/increased tree planting (Cornerstone E), and low urbanization/decreasing timber prices/decreased tree planting (Cornerstone F).

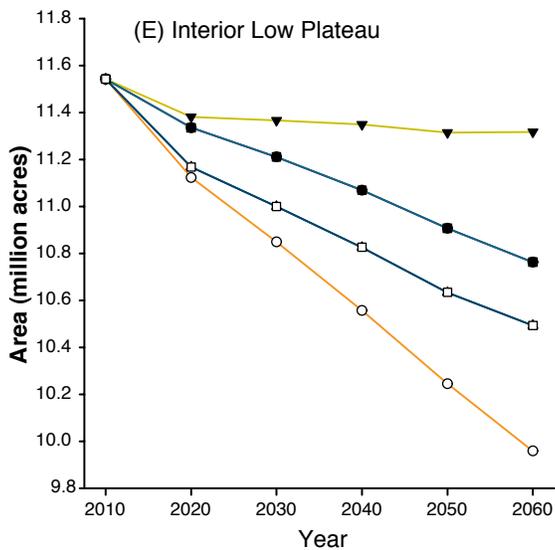
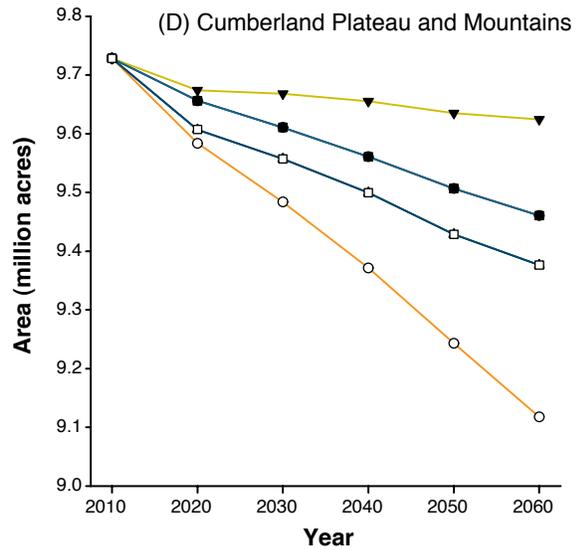
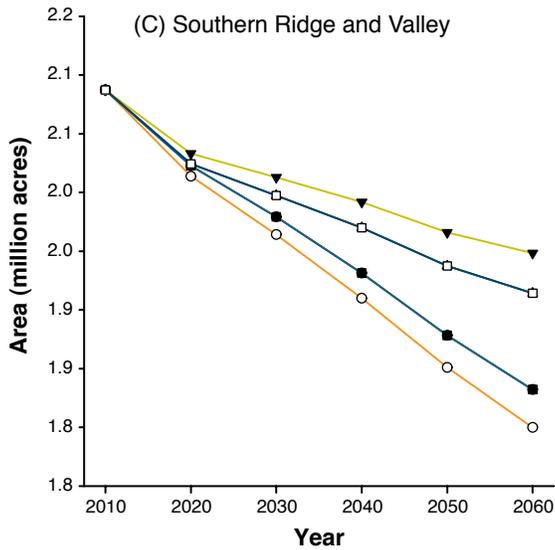
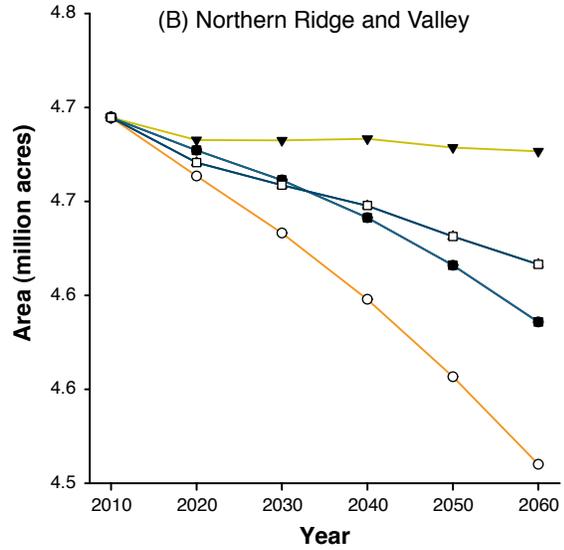
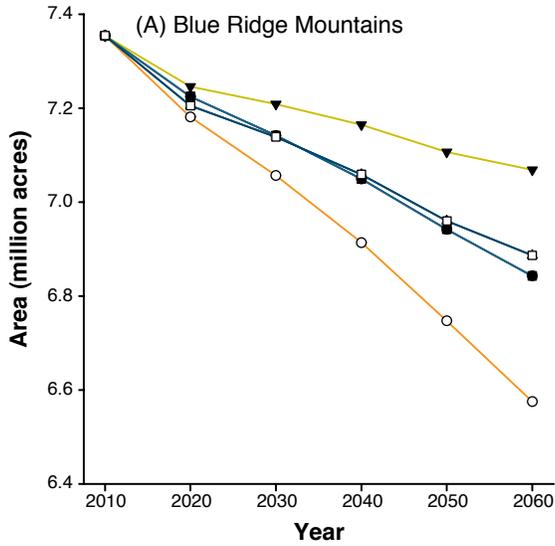
be lost over the next 50 years varies considerably under the Cornerstone Futures, as well as among the five Appalachian-Cumberland sections. If planting rates are held at baseline levels (excluding Cornerstones E and F) the largest loss of forest area would occur under Cornerstone B (high population and income growth coupled with decreasing timber prices): 9.7 percent by 2060, with the largest losses in the Northern Ridge and Valley (13.8 percent), Interior Low Plateau (13.7 percent), and Blue Ridge Mountains (10.6 percent) sections (fig. 43). An improvement in timber markets, even under high population and income growth, would somewhat ameliorate losses as evidenced by the more optimistic projections under Cornerstone A, where higher timber prices shift some rural land toward forest uses resulting in a loss of 5.4 percent (fig. 43).

The lowest rate of forest loss is expected to occur under Cornerstone C (low population and income growth coupled with increasing timber prices): a decrease of 2.2 percent, with the largest losses in the Southern Ridge and Valley (6.7 percent) and Blue Ridge Mountains (3.9 percent)

sections (fig. 43). The effect of timber prices on the amount of forest land comes into play again under Cornerstone D (low population and income growth and decreasing timber prices): at 6 percent, losses are slightly higher than under Cornerstone C (fig. 43).

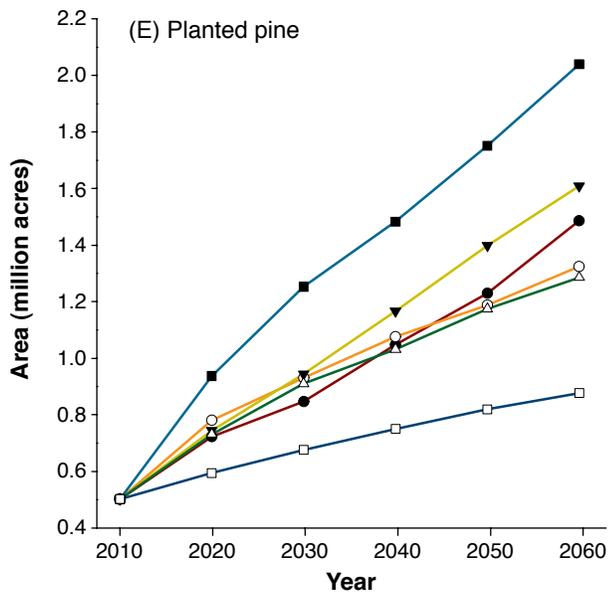
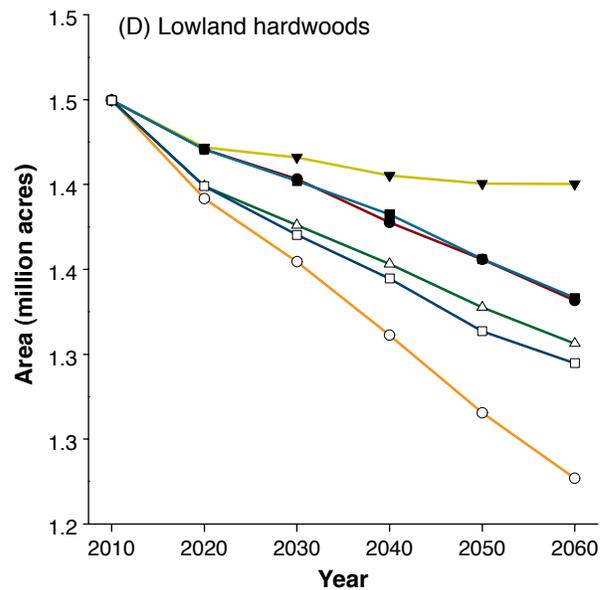
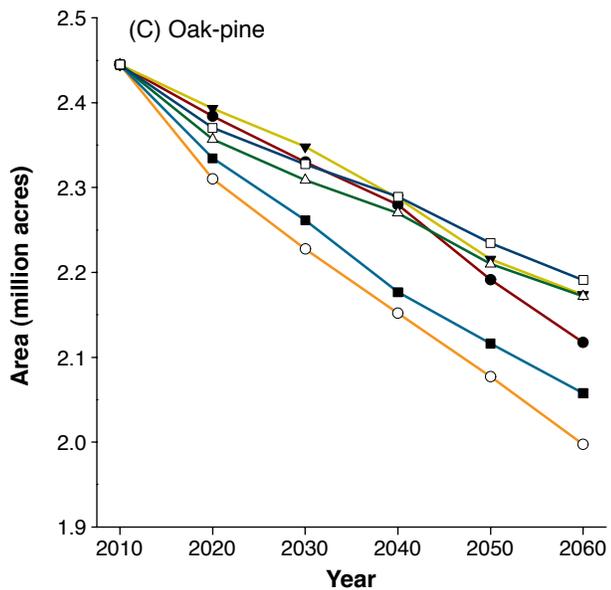
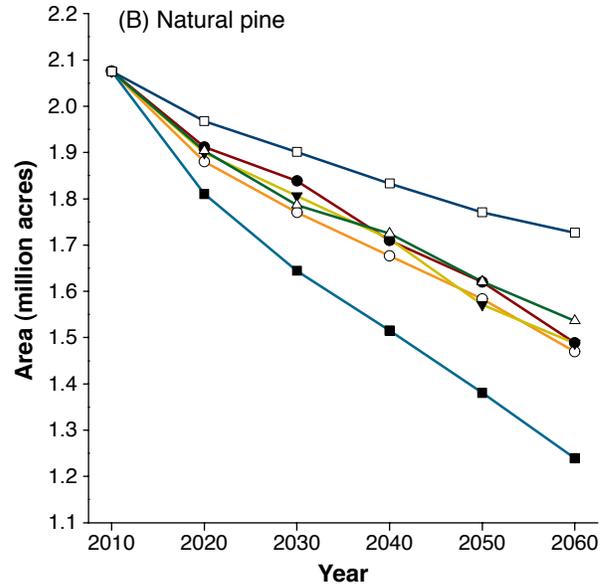
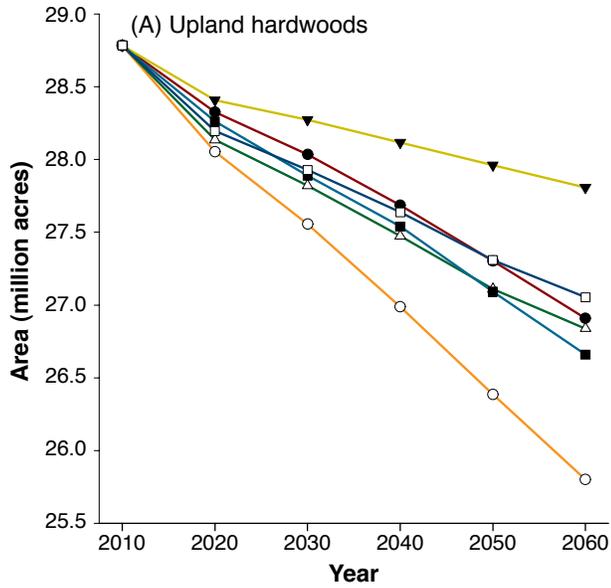
Under all Cornerstone Futures, the loss of forest acreage across the Appalachian-Cumberland highland is forecasted to occur concomitantly with changes in forest management. Currently dominant, upland hardwood forests are forecasted to experience decreases that range from 3.4 percent under Cornerstone C (1.0 million acres) to 10.4 percent under Cornerstone B (2.98 million acres) by 2060 (fig. 44); the Interior Low Plateau, Southern Ridge and Valley, and the Blue Ridge Mountains sections are expected to experience the largest proportional losses (fig. 45). Notwithstanding, the amount of area occupied by the oak-hickory cover type, which is the most prominent cover type in upland hardwood forests, is expected to remain fairly constant across the Cornerstone Futures.

Under all Cornerstone Futures, natural pine, oak-pine, and lowland hardwood acreages are expected to decrease across the Appalachian-Cumberland highland (fig. 44), but planted pine acreage is expected to increase slightly (fig. 44). Figures 46 through 49 show forecasted acreage in natural pine, oak-pine, planted pine, and lowland hardwoods by Appalachian-Cumberland section under Cornerstones A through F. If planting rates are held at baseline levels (excluding Cornerstones E and F), the largest loss of natural pine and oak-pine acreage would occur under Cornerstone B: 29 percent for natural pine and 18 percent for oak-pine. The largest decrease in the natural pine management type would occur under Cornerstone E, which has the highest planting rates and largest increase in the planted pine. If planting rates are held at baseline levels (excluding Cornerstones E and F), the amount of acreage occupied by planted pine would be largest under Cornerstone C, with >1.1 million acres of pine plantations predicted to exist by 2060. If planting rates increase, the acreage of planted pine is forecasted to approach 2.1 million acres (Cornerstone E). Under all Cornerstone Futures, the Blue Ridge Mountains and Interior Low Plateau sections are forecasted to have the largest planted acreages by 2060. However, it is the Northern Ridge and Valley section that is forecasted to experience the largest proportional increase in the amount of the planted pine management type. Despite these apparent increases, planted pine acreage is still forecasted to comprise only 6 percent of the Appalachian-Cumberland land base under the most favorable conditions (Cornerstone E), suggesting it will continue to be of minor importance.



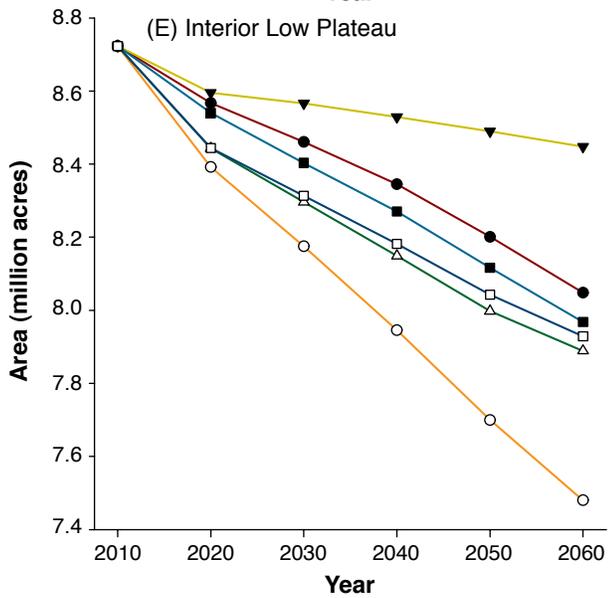
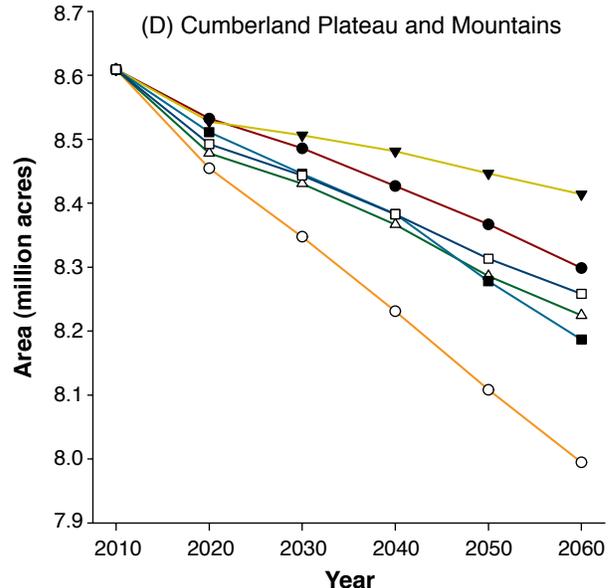
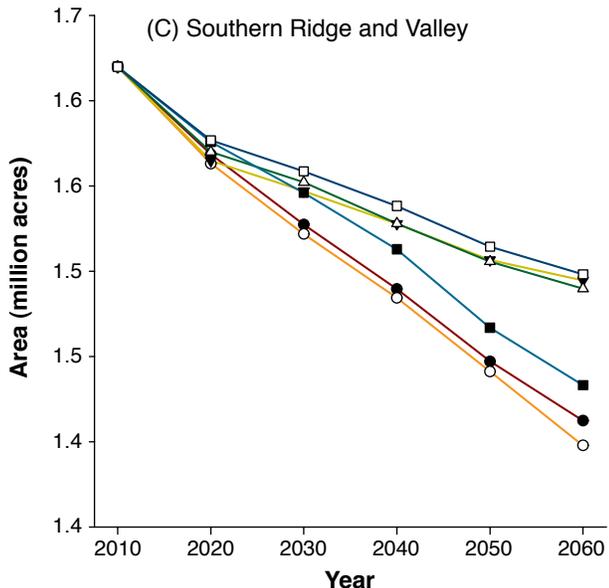
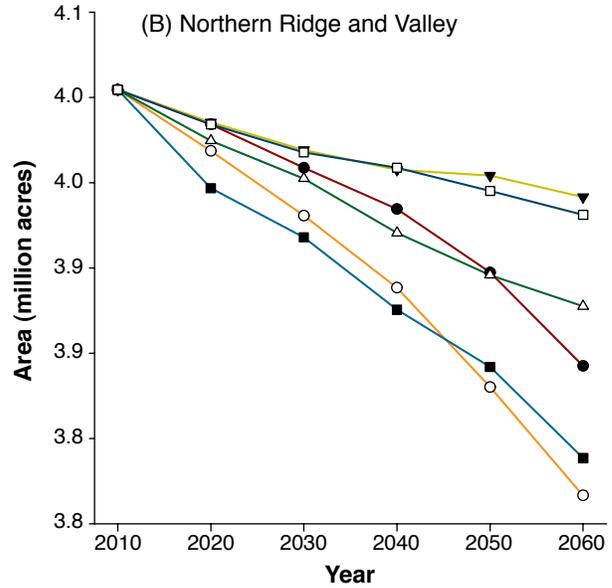
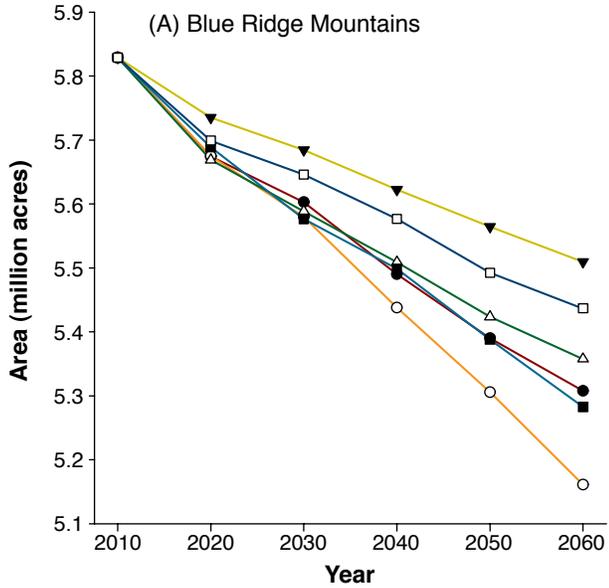
- Cornerstones A and E
- Cornerstone B
- ▼ Cornerstone C
- △ Cornerstones D and F

Figure 43—Forecasted change in forest area for the five sections of the U.S. Appalachian-Cumberland highland—(A) Blue Ridge Mountains, (B) Northern Ridge and Valley, (C) Southern Ridge and Valley, (D) Cumberland Plateau and Mountains, and (E) Interior Low Plateau—under six alternative scenarios (Wear and others 2013): moderate urbanization/increasing timber prices (Cornerstone A), moderate urbanization/decreasing timber prices (Cornerstone B), low urbanization/increasing timber prices (Cornerstone C), low urbanization/decreasing timber prices (Cornerstone D), moderate urbanization/increasing timber prices/increased tree planting (Cornerstone E), and low urbanization/decreasing timber prices/decreased tree planting (Cornerstone F).



- Cornerstone A
- Cornerstone B
- ▼ Cornerstone C
- △ Cornerstone D
- Cornerstone E
- Cornerstone F

Figure 44—Forecasted changes in forest area in the U.S. Appalachian-Cumberland highland by forest management types—(A) upland hardwoods, (B) natural pine, (C) oak-pine, (D) lowland hardwoods, and (E) planted pine—under six alternative scenarios (Wear and others 2013): moderate urbanization/increasing timber prices (Cornerstone A), moderate urbanization/decreasing timber prices (Cornerstone B), low urbanization/increasing timber prices (Cornerstone C), low urbanization/decreasing timber prices (Cornerstone D), moderate urbanization/increasing timber prices/increased tree planting (Cornerstone E), and low urbanization/decreasing timber prices/decreased tree planting (Cornerstone F).



- Cornerstone A
- Cornerstone B
- ▼ Cornerstone C
- △ Cornerstone D
- Cornerstone E
- Cornerstone F

Figure 45—Forecasted change in upland hardwood forest area for the five sections of the U.S. Appalachian-Cumberland highland—(A) Blue Ridge Mountains, (B) Northern Ridge and Valley, (C) Southern Ridge and Valley, (D) Cumberland Plateau and Mountains, and (E) Interior Low Plateau—under six alternative scenarios (Wear and others 2013): moderate urbanization/increasing timber prices (Cornerstone A), moderate urbanization/decreasing timber prices (Cornerstone B), low urbanization/increasing timber prices (Cornerstone C), low urbanization/decreasing timber prices (Cornerstone D), moderate urbanization/increasing timber prices/increased tree planting (Cornerstone E), and low urbanization/decreasing timber prices/decreased tree planting (Cornerstone F).

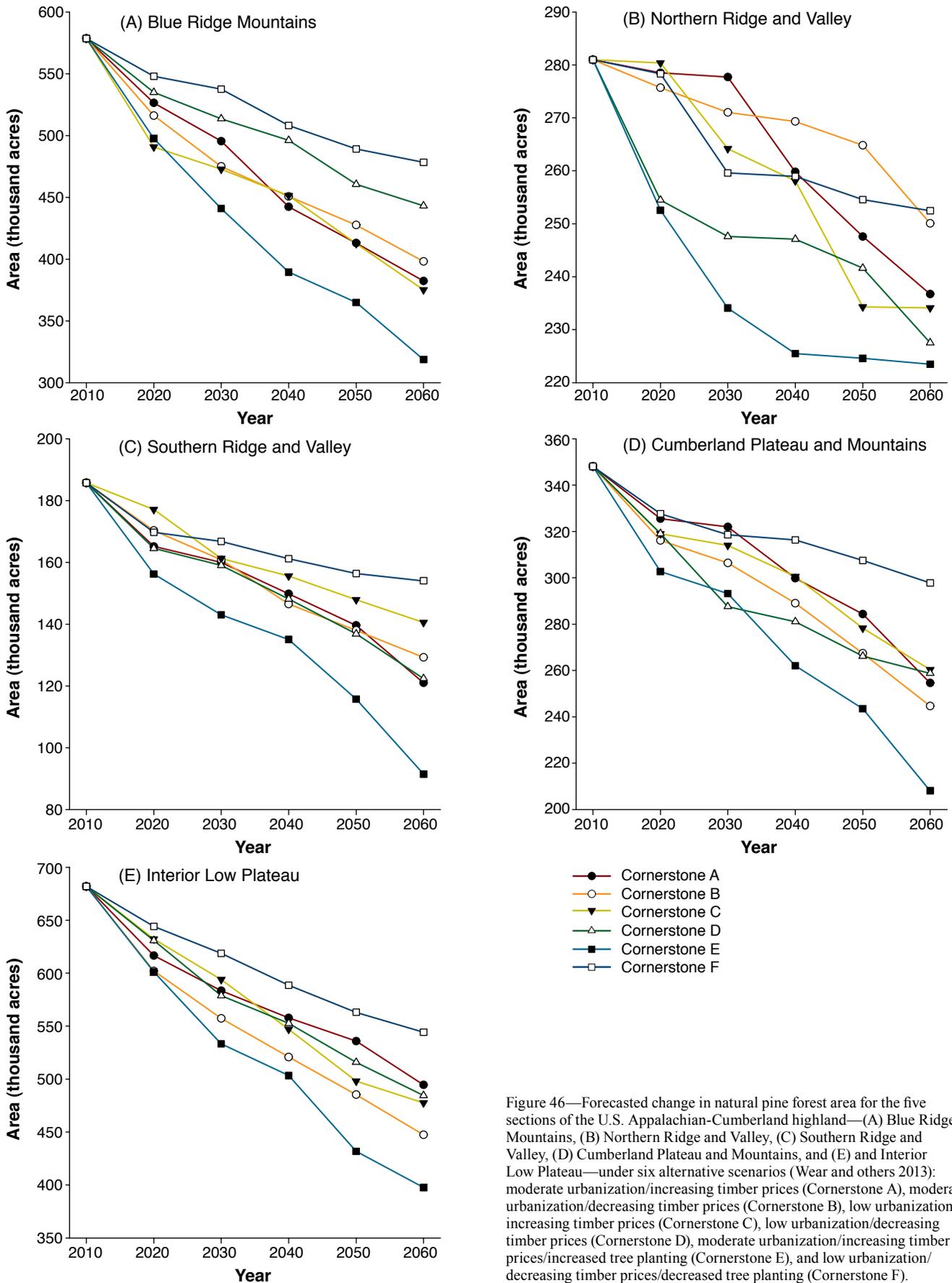


Figure 46—Forecasted change in natural pine forest area for the five sections of the U.S. Appalachian-Cumberland highland—(A) Blue Ridge Mountains, (B) Northern Ridge and Valley, (C) Southern Ridge and Valley, (D) Cumberland Plateau and Mountains, and (E) Interior Low Plateau—under six alternative scenarios (Wear and others 2013): moderate urbanization/increasing timber prices (Cornerstone A), moderate urbanization/decreasing timber prices (Cornerstone B), low urbanization/increasing timber prices (Cornerstone C), low urbanization/decreasing timber prices (Cornerstone D), moderate urbanization/increasing timber prices/increased tree planting (Cornerstone E), and low urbanization/decreasing timber prices/decreased tree planting (Cornerstone F).

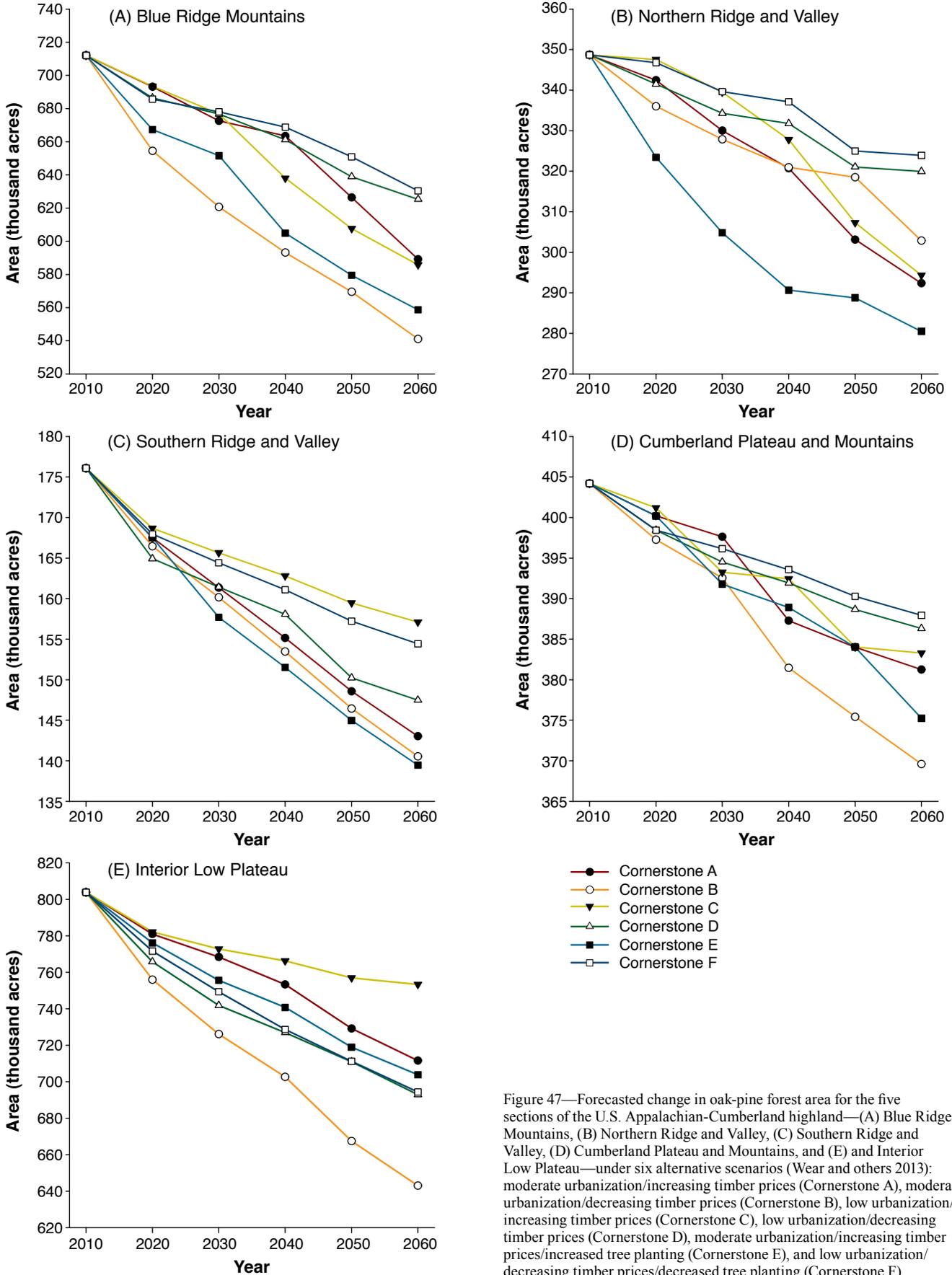
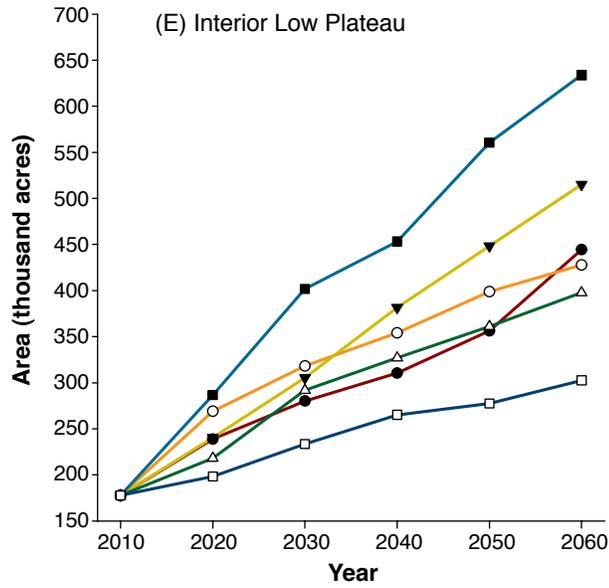
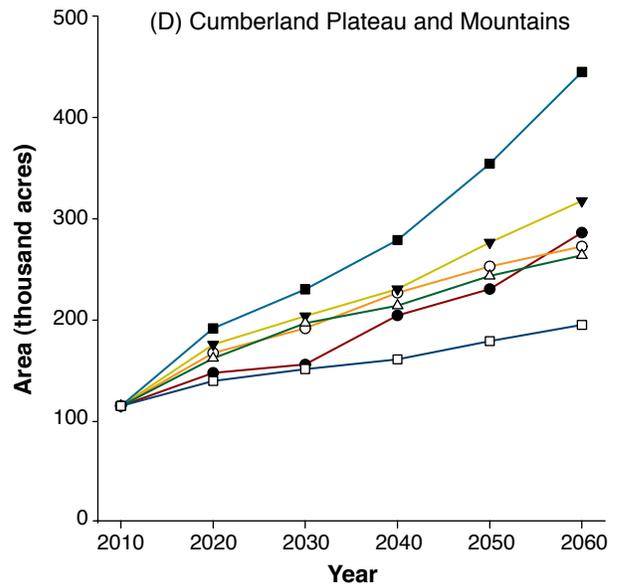
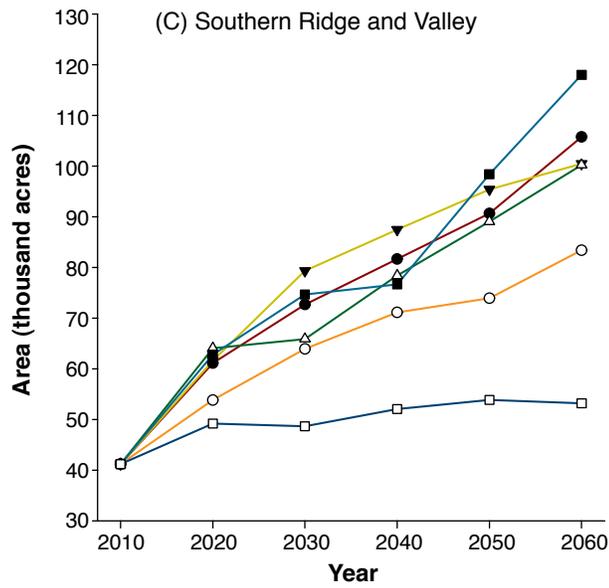
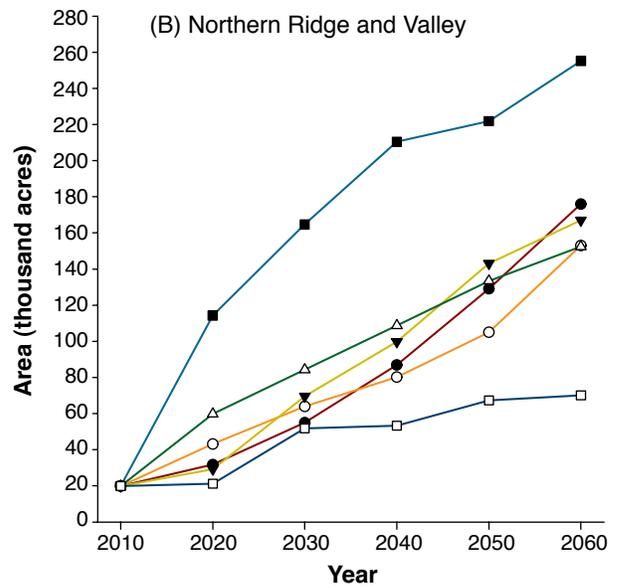
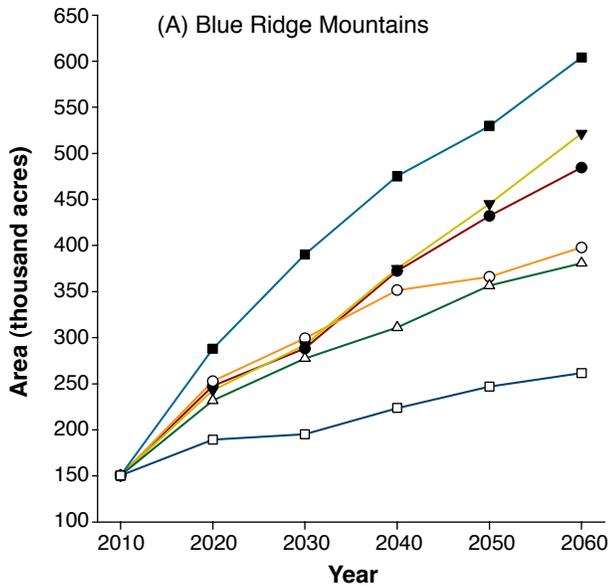


Figure 47—Forecasted change in oak-pine forest area for the five sections of the U.S. Appalachian-Cumberland highland—(A) Blue Ridge Mountains, (B) Northern Ridge and Valley, (C) Southern Ridge and Valley, (D) Cumberland Plateau and Mountains, and (E) Interior Low Plateau—under six alternative scenarios (Wear and others 2013): moderate urbanization/increasing timber prices (Cornerstone A), moderate urbanization/decreasing timber prices (Cornerstone B), low urbanization/increasing timber prices (Cornerstone C), low urbanization/decreasing timber prices (Cornerstone D), moderate urbanization/increasing timber prices/increased tree planting (Cornerstone E), and low urbanization/decreasing timber prices/decreased tree planting (Cornerstone F).



- Cornerstone A
- Cornerstone B
- ▼ Cornerstone C
- △ Cornerstone D
- Cornerstone E
- Cornerstone F

Figure 48—Forecasted change in planted pine forest area for the five sections of the U.S. Appalachian-Cumberland highland—(A) Blue Ridge Mountains, (B) Northern Ridge and Valley, (C) Southern Ridge and Valley, (D) Cumberland Plateau and Mountains, and (E) Interior Low Plateau—under six alternative scenarios (Wear and others 2013): moderate urbanization/increasing timber prices (Cornerstone A), moderate urbanization/decreasing timber prices (Cornerstone B), low urbanization/increasing timber prices (Cornerstone C), low urbanization/decreasing timber prices (Cornerstone D), moderate urbanization/increasing timber prices/increased tree planting (Cornerstone E), and low urbanization/decreasing timber prices/decreased tree planting (Cornerstone F).

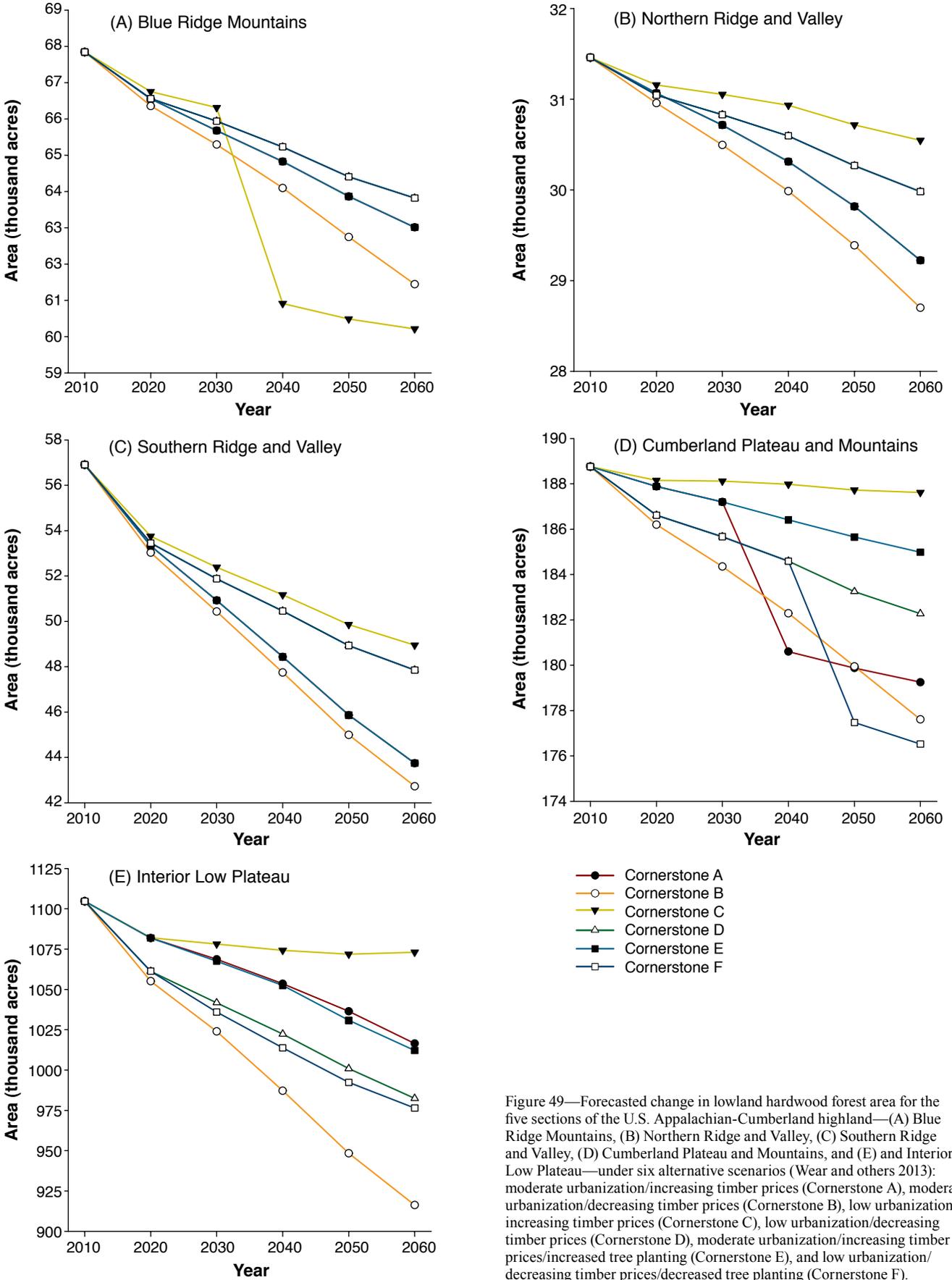


Figure 49—Forecasted change in lowland hardwood forest area for the five sections of the U.S. Appalachian-Cumberland highland—(A) Blue Ridge Mountains, (B) Northern Ridge and Valley, (C) Southern Ridge and Valley, (D) Cumberland Plateau and Mountains, and (E) Interior Low Plateau—under six alternative scenarios (Wear and others 2013): moderate urbanization/increasing timber prices (Cornerstone A), moderate urbanization/decreasing timber prices (Cornerstone B), low urbanization/increasing timber prices (Cornerstone C), low urbanization/decreasing timber prices (Cornerstone D), moderate urbanization/increasing timber prices/increased tree planting (Cornerstone E), and low urbanization/decreasing timber prices/decreased tree planting (Cornerstone F).

Growing Stock Projections

The importance of upland hardwoods on Appalachian-Cumberland landscapes is demonstrated by comparing hardwood growing stock volume (53.5 billion total cubic feet) to softwood growing stock volume (7.1 billion total cubic feet) under current (2010) and forecasted conditions (fig. 50).

Hardwood growing stock—Similar to the amount of hardwood forest area, levels of total hardwood growing stock are tied to urbanization-driven changes in land use. Hardwood growing stock at the end of the projection period (2060) is forecasted to exceed current levels under the three low-growth Cornerstone Futures (fig. 51): 0.8 percent (0.4 billion cubic feet) under Cornerstone C, 3.0 percent (1.6 billion cubic feet) under Cornerstone D, and 3.9 percent (2.1 billion cubic feet)

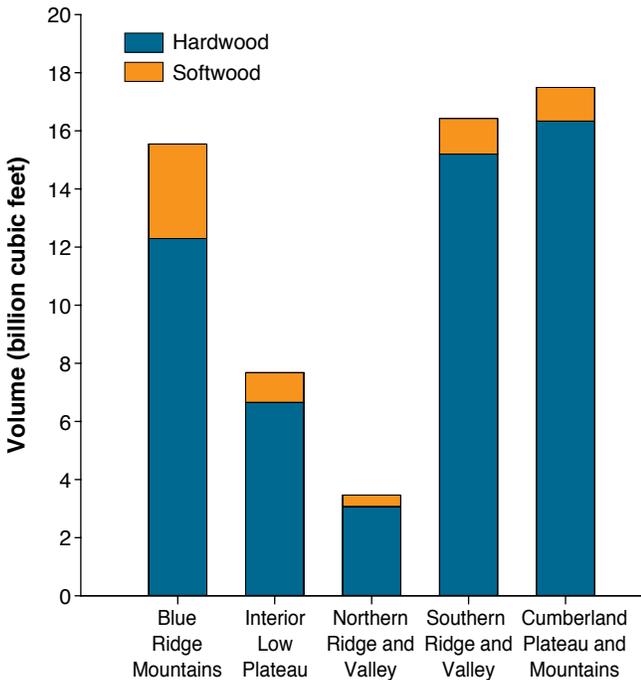


Figure 50—Hardwood and softwood growing stock volume, 2010, by U.S. Appalachian-Cumberland section.

under Cornerstone F. Notwithstanding these overall increases, a decrease is expected for the Blue Ridge Mountains section under all three Cornerstones, and for the Southern Ridge and Valley section under Cornerstone C (fig. 52).

Under Cornerstones A, B, and E hardwood growing stock would increase from 2010 to 2030 for all sections, followed by a precipitous decrease from 2030 to 2060 (fig. 51). Under the three high-growth Cornerstone Futures, total hardwood growing stock volume in 2060 is forecasted to decrease from 2010 levels: 2.6 percent (1.4 billion cubic feet) under Cornerstones A and E and 2.0 percent (1.1 billion cubic feet) for Cornerstone B, with the Blue Ridge Mountains section experiencing the largest proportional decrease under Cornerstones A and B and the Southern Ridge and Valley section experiencing the largest proportional decrease under Cornerstone E (fig. 52).

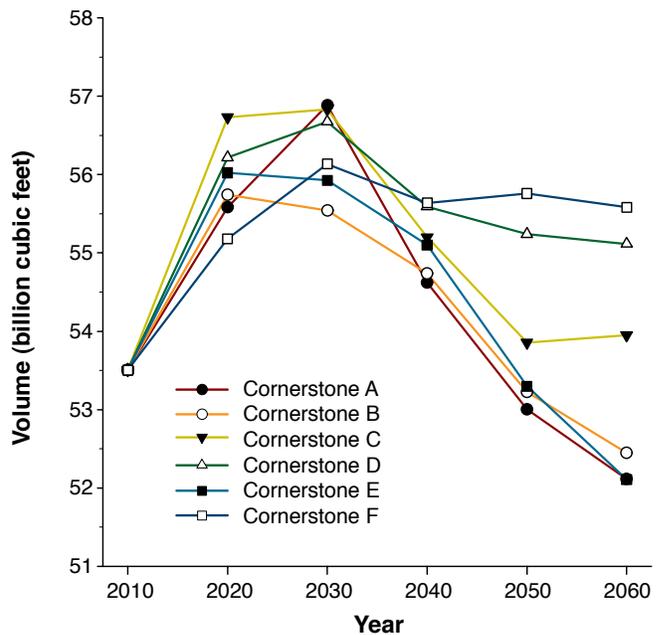
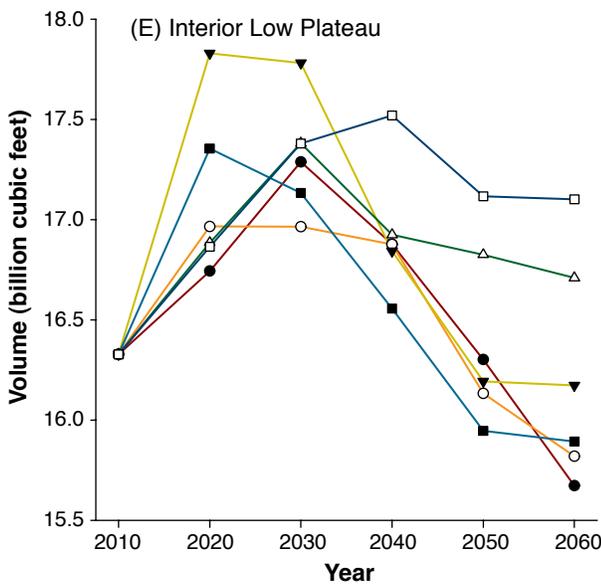
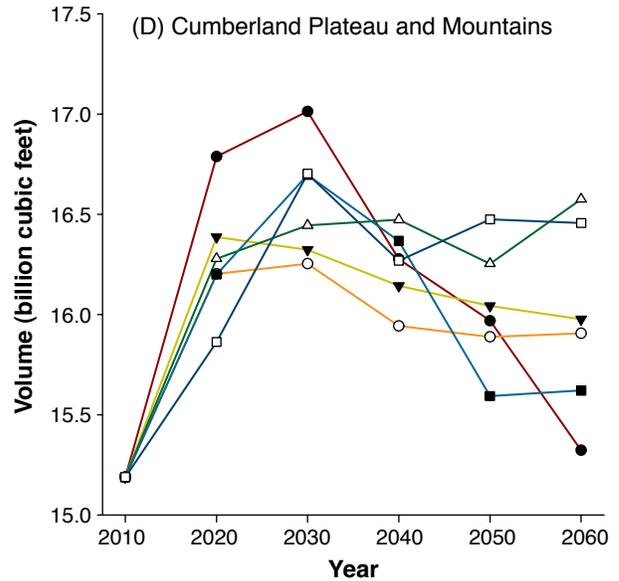
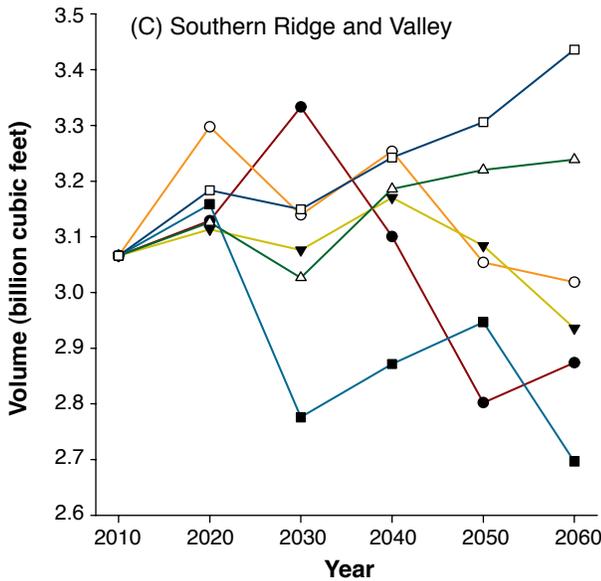
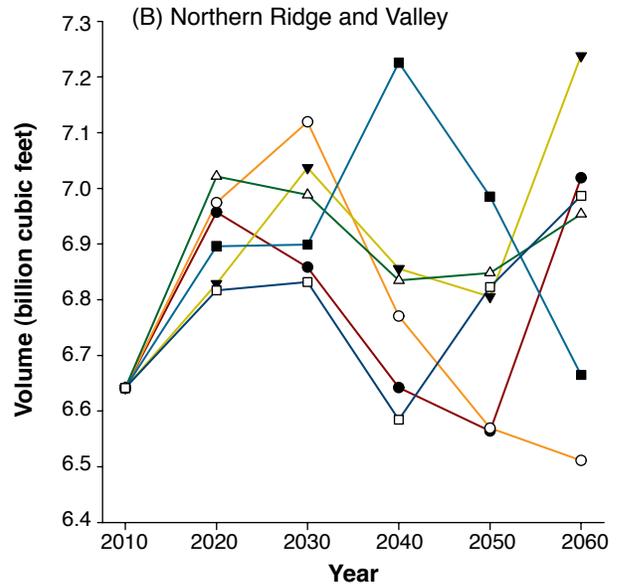
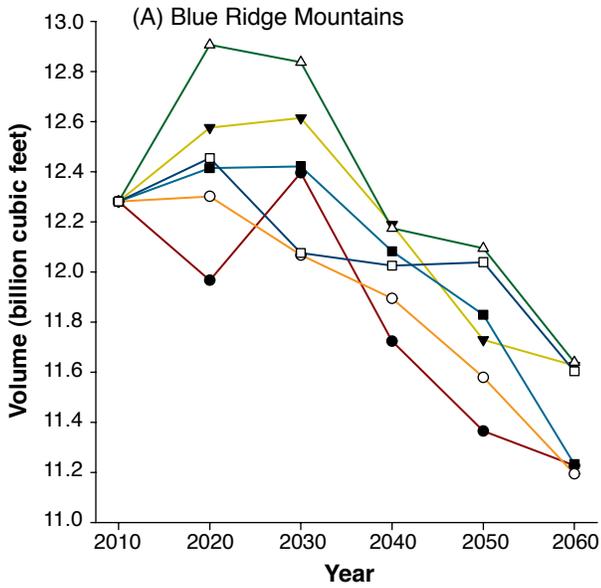


Figure 51—Forecasted change in hardwood growing stock, 2010 to 2060, in the U.S. Appalachian-Cumberland highland under six alternative scenarios (Wear and others 2013): moderate urbanization/increasing timber prices (Cornerstone A), moderate urbanization/decreasing timber prices (Cornerstone B), low urbanization/increasing timber prices (Cornerstone C), low urbanization/decreasing timber prices (Cornerstone D), moderate urbanization/increasing timber prices/increased tree planting (Cornerstone E), and low urbanization/decreasing timber prices/decreased tree planting (Cornerstone F).



- Cornerstone A
- Cornerstone B
- ▼ Cornerstone C
- △ Cornerstone D
- Cornerstone E
- Cornerstone F

Figure 52—Forecasted change in hardwood growing stock, 2010 to 2060, for the five sections of the U.S. Appalachian-Cumberland highland—(A) Blue Ridge Mountains, (B) Northern Ridge and Valley, (C) Southern Ridge and Valley, (D) Cumberland Plateau and Mountains, and (E) Interior Low Plateau—under six alternative scenarios (Wear and others 2013): moderate urbanization/increasing timber prices (Cornerstone A), moderate urbanization/decreasing timber prices (Cornerstone B), low urbanization/increasing timber prices (Cornerstone C), low urbanization/decreasing timber prices (Cornerstone D), moderate urbanization/increasing timber prices/increased tree planting (Cornerstone E), and low urbanization/decreasing timber prices/decreased tree planting (Cornerstone F).

Softwood growing stock—By 2060, increases in total softwood growing stock volume over current (2010) levels (fig. 53) would range from 4.4 percent under Cornerstone B (high population and income growth with decreasing timber prices and baseline planting rates) to 14.2 percent under Cornerstone E (high population and income growth with increasing timber prices and increased planting rates). Under Cornerstones D and E, the volume would increase steadily. In contrast, under Cornerstones A and C, peaks

in volume would be followed by precipitous decreases throughout the 50 year projection period, although the 2060 volumes would still be larger than 2010 volumes. Under Cornerstone B, only the Blue Ridge Mountains section is forecasted to experience a decrease in softwood growing stock volume (17.8 percent); for other sections, increases would range from 11.1 percent in the Cumberland Plateau and Mountains section to 58.4 percent in the Southern Ridge and Valley section (fig. 54).

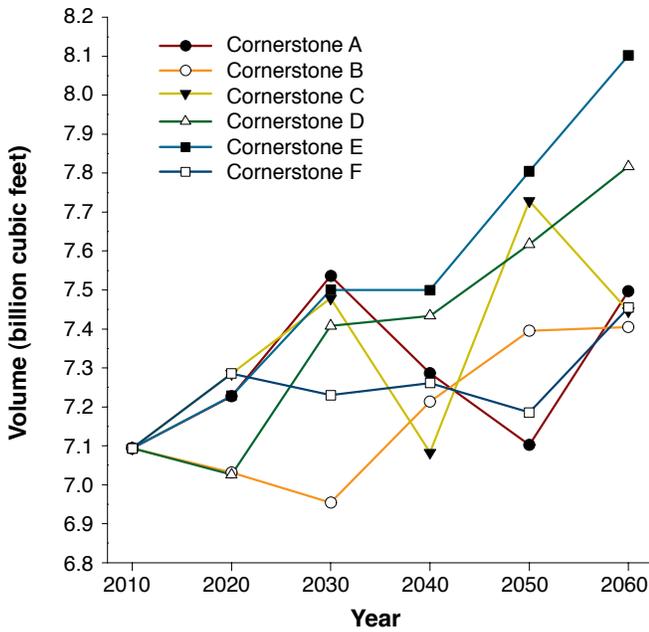


Figure 53—Forecasted change in softwood growing stock, 2010 to 2060, in the U.S. Appalachian-Cumberland highland under six alternative scenarios (Wear and others 2013): moderate urbanization/increasing timber prices (Cornerstone A), moderate urbanization/decreasing timber prices (Cornerstone B), low urbanization/increasing timber prices (Cornerstone C), low urbanization/decreasing timber prices (Cornerstone D), moderate urbanization/increasing timber prices/increased tree planting (Cornerstone E), and low urbanization/decreasing timber prices/decreased tree planting (Cornerstone F).

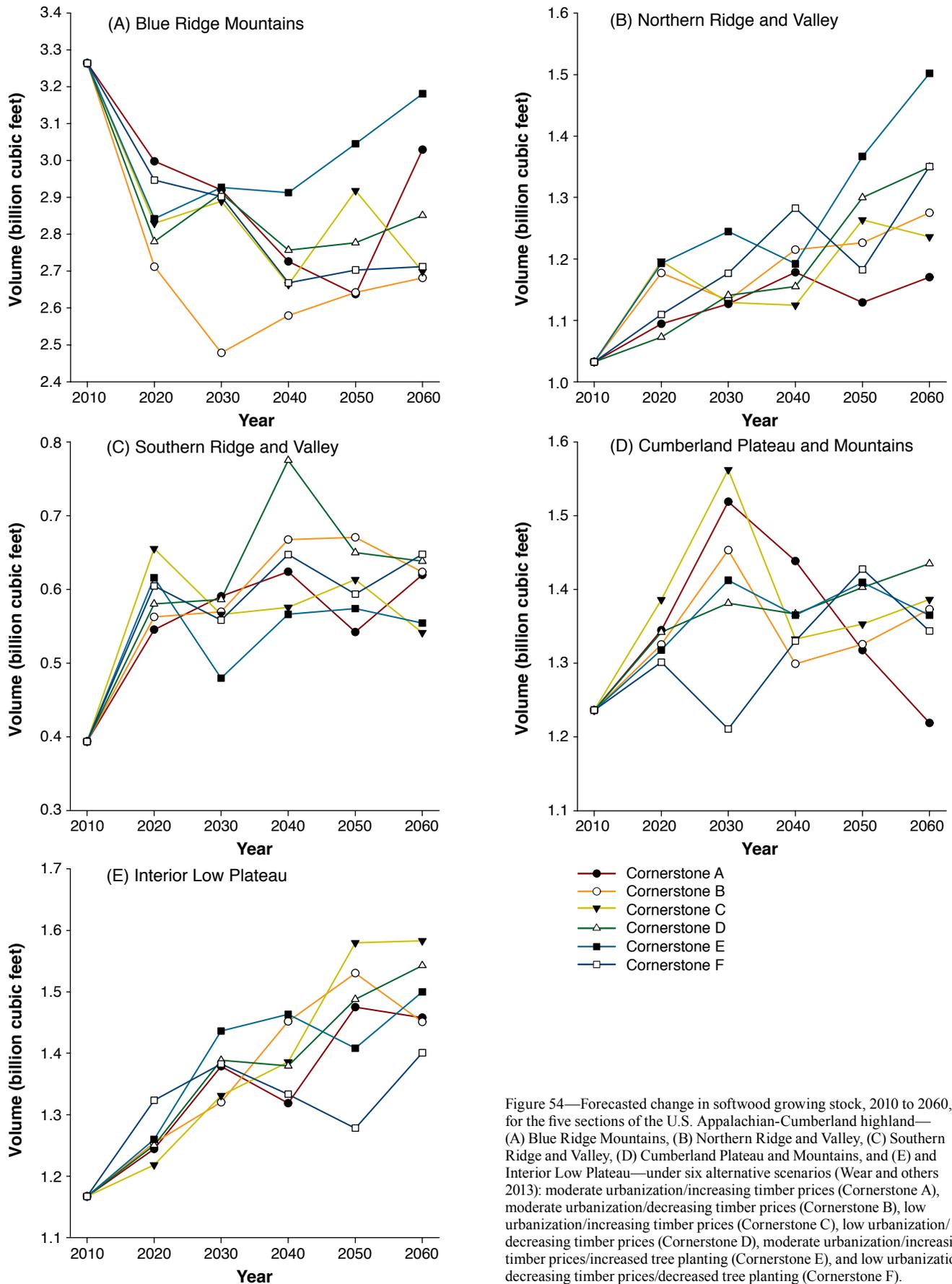


Figure 54—Forecasted change in softwood growing stock, 2010 to 2060, for the five sections of the U.S. Appalachian-Cumberland highland—(A) Blue Ridge Mountains, (B) Northern Ridge and Valley, (C) Southern Ridge and Valley, (D) Cumberland Plateau and Mountains, and (E) Interior Low Plateau—under six alternative scenarios (Wear and others 2013): moderate urbanization/increasing timber prices (Cornerstone A), moderate urbanization/decreasing timber prices (Cornerstone B), low urbanization/increasing timber prices (Cornerstone C), low urbanization/decreasing timber prices (Cornerstone D), moderate urbanization/increasing timber prices/increased tree planting (Cornerstone E), and low urbanization/decreasing timber prices/decreased tree planting (Cornerstone F).

Sawtimber growing stock—Current sawtimber growing stock volume (2010) across the Appalachian-Cumberland highland is about 181.9 billion board feet for hardwoods and 28.7 billion board feet for softwoods (fig. 55). Under all Cornerstones, the amount of hardwood sawtimber growing stock in 2060 is forecasted to exceed current (2010) levels. This increase, regardless of Cornerstone Future, likely reflects a continued shift in the age class distribution of many of the managed forest types towards older—and hence, for the most part—larger stands. The proportional increase in growing stock volume of hardwood sawtimber from 2010 to 2060 (fig. 56) would be largest under the low population and income growth projections (Cornerstones C, D, and F). Under Cornerstones D and F, the volume increase would be relatively steady. In contrast, under Cornerstones A, B, C, and E, strong increases occurring from 2010 to 2030 would be followed by a precipitous decrease (albeit still larger than in 2010) from 2030 to 2060. Although volume is forecasted to increase, substantial variability among the sections is forecasted (fig. 57). For example, regardless of the Cornerstone Future, the Blue Ridge Mountains section is forecasted to experience a decrease in hardwood sawtimber growing stock volume under all Cornerstones, ranging from 4 percent under Cornerstone C (1.7 billion board feet) to 6.7 percent under Cornerstone E (2.9 billion board feet).

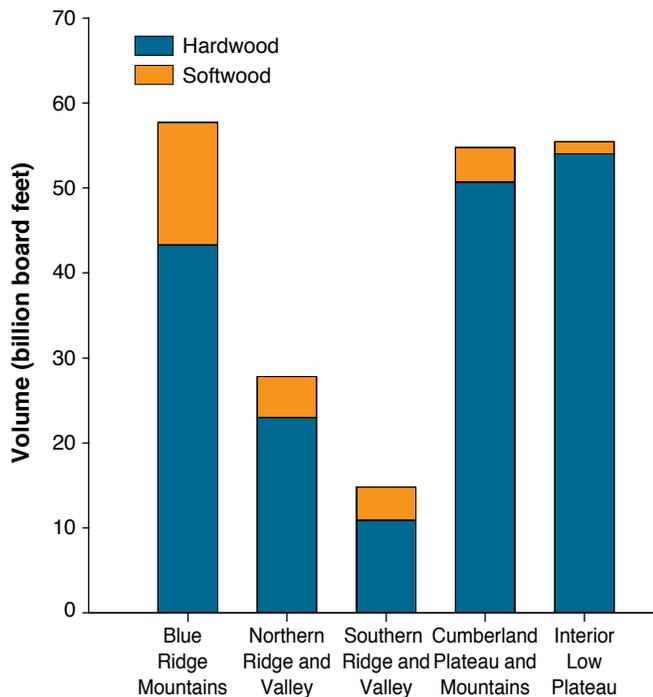


Figure 55—Hardwood and softwood sawtimber growing stock volume, 2010, by U.S. Appalachian-Cumberland section.

All Cornerstones with the exception of Cornerstone C are forecasted to result in an increase in the volume of softwood sawtimber from 2010 to 2060 (fig. 58). Under Cornerstones D, E, and F, the increase would be steady. Under Cornerstones A, B, and C, increases and decreases would occur rapidly throughout the 50-year projection period. If planting rates are held at baseline levels (excluding Cornerstones E and F), the largest increase—7.3 percent (2.1 billion board feet)—is expected under Cornerstone D. If planting rates increase, volume increases would range from 8.8 percent (2.5 billion board feet) under Cornerstone E to 5.0 percent (1.4 billion board feet) under Cornerstone F. Only the Blue Ridge Mountains and the Northern Ridge and Valley sections are forecasted to experience a loss in volume, with the Blue Ridge Mountains section losing volume under all Cornerstone Futures and the Northern Ridge and Valley section losing volume under Cornerstone A only (fig. 59). The Interior Low Plateau section is forecasted to experience the largest proportional increase under all Cornerstone Futures, ranging from 54.1 percent (0.8 billion board feet) under Cornerstone E to 98.9 percent (1.1 billion board feet) under Cornerstone F.

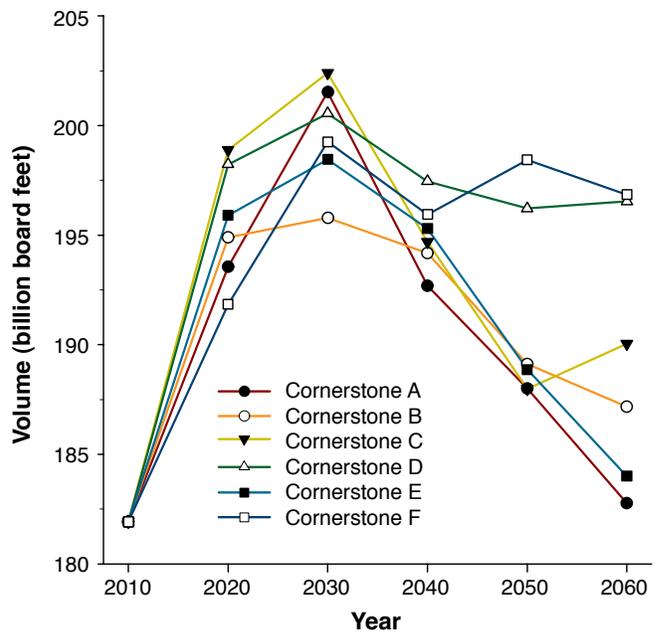


Figure 56—Forecasted change in hardwood sawtimber growing stock, 2010 to 2060, in the U.S. Appalachian-Cumberland highland under six alternative scenarios (Wear and others 2013): moderate urbanization/increasing timber prices (Cornerstone A), moderate urbanization/decreasing timber prices (Cornerstone B), low urbanization/increasing timber prices (Cornerstone C), low urbanization/decreasing timber prices (Cornerstone D), moderate urbanization/increasing timber prices/increased tree planting (Cornerstone E), and low urbanization/decreasing timber prices/decreased tree planting (Cornerstone F).

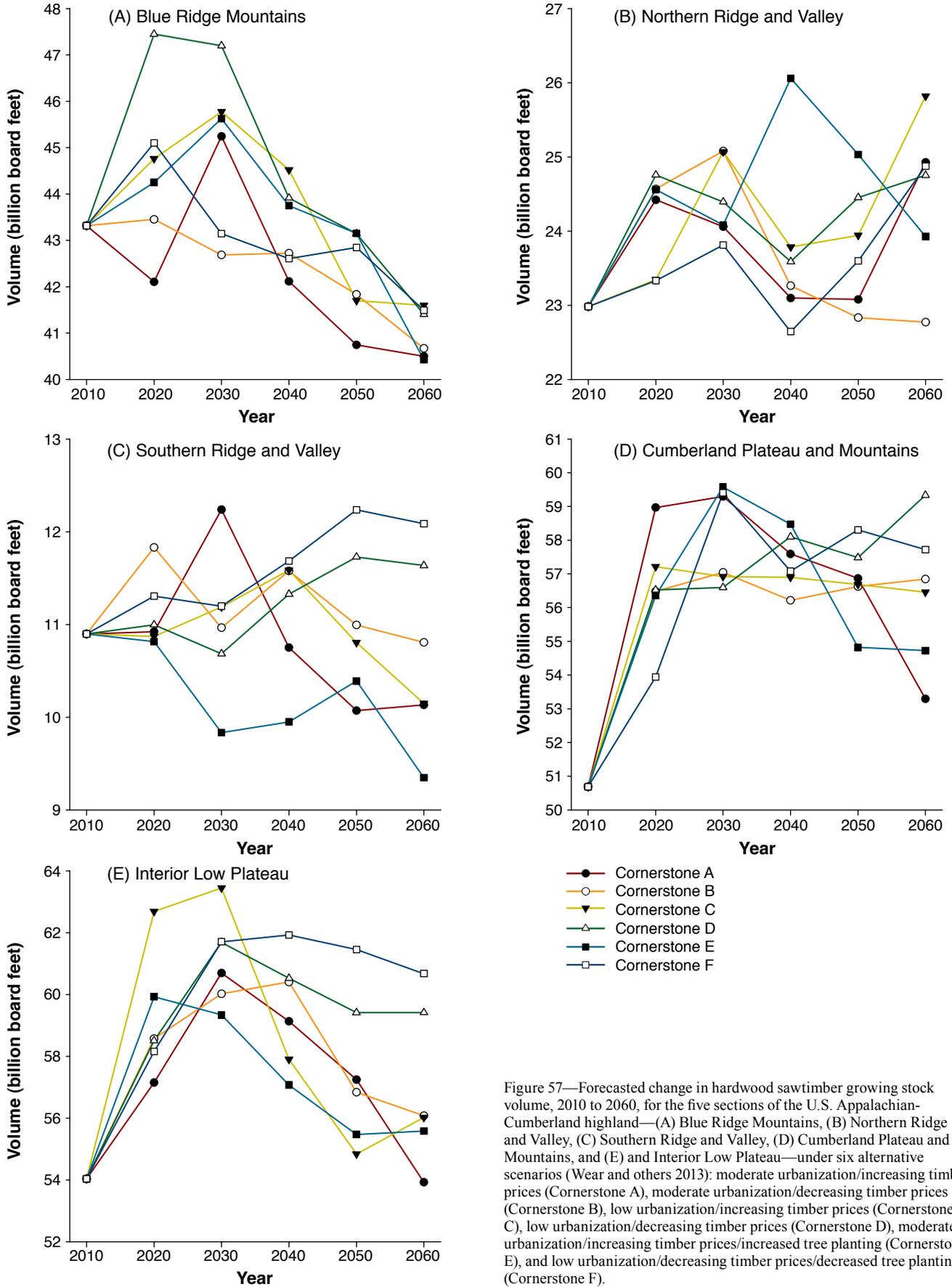


Figure 57—Forecasted change in hardwood sawtimber growing stock volume, 2010 to 2060, for the five sections of the U.S. Appalachian-Cumberland highland—(A) Blue Ridge Mountains, (B) Northern Ridge and Valley, (C) Southern Ridge and Valley, (D) Cumberland Plateau and Mountains, and (E) and Interior Low Plateau—under six alternative scenarios (Wear and others 2013): moderate urbanization/increasing timber prices (Cornerstone A), moderate urbanization/decreasing timber prices (Cornerstone B), low urbanization/increasing timber prices (Cornerstone C), low urbanization/decreasing timber prices (Cornerstone D), moderate urbanization/increasing timber prices/increased tree planting (Cornerstone E), and low urbanization/decreasing timber prices/decreased tree planting (Cornerstone F).

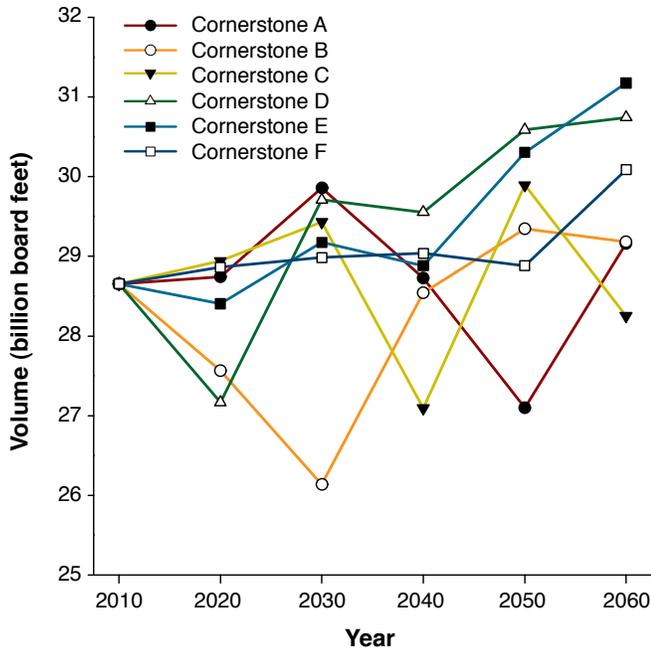


Figure 58—Forecasted change in softwood sawtimber growing stock volume, 2010 to 2060, in the U.S. Appalachian-Cumberland highland under six alternative scenarios (Wear and others 2013): moderate urbanization/increasing timber prices (Cornerstone A), moderate urbanization/decreasing timber prices (Cornerstone B), low urbanization/increasing timber prices (Cornerstone C), low urbanization/decreasing timber prices (Cornerstone D), moderate urbanization/increasing timber prices/increased tree planting (Cornerstone E), and low urbanization/decreasing timber prices/decreased tree planting (Cornerstone F).

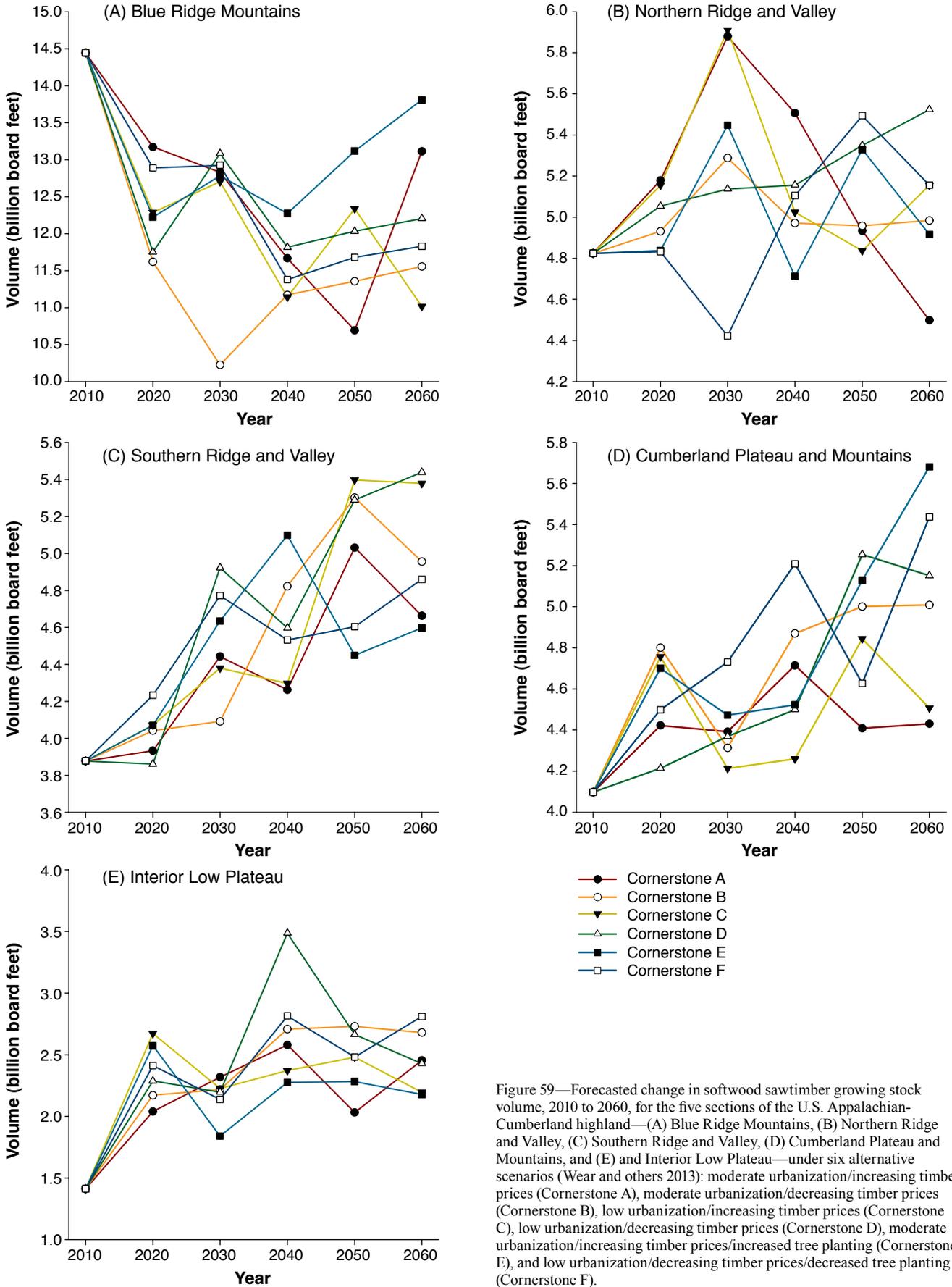


Figure 59—Forecasted change in softwood sawtimber growing stock volume, 2010 to 2060, for the five sections of the U.S. Appalachian-Cumberland highland—(A) Blue Ridge Mountains, (B) Northern Ridge and Valley, (C) Southern Ridge and Valley, (D) Cumberland Plateau and Mountains, and (E) Interior Low Plateau—under six alternative scenarios (Wear and others 2013): moderate urbanization/increasing timber prices (Cornerstone A), moderate urbanization/decreasing timber prices (Cornerstone B), low urbanization/increasing timber prices (Cornerstone C), low urbanization/decreasing timber prices (Cornerstone D), moderate urbanization/increasing timber prices/increased tree planting (Cornerstone E), and low urbanization/decreasing timber prices/decreased tree planting (Cornerstone F).

Summary

Largely because of urbanization-driven changes in land use, total forest cover is forecasted to decrease across the Appalachian-Cumberland highland from 2010 to 2060 (fig. 42) along with the largest component—upland hardwoods—regardless of Cornerstone Future. The amount of the upland hardwoods decrease, however, varies greatly by both Cornerstone Future and Appalachian-Cumberland section. Despite the loss of upland hardwood area, the portion of upland hardwood forests classified as oak-hickory would remain fairly constant over the 50-year projection period. This is important because of the widespread ecological and economic significance of oak-hickory forests in Appalachian-Cumberland highland.

The area classified as natural pine is expected to decrease over the 50-year projection period (figs. 44 and 46), while the area classified as planted pine is forecasted to increase (figs. 44 and 48). Because losses of upland-hardwood area are driven by future rates of urbanization, the projected increase in planted pine area appears to be driven, in part, by the conversion of natural pine or oak-pine (or both) to pine plantations.

Hardwoods comprise the largest proportion of the current (2010) total hardwood growing stock. Although total hardwood growing stock could decrease by an average of 2.4 percent under Cornerstone Futures A, B, and E, hardwoods will continue to comprise the largest proportion of the total growing stock (figs. 51 and 52). Although not a substantial contribution to total growing stock, the softwood component is forecasted to be, on average, 7.4 percent larger by 2060—attributable, in part, to the slight increase in planted-pine area.

The forecasted loss of area in upland hardwoods is largely driven by urbanization-driven changes in land use under the Cornerstone Futures, with the largest losses occurring near larger urban areas (such as Asheville, NC; Knoxville, TN; Nashville, TN; and Lexington, KY). In general, age structure of upland hardwoods will likely continue to be dominated by the older (≥ 80 years) classes.

For a broader discussion of forest conditions in the South, see Huggett and others (2013).

WILDLIFE AND FOREST COMMUNITIES

The Southern United States has a high level of plant and animal diversity, largely the result of strong edaphoclimatic and topographic gradients as well as variation in natural disturbance regimes characteristic of the region. Although one of the smaller subregions in the South, the Appalachian-Cumberland highland also contains a highly diverse suite of plant and animal communities, including many endemic species that are dependent on its specific physical, climatic, or biological attributes. This diversity is threatened by the changes in land use and associated patterns of habitat fragmentation caused primarily by parcelization of private forests and climate change that are forecasted to occur under the Cornerstone Futures.

The Appalachian-Cumberland highland contains 484 native terrestrial vertebrates in 77 distinct ecosystems. This includes 90 amphibians (of which 60 are salamanders), 257 birds, 77 mammal, and 60 reptiles (table 10).

Table 10—Vertebrate species richness in the five sections of the U.S. Appalachian-Cumberland highland

Section	Amphibians		Birds						Mammals				Reptiles		
	Frogs and toads	Salamanders	Perching birds	Raptors	Shorebirds	Wading birds	Waterfowl	Other birds	Bats	Carnivores	Rodents	Other mammals	Lizards	Snakes	Turtles
	-----Number of species-----														
Blue Ridge Mountains	17	54	132	13	17	11	21	42	16	11	26	18	9	26	13
Northern Ridge and Valley	16	41	130	14	17	7	24	42	11	12	23	16	7	24	13
Southern Ridge and Valley	15	41	130	12	16	8	20	43	14	11	26	16	9	21	11
Cumberland Plateau and Mountains	20	35	135	14	17	11	22	43	16	11	25	15	9	24	12
Interior Low Plateau	25	32	139	15	16	11	24	45	16	12	23	16	9	29	15

Sources: NatureServe (2011); Trani Griep and Collins (2013).

A number of species are considered to be of conservation concern, defined as a global status rank of critically imperiled, imperiled, or vulnerable (NatureServe 2012). These species are increasingly threatened by habitat alteration, isolation, introduction of invasive species, environmental pollutants, commercial development, human disturbance, and exploitation. Vertebrate species of conservation concern in each of the five Appalachian-Cumberland sections are listed in table 11. Of them,

four—the Blue Ridge Mountains, Southern Ridge and Valley, Cumberland Plateau and Mountains, and Interior Low Plateau sections—are areas of emerging concern for conservation.

The Blue Ridge Mountains section supports a noteworthy 54 species of salamanders, 18 of which are imperiled or vulnerable (table 11), and the Northern and Southern Ridge and Valley sections support 41. Threats to salamanders in

Table 11—Vertebrate species of global conservation concern in the five sections of the U.S. Appalachian-Cumberland highland: Blue Ridge Mountains, Northern Ridge and Valley, Southern Ridge and Valley, Cumberland Plateau and Mountains, and Interior Low Plateau

Taxonomic group	Species name	Section	Status
Frogs and toads	Carolina gopher frog (<i>Lithobates capito</i>)	Low Plateau	V
Salamanders	Berry Cave salamander (<i>Gyrinophilus gulolineatus</i>)	Southern Ridge	CI
	Blue Ridge gray-cheeked salamander (<i>Plethodon amplus</i>)	Blue Ridge	CI
	South Mountain gray-cheeked salamander (<i>Plethodon meridianus</i>)	Blue Ridge	CI
	Shenandoah salamander (<i>Plethodon shenandoah</i>)	Northern Ridge	CI
	Cumberland dusky salamander (<i>Desmognathus abditus</i>)	Cumberlands	I
	Dwarf black-bellied salamander (<i>Desmognathus folkertsi</i>)	Blue Ridge	I
	Tennessee cave salamander (<i>Gyrinophilus palleucus</i>)	Southern Ridge, Cumberlands, Low Plateau	I
	Tellico salamander (<i>Plethodon aureoles</i>)	Blue Ridge	I
	Cheoah Bald salamander (<i>Plethodon cheoah</i>)	Blue Ridge	I
	Peaks of Otter salamander (<i>Plethodon hubrichti</i>)	Northern Ridge	I
	Red-legged salamander (<i>Plethodon shermani</i>)	Blue Ridge	I
	Shenandoah Mountain salamander (<i>Plethodon Virginia</i>)	Northern Ridge	I
	Green salamander (<i>Aneides aeneus</i>)	Blue Ridge, Southern Ridge, Cumberlands, Low Plateau	V
	Hellbender (<i>Cryptobranchus alleganiensis</i>)	All	V
	Seepage salamander (<i>Desmognathus aeneus</i>)	Blue Ridge, Southern Ridge	V
	Imitator salamander (<i>Desmognathus imitator</i>)	Blue Ridge	V
	Santeetlah dusky salamander (<i>Desmognathus santeetlah</i>)	Blue Ridge	V
	Pygmy salamander (<i>Desmognathus wrighti</i>)	Blue Ridge, Northern Ridge, Southern Ridge	V
	Junaluska salamander (<i>Eurycea junaluska</i>)	Blue Ridge	V

CI = critically imperiled; I = imperiled; V = vulnerable.
Source: NatureServe (2011).

(Continued)

these sections include forest fragmentation associated with land use change and residential development because loss of habitat connectivity would make migration in response to a changing climate and disturbances difficult.

Numbers of imperiled mammals are particularly high in the Interior Low Plateau section, Cumberland Plateau and Mountains section, Southern Ridge and Valley section, and North Carolina portion of the Blue Ridge Mountains

section. Mammals of particular interest and of conservation concern include the eastern small-footed bat (*Myotis leibii*), Carolina northern flying squirrel (*Glaucomys sabrinus coloratus*), Virginia northern flying squirrel (*Glaucomys sabrinus fuscus*), Indiana bat (*Myotis sodalis*), and Virginia big-eared bat (*Corynorhinus townsendii virginianus*). These species are sensitive to habitat fragmentation (which causes population isolation) and land-use conversion resulting from urbanization and residential development. Bat

Table 11 (continued)—Vertebrate species of global conservation concern in the five sections of the U.S. Appalachian-Cumberland highland: Blue Ridge Mountains, Northern Ridge and Valley, Southern Ridge and Valley, Cumberland Plateau and Mountains, and Interior Low Plateau

Taxonomic group	Species name	Section	Status
Salamanders	Red-cheeked salamander (<i>Plethodon jordani</i>)	Blue Ridge	V
	Southern gray-cheeked salamander (<i>Plethodon metcalfi</i>)	Blue Ridge	V
	Northern gray-cheeked salamander (<i>Plethodon montanus</i>)	Blue Ridge	V
	White-spotted salamander (<i>Plethodon punctatus</i>)	Northern Ridge	V
	Southern Appalachian salamander (<i>Plethodon teyahalee</i>)	Blue Ridge	V
	Weller's salamander (<i>Plethodon welleri</i>)	Blue Ridge, Northern Ridge	V
Birds	Bachman's sparrow (<i>Peucaea aestivalis</i>)	Southern Ridge, Cumberlands, Low Plateau	V
	Red-cockaded woodpecker (<i>Picoides borealis</i>)	Southern Ridge, Cumberlands, Low Plateau	V
Bats	Indiana bat (<i>Myotis sodalis</i>)	All	I
	Rafinesque's big-eared bat (<i>Corynorhinus rafinesquii</i>)	Blue Ridge, Southern Ridge, Cumberlands, Low Plateau	V
	Southeastern myotis (<i>Myotis austroriparius</i>)	Blue Ridge, Low Plateau	V
	Gray bat (<i>Myotis grisescens</i>)	Blue Ridge, Northern Ridge, Southern Ridge, Cumberlands	V
	Eastern small-footed bat (<i>Myotis leibii</i>)	Blue Ridge, Northern Ridge, Low Plateau	V
Rodents	Allegheny woodrat (<i>Neotoma magister</i>)	Blue Ridge, Northern Ridge, Southern Ridge, Cumberlands	V
Snakes	Kirtland's snake (<i>Clonophis kirtlandii</i>)	Low Plateau	I
Turtles	Bog turtle (<i>Glyptemys muhlenbergii</i>)	Blue Ridge	V
	Alligator snapping turtle (<i>Macrochelys temminickii</i>)	Low Plateau	V

CI = critically imperiled; I = imperiled; V = vulnerable.
Source: NatureServe (2011).

populations face additional pressures from disturbance to hibernation and maternity colonies.

An emerging issue that is and will continue to affect wildlife communities is white-nose syndrome, an infectious disease that affects bats hibernating in cold caves and mines during winter. The disease is caused by a cold-loving fungus, *Geomyces destructans* (Lorch and others 2011) that may have been brought to North America from Europe. The disease causes the bats to alter their hibernation cycles in ways that quickly burn through their winter fat reserves. It also causes extensive damage to the bats' wings, which can affect many other physiological processes such as water balance and ability to fly (Cryan and others 2010). White-nose syndrome is currently found in 19 U.S. States—including Kentucky, Tennessee, Virginia, North Carolina, and Alabama—and four Canadian Provinces. In the Northeastern United States, little brown bats (*Myotis lucifugus*) decreased by 91 percent, Indiana bats decreased by 72 percent, northern long-eared bats (*Myotis septentrionalis*) decreased by 98 percent, and tri-colored bats (*Perimyotis subflavus*) decreased by 75 percent from 2006 to 2011 (Turner and others 2011)—for an estimated loss of 5.5 to 6.5 million bats. Although difficult to quantify, the loss of so many predators will likely affect the abundance and composition of night-flying arthropods, many of which can impact forestry and agricultural interests.

The Appalachian-Cumberland highland is second in the South in the number of Federally listed vascular plant species (37), with an additional 172 considered species of concern. Most of the threatened and endangered plant species are endemic to rare community types, including bog habitats and rocky, mountain outcrops (table 12). Because the habitat associated with many of these species is limited, special management actions may be required to maintain existing populations (including reintroduction of fire).

Early successional habitats, defined as forest habitats in the ≤ 10 year age class, are of importance to a variety of species. Under Cornerstone A (moderate urbanization and increasing timber prices), the largest losses in early successional habitats are expected in the Northern Ridge and Valley section, with scattered losses occurring in the Blue Ridge Mountains and northern Interior Low Plateau sections. The loss of early successional habitats in these sections could affect species of management concern, including the American woodcock (*Scolopax minor*), blue-winged warbler (*Vermivora pinus*), chestnut-sided warbler (*Dendroica pennsylvanica*), golden-winged warbler (*Vermivora chrysoptera*), ruffed grouse (*Bonasa umbellus*), and veery (*Catharus fuscescens*). Under Cornerstone A, the eastern Tennessee portion of the Southern Ridge and Valley section and the Cumberland Plateau and Mountains section are forecasted to gain early successional habitats. Although benefitting some species, an increase in the amount of early successional habitats, coupled with a reduction

in the amount of mature forest, could threaten plants and animals associated with interior forest conditions.

High elevation forests such as red spruce, Fraser fir, eastern hemlock, and northern hardwood forests occur $>4,000$ feet in the northern Blue Ridge Mountains section (central and northern Virginia) and the southern Blue Ridge Mountains section (eastern Tennessee, western North Carolina, and limited areas of northern Georgia). These forests are subject to chronic air pollution, acid deposition, and natural disturbances (such as hurricane-related wind disturbances and ice storms). Although climate change could impact these ecosystems by decreasing the winter cold period required for seed germination of select species, pressure from urbanization, wildfires and other natural disturbances, recreation and other human disturbances, and loss of forest connectivity are immediate threats to the health of these high elevation ecosystems.

Overall, urbanization-driven changes in land use coupled with projected decreases in forest acreage and loss of forest connectivity near metropolitan areas—such as the metropolitan areas of Nashville (Interior Low Plateau section) and Knoxville (Cumberland Plateau and Mountains section) in Tennessee, and Asheville (Blue Ridge Mountains section) in North Carolina—could threaten the diversity and abundance of bats, salamanders, and concentrations of sensitive plant species; and could increase habitat fragmentation, making migration in response to climate and disturbances difficult. Recreational use, which is expected to increase concomitant with increased urbanization under the Cornerstone Futures, could add additional pressure on rare and endemic communities.

Summary

The Appalachian-Cumberland highland hosts a highly diverse suite of plant and animal communities. Of its 484 native terrestrial vertebrates, numerous species are of conservation concern (table 11). Changes in land use, coupled with increases in habitat fragmentation caused primarily by parcelization of private land, would have large impacts on the biodiversity and health of its wildlife and plant communities. The effects of habitat fragmentation would be most noticeable in and around metropolitan areas that include Nashville, TN, Knoxville, TN, and Asheville, NC.

Many plant and animal species benefit from early successional habitat. A loss of these habitats is forecasted to occur over the 50-year projection period, with the largest losses occurring under a moderate urbanization and increasing timber price projection (Cornerstone A). Notwithstanding, parts of the Southern Ridge and Valley section and the Cumberland Plateau and Mountains sections could actually experience gains in the amount of area classified as early successional habitat under Cornerstone A.

Table 12—Endangered and threatened plant species and associated habitats in the U.S. Appalachian-Cumberland highland

ENDANGERED SPECIES	
Name	Primary habitat
Braun's rockcress (<i>Arabis perstellata</i>)	Mesic, shady, steep, north-facing wooded slopes
Bunched arrowhead (<i>Sagittaria fasciculata</i>)	Streamsides, swamp-forest bogs
Cumberland sandwort (<i>Minuartia cumberlandensis</i>)	Cool, humid, cave-like overhangs
Green pitcherplant (<i>Sarracenia oreophila</i>)	Bogs
Leafy prairie-clover (<i>Dalea foliosa</i>)	Barrens, grasslands/other herbaceous areas
Morefield's leatherflower (<i>Clematis morefieldii</i>)	Open cedar-hardwood forests; seeps and ephemeral limestone streams (rocky woodlands)
Northeastern bulrush (<i>Scirpus ancistrochaetus</i>)	Bogs
Persistent trillium (<i>Trillium persistens</i>)	Mixed hemlock-pine-hardwood forests; steep slopes, streamsides
Peters Mountain mallow (<i>Iliamna corei</i>)	Exposed sandstone outcrops
Pyne's ground-plum (<i>Astragalus bibullatus</i>)	Limestone cedar glades
Reflexed blue-eyed-grass (<i>Sisyrinchium dichotomum</i>)	Rocky oak-hickory slopes
Running buffalo clover (<i>Trifolium stoloniferum</i>)	Mesic woodlands
Ruth's silk-grass (<i>Pityopsis ruthii</i>)	Streamsides, rock crevices
Shalebarren rockcress (<i>Arabis serotina</i>)	Rocky oak-hickory slopes
Short's goldenrod (<i>Solidago shortii</i>)	Natural openings in dry oak-hickory stands, cedar glades, glade-like areas
Smooth purple coneflower (<i>Echinacea laevigata</i>)	Bare rock/talus/scree, cliffs, forests/woodlands, grasslands/other herbaceous areas
Spreading avens (<i>Geum radiatum</i>)	Montane rock outcrops
Spring Creek bladderpod (<i>Lesquerella perforata</i>)	Bare rock/talus/scree, croplands/hedgerows, old fields
Sweet pitcherplant (<i>Sarracenia rubra</i> spp.)	Bogs/fens
Tennessee yellow-eyed-grass (<i>Xyris tennesseeensis</i>)	Forested or herbaceous wetlands, riparian areas
Venus' pride (<i>Houstonia purpurea</i> var. <i>montana</i>)	Montane rock outcrops
THREATENED SPECIES	
Name	Primary habitat
Blue Ridge goldenrod (<i>Solidago spithamea</i>)	Montane peaks, cliffs, talus slopes
Cumberland false rosemary (<i>Conradina verticillata</i>)	Only boulder/cobble/gravel-bars, river-gorge flood plains
Dwarf-flower heartleaf (<i>Hexastylis naniflora</i>)	Rich deciduous woods, bluffs
Eastern prairie white-fringed orchid (<i>Platanthera leucophaea</i>)	Mesic to wet prairies, wet sedge meadows, sedge-sphagnum bog mats
Hart's-tongue fern (<i>Asplenium scolopendrium</i>)	Mesic hardwood forests, sinkholes
Heller's blazingstar (<i>Liatris helleri</i>)	Montane rock outcrops, grassy balds
Large-flower skullcap (<i>Scutellaria montana</i>)	Rocky shallow soils; submesic-to-xeric, well-drained, slightly acidic oak-pine forests
Lyrate bladderpod (<i>Lesquerella lyrata</i>)	Barrens, croplands/hedgerows, grasslands/other herbaceous
Mountain golden-heather (<i>Hudsonia montana</i>)	Oak/heath forests
Price's potato-bean (<i>Apios priceana</i>)	Open, rocky, wooded slopes; floodplain edges
Small whorled pogonia (<i>Isotria medeoloides</i>)	White pine or mesic oak-hickory forests
Swamp-pink (<i>Helonias bullata</i>)	Forest-bog complexes
Virginia roundleaf birch (<i>Betula uber</i>)	Forested wetlands, riparian areas
Virginia sneezeweed (<i>Helenium virginicum</i>)	Small areas around sinkholes
Virginia spiraea (<i>Spiraea virginiana</i>)	Riverside scour zones
White-haired goldenrod (<i>Solidago albopilosa</i>)	Shallow, sandstone, cave-like structures

Source: NatureServe (2012).

The loss of early successional habitats will likely affect many species of management concern, while an increase in early successional habitat would pose threats to plants and animals associated with interior forest conditions (older age classes).

Habitat fragmentation and loss of habitat connectivity would inhibit species migration in response to climate change. The potential effects of climate change on high-elevation forest habitats in the Blue Ridge Mountains and Northern Ridge and Valley sections are of particular concern. These high-elevation systems will likely experience pressures related to urbanization and habitat fragmentation, as well as increased temperatures and an increase in the frequency of natural disturbances (perhaps associated with climate change).

For a broader discussion of wildlife and at-risk forest communities, see Trani Griep and Collins (2013).

WATER AND FORESTS

Of the three broad land use categories in the South—forestry, agriculture, and urban—forests provide the cleanest and most stable supply of water, the source of drinking water, recreational opportunities, and power generation for millions of people as well as critical aquatic habitat for a variety of wildlife species. Although population growth and associated alterations in land use (loss of forest land and increase in urbanization) will likely be the primary drivers of changes in water quantity and quality across the South, climate change could exacerbate these changes and directly and indirectly affect water resources.

Land Use Changes and Water Resources

In the Appalachian-Cumberland highland, the movement of water largely follows hydrologic flowpaths that are primarily driven by elevation gradients. As urbanization increases, as predicted under the four primary Cornerstone Futures (chapter 2), the proportion of impervious land area can also be expected to increase. In contrast to urban watersheds, forested watersheds yield less total water. However, forested watersheds usually have a higher percentage of water available for human use than urban watersheds; therefore an increase in urbanization usually translates into less water for human consumption. In addition, an increase in impervious surface area can result in more stream sediment; higher concentrations of nutrients, pesticides, and pharmaceuticals (Clinton and Vose 2006, Lenat and Crawford 1994, Paul and Meyer 2001, Schoonover and others 2005); and the potential for urbanization-associated erosion (depending on topography).

Water Resources and Climate Change

As measured by the water supply stress index or WaSSI (Lockaby and others 2013) from 1995 to 2005 (baseline conditions), water stress in the Appalachian-Cumberland highland was low (<0.40), with higher levels associated with population centers (fig. 60). Although the changes in water stress resulting from land use by 2050 are predicted to be negligible (fig. 61), the effects of population change are predicted to increase water stress substantially, with the largest proportional increase in and around the major population centers (fig. 61). Although water stress may be most visible around population centers, rural communities could well experience increased stress because groundwater is the primary source of potable water in rural areas (Fox and others 2011). Consequently, as development proceeds and urban centers expand, smaller municipalities and rural communities dependent on well water could experience the combined effects of climate change and population increases on groundwater supply. Although all Cornerstone Futures forecast an increase in air temperature in the Appalachian-Cumberland highland, their forecasted precipitation patterns have a high degree of uncertainty and variability. Depending on the scenario, by 2050 water supply stress will increase in some areas of the subregion, while other areas will experience a decrease or no change in water supply stress (fig. 62).

Consequences

Land use change will likely have the most impact on future water quality and quantity across the Appalachian-Cumberland highland. In general, conversion of forest land to other uses, which is forecasted under all the Cornerstone Futures, is dominated by the conversion to urban land. Precipitation patterns are the primary drivers of peak flow, turbidity, and flooding (Caldwell and others 2012); however, loss of forest land coupled with an increase in urban land uses will likely exacerbate discharge rates, peak flow, and velocity of streams (Sun and Lockaby 2012). The Appalachian-Cumberland highland, with its varied topography, will likely experience some of the most substantial effects of urbanization on hydrological responses, including peak flows and stream hydrographs (Grimm and others 2004). In addition, conversion away from forest land uses results in higher velocity and channel scouring, which create unstable habitat for aquatic species. In the Appalachian-Cumberland highland, and in the Appalachian Mountains, in particular, the negative impacts of forest loss on aquatic habitat are most severe. Species richness and abundance generally decline with the loss of forest land, leading to site-specific loss of species groups.

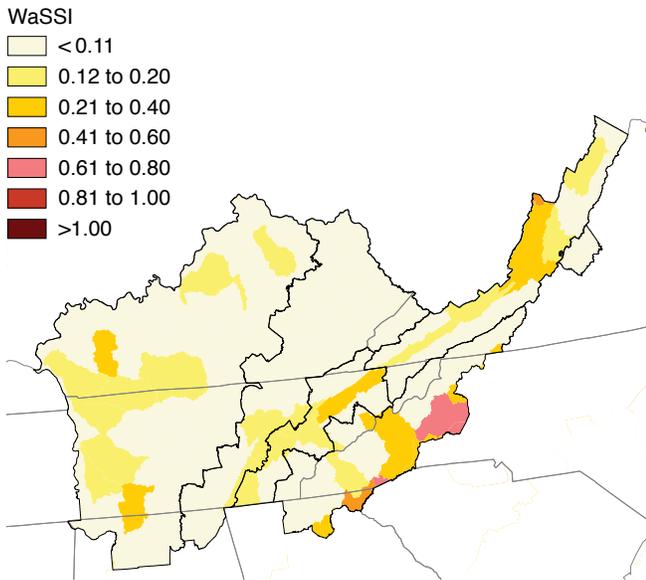


Figure 60—Water supply stress index, 1995 to 2005, for the U.S. Appalachian-Cumberland highland; water stress is defined by the Water Supply Stress Index (WaSSI) and calculated by dividing water supply into water demand.

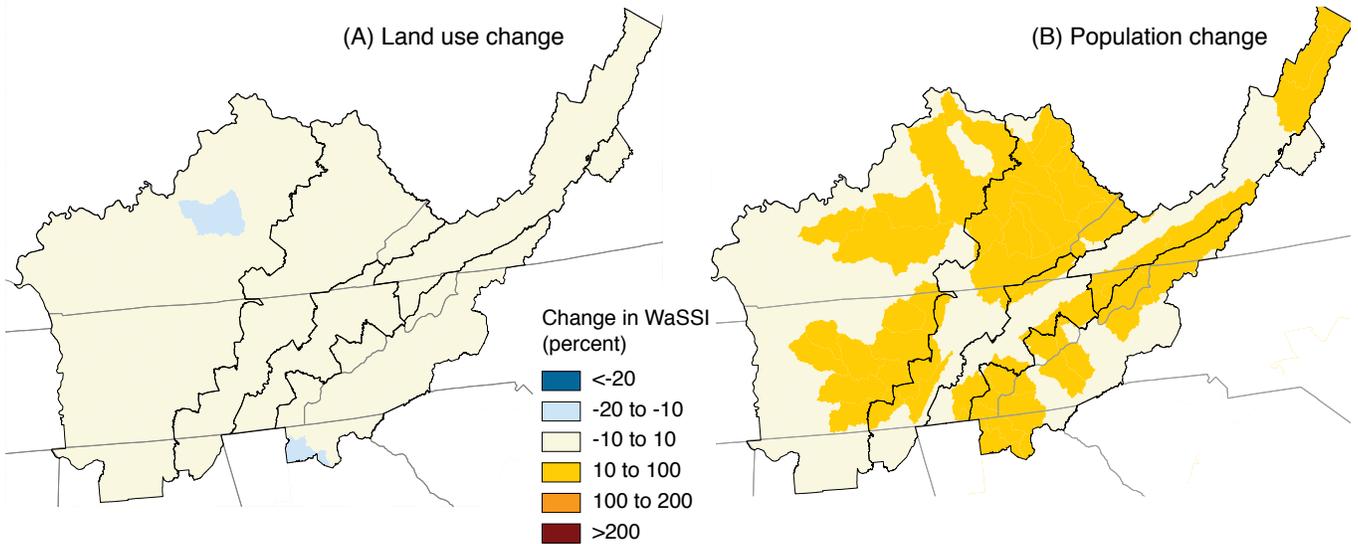


Figure 61—Predicted change in water stress, 2050, for the U.S. Appalachian-Cumberland highland that is attributable to (A) land use change or (B) population change; water stress is defined by the Water Supply Stress Index (WaSSI) and calculated by dividing water supply into water demand.

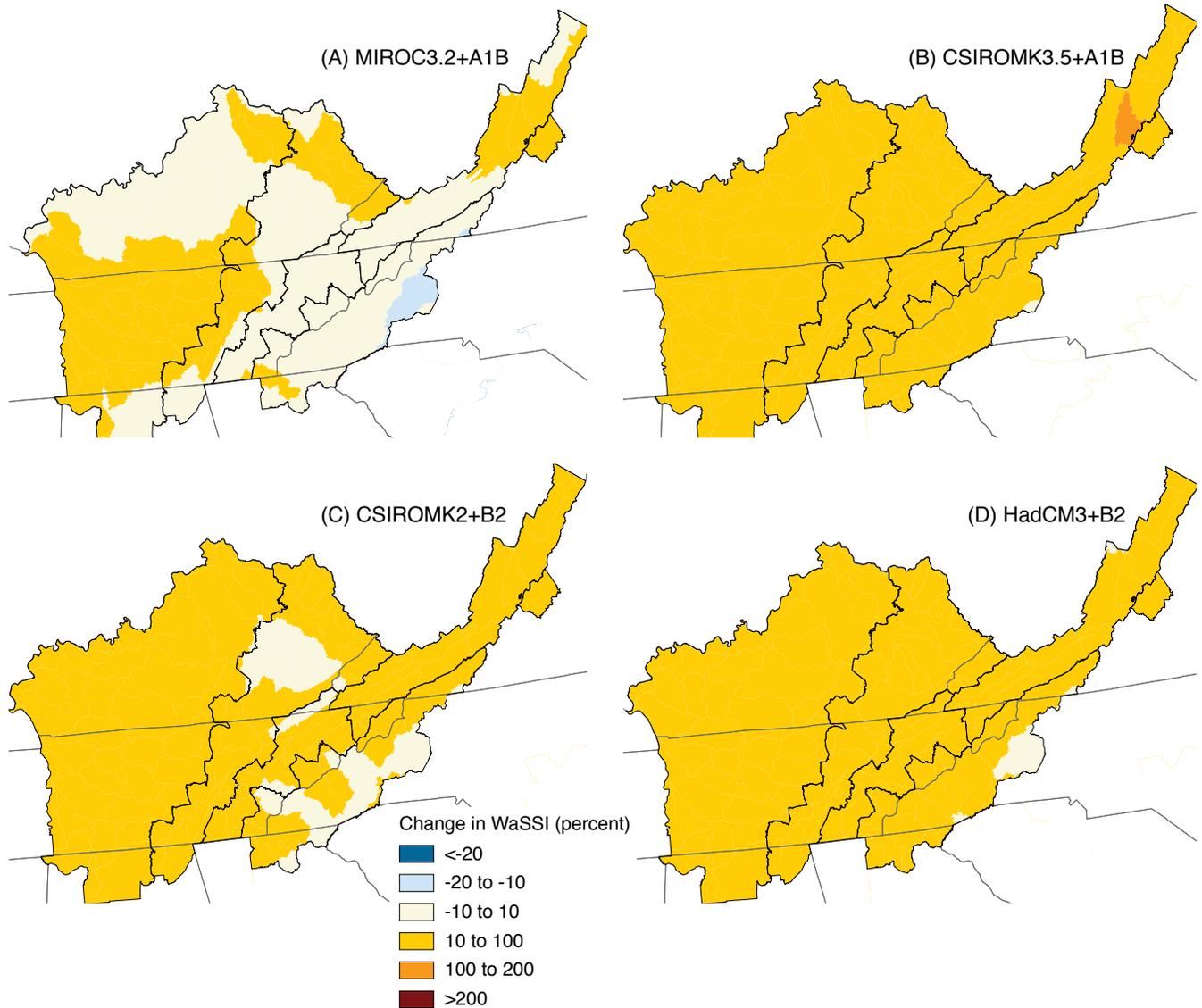


Figure 62—Predicted change in water stress, 2050, for the U.S. Appalachian-Cumberland highland under Cornerstone Futures A through D; water stress is defined by the Water Supply Stress Index (WaSSI) and calculated by dividing water supply into water demand; each of the Cornerstone Futures represents a general circulation model—MIROC3.2, CSIROMK3.5, CSIROMK2, or HadCM3—paired with one of two emission scenarios—A1B representing low-population/high-economic growth, high energy use; B2 representing moderate growth and use; (A) MIROC3.2+A1B, (B) CSIROMK3.5+A1B, (C) CSIROMK2+B2, and (D) HadCM3+B2 (McNulty and others 2013).

Independent of climate, the change from forest to urban land uses coupled with increases in population would increase water supply stress (based model results) across the Appalachian-Cumberland highland. Because water stress is sensitive to population changes, the largest proportional increase in water stress is expected to occur where urban land uses and rates of urbanization and population growth are forecasted to be highest (fig. 61). Although increased temperatures are forecasted under all four Cornerstone Futures, model consensus on the forecasted patterns of precipitation is low. In general, stream flows and water supply will likely decrease and become more variable over the next 50 years, with an increase in the water supply stress forecasted to be between 10 and 100 percent for most of the Appalachian-Cumberland highland (fig. 62).

Impervious land area increases of ≤ 5 percent can affect water quality, with significant degradation occurring at increases of 10 to 20 percent (Arnold and Gibbons 1996, Bledsoe and Watson 2001), and severe deterioration occurring at increases >30 percent (Calhoun and others 2003, Paul and Meyer 2001). Where urbanization is forecasted to be substantial—which in the Appalachian-Cumberland highland includes areas in and around Nashville, TN, Asheville, NC, and Lexington, KY—key bioindicators of water quality degradation will require monitoring. An increase in urban areas is forecasted under all Cornerstone Futures, thereby increasing the need for measures to decrease or mitigate the negative effects on water quality and quantity, including an increased emphasis on the retention of green space in urban areas and conservation programs.

For a broader discussion of water and forests, see Lockaby and others (2013).

OUTDOOR RECREATION

Larger numbers of individuals, families, and other households in all likelihood will translate directly into higher demand for outdoor recreation venues, but at the same time create more pressures on remaining natural lands. As land and water resources in rural areas are increasingly pressured by expanding urban and other development, private land and water could become less available for outdoor recreation for some segments of the population.

Current Trends

From 2000 to 2008, the number of people ages ≥ 16 who participated in one or more of 60 outdoor activities (not necessarily forest dependent) increased by 7.3 percent in the United States—and even higher in the South, with

participants increasing about 11 percent, from 68 million to 75 million. The South had a higher rate of participation in hunting and fishing activities (38.8 percent) than in other regions of the United States (table 13), and had the second highest participation rate in motorized activities with 37.1 percent participating. The two activities with the highest participation rates are visiting recreation and historic sites (78.9 percent) and viewing/photographing nature (73.2 percent); for these activities, participation rates were even higher in other regions.

Federal, State, and local governments offer millions of acres of land for public recreation use. Federal agencies manage nearly 640 million acres in the United States and 30.5 million acres in the South, about 44 percent of which is managed by the USDA Forest Service. For all Federally managed land, the number of Federal acres per 1,000 people decreased by 15.4 percent from 1995 to 2008. Because the amount of Federal acreage remained relatively stable, the decrease was primarily attributable to an increase in population. During the same period, the acreage under the State park system per 1,000 people grew by more 8.8 percent.

Most counties in the South have from 0.07 to 1.46 acres of public land per person, increasing to 18.31 in the Virginia mountains. Federal or State park land is <0.3 acres per person. By 2060, availability is projected to decrease to 0.17 acres.

Non-Federal forest area is expected to change with continuing conversions from forests and farmlands to cities and suburbs. More than 30 percent of the total land area is non-Federal forest, or 1.66 acres per person. Per capita non-Federal forest is predicted to decrease to 0.95 acres per person by 2060.

Projections 2010 to 2060

For the South as a whole, recreation participation is expected to increase. The amount of growth will likely be variable, depending on the specific recreation activity and the amount of population growth. To develop projections for the 50-year period, three population growth storylines (Intergovernmental Panel on Climate Change 2007) were evaluated for 10 popular outdoor recreation activities. The storylines incorporated into the recreation projections were A1B (medium population growth and the highest household income), A2 (highest level of population growth and lowest household income), and B2 (lowest population growth and moderate household income). Based on the forecasts of land use change from Wear (2013), forest land per capita from 2008 to 2060 is expected to decrease about 45 percent under A1B, 50 percent under A2, and about 37 percent under B2.

Table 13—Participants for seven activity groups, 2005 to 2009, in the four regions of the United States

Activity group	Region	Percent of participants ^a	Percent of population ^a	Percent participating
Visiting recreation and historic sites (Family gatherings, picnicking, visiting the beach, visiting historic or prehistoric sites, and camping)	North	42.0	40.7	82.7
	South	29.7	31.4	78.9
	Rocky Mountains	10.1	10.1	81.9
	Pacific Coast	18.2	17.8	81.4
Viewing/photographing nature (View/photograph birds, natural scenery, other wildlife besides birds, and wildflowers, trees, and other plants)	North	40.8	40.7	75.6
	South	30.7	31.4	73.2
	Rocky Mountains	10.5	10.1	78.1
	Pacific Coast	17.9	17.8	75.8
Backcountry activities (Backpacking, day hiking, horseback riding on trails, mountain climbing, and visiting a wilderness or primitive area)	North	40.1	40.7	43.1
	South	26.0	31.4	37.4
	Rocky Mountains	13.0	10.1	57.4
	Pacific Coast	20.9	17.8	51.4
Motorized activities (Motorboating, off-highway vehicle driving, snowmobiling, using personal watercraft, and waterskiing)	North	40.8	40.7	36.4
	South	31.1	31.4	37.1
	Rocky Mountains	10.7	10.1	39.1
	Pacific Coast	17.4	17.8	35.6
Hunting and fishing (Anadromous fishing, coldwater fishing, warmwater fishing, saltwater fishing, big game hunting, small game hunting, and migratory bird hunting)	North	38.6	40.7	32.4
	South	35.5	31.4	38.8
	Rocky Mountains	10.9	10.1	37.1
	Pacific Coast	15.0	17.8	28.8
Non-motorized boating (Canoeing, kayaking, rafting, rowing, and sailing)	North	45.6	40.7	23.0
	South	27.5	31.4	18.0
	Rocky Mountains	9.2	10.1	18.7
	Pacific Coast	17.7	17.8	20.4
Snow skiing and boarding (Cross country skiing, downhill skiing, and snowboarding)	North	49.6	40.7	14.0
	South	14.5	31.4	5.5
	Rocky Mountains	12.6	10.1	14.7
	Pacific Coast	23.3	17.8	15.1

^aPercentages sum down to 100 within the four regions of each activity group.

Sources: USDA Forest Service (2009); Cordell and others (2013).

Developed site use—The most popular of the land-based activities in the South, developed site use includes family gatherings, picnicking, and developed camping. On average from 2005 to 2009, 80 percent of southern adults participated in developed site use activities (table 14). Per capita participation growth is expected to be relatively static over the next 50 years. Nevertheless, the overall number of participants will grow by the rate at which the population increases for each storyline.

Backcountry activities—Hiking is the most popular single land based backcountry activity (table 14); participation per capita is expected to increase by 12 to 15 percent by 2060. Per capita participation in horseback riding on trails is projected to decrease by 5 to 9 percent under the B2 and A2 storylines and to increase by 9 percent under the A1B storyline, primarily because of higher income growth. Expected increases in population over the 50-year horizon would result in an overall increase in participation. For motorized off-road driving, participation rates are projected to decrease by about 8 percent across all storylines, resulting in participant numbers growing less than the population growth rate.

Visiting primitive areas includes backpacking, primitive camping, and visiting a wilderness—either designated or undesignated. Annual per capita participation in these activities is expected to decrease by ≤ 7 percent in the next 50 years. However, by 2060 overall participation is expected to increase by 43 to 76 percent across the three storylines because population growth would offset the decrease in participation rates.

Boating—Two water-based activity aggregates—motorized and nonmotorized (table 14)—were examined by Bowker and others (2013). By 2060, participation rates for motorized use—which includes motor boating, waterskiing, and personal watercraft use—are projected to increase by 10 percent under storyline A1B and decrease by ≤ 5 percent under storylines A2 and B2. This difference can be attributed to A1B’s higher growth rate for household income. Annual days of motorized water use are expected to grow from 2008 levels by 38 to 86 percent, depending on which storyline proves to be most accurate.

Nonmotorized water use aggregate includes canoeing, kayaking, and rafting. Despite rapid growth over the past decade, per capita adult participation is projected to be stable out to 2060, resulting in participant numbers growing at the same rate as the population, or 45 to 81 percent.

Wildlife-based activities—Wildlife activities assessed by Bowker and others (2013) include birding, fishing, and hunting (table 14). By far, birding has the highest number of annual days per participant in the South—likely reflective of the many levels or intensities of participant engagement, from watching feeders to pursuing sightings in remote forests. Per capita participation in birding is projected to increase 7 to 10 percent over the next 50 years under all three storylines, meaning that birder numbers will increase faster than the adult population at large. Because days per participant are expected to decrease by 9 to 13 percent, the total number of days of birding would increase marginally less than the population.

Table 14—Outdoor recreation activity by southern adults ≥ 16 years, 2008, by number of participants and days of participations

Activity type	Activity	Participation rate (percent)	Participants (millions)	Days of participation (millions)
Land based	Developed site use (family gathering, picnicking, developed camping)	79.9	63.2	672
	Horseback riding on trails	7.1	5.7	99
	Day hiking	25.2	20.3	463
	Primitive (visiting a wilderness, primitive camping/backpacking)	35.3	16.9	562
	Motorized off-road	21.3	28.2	412
Water based	Motorized water (motor boating, water skiing, personal water craft)	27.0	21.3	384
	Non-motorized (canoeing, kayaking, rafting)	15.4	12.2	80
Wildlife based	Birding (viewing or photographing)	34.2	27.0	2,862
	Fishing	35.7	28.0	573
	Hunting	13.7	10.8	230

Sources: USDA Forest Service (2009); Bowker and others (2013).

Fishing has the second highest participation rate for southerners among the activities examined by Bowker and others (2013). In the past decade, fishing participants increased by >20 percent. Under the storylines, the fishing participation rate is expected to decrease by 10 to 18 percent. Therefore, the number of days of fishing is expected to grow slower than the population, or 30 to 51 percent. Fishing is expected to remain among the top recreation activities in the South.

Approximately 13 percent of adults in the South reported hunting in 2008 for a total of 230 million days (table 14). From 1999 to 2009, hunting participants increased 16 percent for small game and 25 percent for large game. Per capita participation is expected to decrease 26 to 42 percent over the next 50 years (table 15). Among the factors driving the decrease in participation rate include: increasing population density, growth in the Asian and Hispanic segments of society, higher levels of education, and decreasing forest land per capita. Despite the lower participation rate, the number of southern hunters is expected to increase by 8 percent under storyline B2 and 25 percent under storyline A1B. Total days of hunting are forecast to grow at about the same rate as hunters—8 to 24 percent.

Growing Importance of National Forests

National forest lands in the Interior Low Plateau section of the Appalachian-Cumberland highland include portions of the William B. Bankhead National Forest, portions of the Daniel Boone National Forest, and the entire Land Between the Lakes National Recreation Area. National forest lands in the Cumberland Plateau and Mountains section include most of the Daniel Boone National Forest and portions of the Jefferson National Forest. National forest lands in the Southern Ridge and Valley section include portions of the Cherokee National Forest and the Lee County portion of the Jefferson National Forest. National forest lands in the Northern Ridge and Valley section include portions of the Cherokee National Forest and most of the Jefferson National Forest and George Washington National Forest. National forest lands in the Blue Ridge Mountains section include portions of the Chattahoochee National Forest, the entire Nantahala National Forest and Pisgah National Forest, and portions of the George Washington National Forest and Jefferson National Forest.

Table 15—Forecasted recreational hunting by southern adults ≥ 16 years, 2008–2060, based on an expectation of high population and income growth, high population growth but low income growth, or low population growth and income growth

Assumptions for population and income growth	Year						
	2008	2060	2020	2030	2040	2050	2060
	Percent of adults participating			Percent decrease from 2008			
High population and income growth	13.7	10.1	8	16	21	24	26
High population growth, low income growth	13.7	8.1	11	21	29	35	41
Low population and income growth	13.7	9.7	8	17	21	25	29
	Million adult participants		Percent increase from 2008				
High population and income growth	10.8	13.5	8	12	15	20	25
High population growth, low income growth	11.0	12.2	5	7	9	20	11
Low population and income growth	10.8	11.6	7	7	7	9	8
	Days per participant		Percent increase (decrease) from 2008				
High population and income growth	21.7	21.5	0	0	(1)	(1)	(1)
High population growth, low income growth	21.7	21.5	0	(1)	(1)	(1)	(1)
Low population and income growth	21.7	21.7	0	0	0	0	0
	Million days per year		Percent increase from 2008				
High population and income growth	230	286	8	11	15	19	24
High population growth, low income growth	234	255	5	7	8	9	9
Low population and income growth	230	248	7	7	7	8	8

Sources: <http://www.srs.fs.usda.gov/trends/research/sffpa2010.html>; Bowker and others (2013).

Below are forecasts for visitation to the four major site types in the national forests of the Appalachian-Cumberland highland: developed use day sites, overnight use developed sites, wilderness, and general forest areas.

Developed use day sites—Visitation to developed use day sites—all of which have some combination of built structures including picnic areas, playgrounds, shelters, boat ramps, toilets, parking lots—is the second most popular of site visit destinations in southern national forests, accounting for 6.5 million recreation visits in 2008. According to National Visitor Use Monitoring data for 2005 to 2009, national forests with lands in the Appalachian-Cumberland highland reported about 3.5 million visits to these sites (note that some of the national forests included in the estimate contain lands outside of the Appalachian-Cumberland highland). Although the annual visits per group to these sites are projected to decrease by 5 to 8 percent across the storylines, total visits are projected to increase over the next 50 years: 35 percent under B2, 47 percent under A1B, and about 70 percent under A2.

Overnight developed use sites—With facilities such as cottages, recreational vehicle hookups, camp sites, electricity, and running water, overnight use developed sites on southern national forests accommodated about 2.3 million visits in 2008. According to National Visitor Use Monitoring data for 2005 to 2009, national forests with lands in the Appalachian-Cumberland highland reported about 1.2 million visits to these sites (note that some of the national forests included in the estimate contain lands outside of the Appalachian-Cumberland highland). Annual visits per group are projected to decrease by 7 percent under storyline A2, and by 14 percent under storyline A1B. However, because of forecasted population growth, an increase of 30 to 64 percent is projected.

Wilderness—Annual visits per group to designated wilderness sites in southern national forests are expected to decrease slightly, 3 to 5 percent, over the next 50 years. This relatively stable per group annual visitation rate, when combined with population growth, suggests that visits to southern national forest wildernesses will likely experience higher growth than the other site types: between 38 percent (storyline B2) and 72 percent (storyline A2). Despite faster relative growth in visits, wilderness visits will likely remain the smallest in absolute terms.

General forest areas—Visits to general forest areas in southern national forests greatly exceeded recreation visits to the other three site types combined. The average annual visits per group are projected to decrease 12 to 24 percent

by 2060. The largest decrease, expected under storyline A1B, would primarily be driven by increased household income. The negative relationship between visits and income forecasted under the A1B storyline is likely attributable to recreationists selecting more luxurious recreational destinations. The expected increase in population over the next 50 years would offset the drop in average visits per group, yielding increases of 22 percent for storylines A1B and B2, and 55 percent for storyline A2.

Overall, visits to national forests will likely grow, slightly lagging population growth. General forest area use density is expected to rise 22 to 55 percent as national forests substitute for private forests that succumb to development. This could be a concern for forest managers because general forest area activities—such as hunting, horseback riding, and off-roading—often require more space between users for high-quality experiences.

Summary

Despite projections of continued losses in forest acreage across the Appalachian-Cumberland highland and changing demographics, outdoor recreation will likely continue to grow in both numbers of participants and days of participation across all activities and venues, private and public. In general, the number of projected participants and days of participation are expected to increase at a rate near or somewhat below the rate of population growth in the South. Increases in projected participants and days of participation vary, depending on the specific recreation activity and the storyline.

Forecasted increases in pressure on national forest lands by recreationists either opposed to or unfamiliar with the underlying reasons for active forest management could result in conflicts with other interested publics, as well as increased debate about the role of active management on public lands (Bengston and Xu 2001, Wear and Greis 2002). Outreach and education efforts by public land managers and involvement of citizenry in the planning process could alleviate some of these pressures.

The projected growth in recreation use is likely to put increasing pressure on existing infrastructure, both built and natural. In some situations, investing in infrastructure could relieve congestion problems. Private forest owners could also help to meet demand by increasing recreation infrastructure and access on their land.

For a broader discussion of outdoor recreation in the South, see Bowker and others (2013).

CONCLUSIONS

As the dominant land use across the Appalachian-Cumberland highland, forest land is a source of economic revenue and provides for a variety of ecosystem goods and services, including water quality and quantity, biodiversity (plant and animal), wildlife habitat quality, forest products, and carbon storage. A detailed synthesis of data from the Southern Forest Futures Project (Wear and Greis 2013) revealed that Appalachian-Cumberland forests, along with goods and services that they provide, are on track to experience substantial changes over the next 50 years.

Changes in the characteristics of forests as well as the goods and services they provide will be driven by numerous factors, including future climate, socioeconomic factors, future forest product markets, tax policy, land ownership patterns (for example, transfers from forest industry to timber investment management organizations and real estate investment trusts), and land use patterns (such as the change from forest uses to urban uses). In the Appalachian-Cumberland highland, the relationships among these drivers of future forest conditions—although complex and, for the most part, unknown—are expected to impact a wide range of ecosystem goods and services and create new management challenges.

The forecasted increase in urban land uses at the expense of forests would have cascading effects on overall ecosystem structure and function, leading to increased habitat fragmentation and loss of habitat connectivity and potentially producing negative impacts on the diverse suite of flora and fauna on Appalachian-Cumberland landscapes. This is a particularly important issue for species of management concern and populations that are endemic to specific habitats. Forest fragmentation can also degrade water and air quality and increase the susceptibility of forest interiors to invasive plant and animal species (Fox and others 2011). An increase in urban land use would mean an increase in impervious surfaces, which can further degrade water quality and quantity. Population growth and expansion of urban centers can lead to an expanded wildland-urban interface; this and the increase in wildfire potential resulting from climate change would exacerbate wildfire concerns for land managers. Furthermore, changes in land use, population growth, and climate change could interact to increase the rate of infestation by invasive plants, which is of both an ecological and economic concern.

With continued growth of the human population across the Appalachian-Cumberland highland, demands on forest land for many outdoor recreation activities would continue to grow as well. Although the rate of participation in some activities is likely to decrease over the next 50 years, the increase in population would outpace those decreases so

that overall participation would increase over time. For activities with increased participation rates, the added pressure of population increases would result in even larger increases in demand. A shrinking forest land base, regardless of degree, would result in more pressures and impacts on recreation use, both in overcrowding and in resource degradation. The result of a relatively fixed public land base and increasing demand would be a decrease in acres per capita available for recreation. On private lands, the decrease in forest acreage, along with fragmentation and the divestment of holding will likely result in less private land available for recreation.

Restoring ecosystem structure and function and improving forest resilience could be the keys to mitigating the negative effects of the changes that are predicted. Management challenges associated with ensuring that Appalachian-Cumberland forests continue to provide a full range of ecosystem goods and services could be resolved with the development of science-based management prescriptions, models, and tools. In situations where management/mitigation options have not been established, the key to sustainable management could be the synthesis of old research combined with multidisciplinary, issue-driven experimentation.

MANAGEMENT IMPLICATIONS

Appalachian-Cumberland forests are forecasted to experience dramatic changes over the next 50 years, including decreases in total area that are largely attributable to human population growth and land use changes associated with increased urbanization. Increased population and loss of forest land would likely put added pressure on the remaining forest land to supply the wide range of ecosystem goods and services that society expects, including—but not limited to—water quality and quantity, wildlife habitat, wood products, carbon storage and sequestration, recreational opportunities, and natural settings.

The management implications of supplying ecosystem goods and services from a decreasing forested land base are daunting. The numerous threats to overall ecosystem structure and function forecasted to occur over the next 50 years (2010 to 2060) can only be addressed if forest management takes a proactive approach to forest health (at a landscape scale) rather than reacting to events. Although the detailed effects that climate change could have on the diverse suite of Appalachian-Cumberland forest habitats is unknown, forest managers can rely on one certainty: the climate of future forests will be different from the climate that influenced the forests under their stewardship—the trend is for warmer temperatures, more unpredictable precipitation, and an increase in the number and extent of episodic drought events.

On many Appalachian-Cumberland landscapes, the management focus is on the restoration of resistant and resilient forests. Restoration of resiliency, the ability of a system to return to predisturbance structure and function, is accomplished by maintaining or enhancing species and structural diversity at the stand and landscape levels. Adding complexity (Puettmann and others 2009) to the landscape through traditional and novel forest management techniques can improve resilience to climate change and disturbance events by increasing the response diversity—the number of ways in which a system can respond (Elmqvist and others 2003). Without high levels of response diversity, the ability of a given forest to adapt or recover from future disturbances will be diminished, reducing its ability to provide key goods and services.

The interacting effects of climate change with population growth and increased urbanization—and accompanying expansion of the wildland-urban interface—will require land managers to address the increase in the potential, severity, and extent of wildfire throughout the Appalachian-Cumberland highland. Hazardous fuel reduction efforts accomplished through controlled burning would reduce wildfire potential; however, as population increases, smoke management issues could make widespread controlled burning more difficult to implement.

The concepts and tools for restoring the stand and landscape attributes that promote resistance and resilience to climate change and other disturbance events are also the keys to slowing the spread and reducing the impacts of invasive plants across the Appalachian-Cumberland highland. Site-specific controls will continue to be important for slowing the spread of invasive plants; however, restoring and maintaining healthy, diverse, and complex ecosystems would also be helpful. Because invasive plants occur across all ownerships, eradication and control programs must be collaborative if they are to succeed at any meaningful scale (Fox and others 2011). As with any pressing issue, public awareness, knowledge, and cooperative programs, along with forest management and eradication efforts, will continue to be important factors limiting the spread of invasive plants.

Appalachian-Cumberland wildlife and plant diversity is substantial. The number of species listed as imperiled or of management concern ensures that wildlife conservation will continue to be a challenge over the next 50 years. Combining forest management and wildlife conservation efforts would help address many wildlife issues that are associated with habitat quality or habitat extent. Forest management prescriptions developed with input from wildlife experts would also be helpful in addressing habitat fragmentation and connectivity issues that threaten a variety of vertebrate species.

With population centers expanding and forest land being converted to urban uses, water quality and water quantity would become increasingly important issues in the Appalachian-Cumberland highland; one example is the increase in impervious land area that accompanies continued urban development. Direct and indirect effects of a decreased water supply are numerous. In rural areas, decreasing water supply could hinder wildfire and structural fire suppression efforts. The projections of ever decreasing water supplies, coupled with increasing population and urbanization, portend a critical need for improved rural water supplies. State agencies such as the Virginia Department of Forestry have been proactive, implementing measures—such as the developed dry hydrant program—to ameliorate some of the issues of decreased water supply in rural areas and ensure that fire suppression efforts and other critical activities continue in spite of reduced supplies. Such efforts need to extend to all levels of government, raising awareness of the water-related issues associated with urban development and establishing bioindicator systems for monitoring issues associated with conversion and loss of forest land.

Because of their well-defined missions, mandates, and authorizing statutes, public lands have the highest potential for restoration activities centered on the conservation of biodiversity and complexity (Hunter 1999, Puettmann and others 2009). The vast majority of Appalachian-Cumberland forest land, however, is privately owned. Although not required to manage for multiple uses, these lands are, in fact, managed for a variety of resource benefits, including timber production (linked to investment and income potential), wildlife habitat, and recreation (Fox and other 2011). As such, they greatly contribute to all the benefits forest land provides: water quality and quantity, aesthetic values, clean air, economic and employment activities, wildlife habitat, and carbon storage.

Best management practices that outline voluntary and State-mandated forest operation activities exist throughout the Appalachian-Cumberland highland. When followed, best management practices can promote improved ecological conditions on private forest land. On a purely financial level, the viability of forest management investments is determined by harvest returns, rotation lengths, and tax incentives (Greene and others 2013). In the Appalachian-Cumberland highland, where timber prices are variable and rotation lengths are long, tax policy could be an effective mechanism for mitigating the parcelization and fragmentation forecasted to occur on private lands over the next 50 years. Although nomenclature changes across States, programs such as the present-use value tax program in North Carolina allow forests to be taxed at their present use rather than at their highest market value (such as developed land), provided they

are under a management plan. Because Federal tax policies on forest ownership are relatively standard throughout the United States, it is the variability in tax rates and incentives among individual States that contributes greatly to the level that private forests are converted to other uses (Greene and others 2013). Pressures that result in conversion of forests to other uses, particularly those associated with development, are forecasted to increase into the foreseeable future. As

found by Greene and others (2013), financial and tax incentive programs are successful not only in promoting sustainable forestry practices among private owners, but also in preventing land use conversion and parcelization. However, participation is limited by funding limits and by owner confusion about program requirements (Greene and others 2013), which could be overcome by educational and outreach programs and increases in funding mechanisms.

Appalachian-Cumberland forests are complex and diverse. These forests have proven resilient, recovering from the abusive land practices that occurred during the late 19th and early 20th centuries. Although a broad view of the past suggests the forests are resilient to a variety of disturbances, forecasts suggest that environmental conditions (such as climate), nonnative insects and diseases, forest fragmentation, and increased societal pressures could create novel conditions that affect ecosystem structure and function and the ability of forests to respond to disturbance—the result being decreases in benefits from forests. Because the issues that will affect forests over the next 50 years cross ownership boundaries, an ‘all-lands approach’ would be the most effective way to ensure continued ecological and economic benefits.

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The U.S. Appalachian-Cumberland highland consists of about 62.3 million acres in portions of Alabama, Georgia, North Carolina, Tennessee, Kentucky, and Virginia; and is divided into five sections—Blue Ridge Mountains; Interior Low Plateau; Northern Ridge and Valley; Southern Ridge and Valley; and Cumberland Plateau and Mountains. Appalachian-Cumberland forests provide a multitude of ecological services and societal benefits. This publication presents results from the Southern Forest Futures Project specific to the Appalachian-Cumberland subregion, along with associated challenges to forest management. Forecasted scenarios suggest that environmental conditions, nonnative insects and diseases, forest fragmentation, and increased societal pressure on forest land could create novel conditions that affect ecosystem structure and function. Continued changes in the societal forces that shape forest conditions, including urbanization, have the potential to affect many of the ecosystem services provided by Appalachian-Cumberland forests, including commercial and noncommercial forest products (such as timber harvesting and mushroom collecting), water quantity and quality, recreation, wildlife habitat, and biological complexity.

Keywords: Appalachian-Cumberland, conservation, forest management, Southern Forest Futures Project.



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