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Outlook for Piedmont Forests:

A SUBREGIONAL REPORT from the Southern Forest Futures Project

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Cover photos

MAIN IMAGE: Sunrise in Floyd County, VA (Eric R. Day, Virginia Polytechnic Institute and State University, Bugwood.org).
TOP ROW L TO R: Urbanization could significantly reduce forest cover in the South (Larry Korhnak, courtesy of Interface South); flames from the Table Rock fire approach the road in Burke County, NC (USDA Forest Service photo); kudzu infestation in Tift County, GA (Chris Evans, Illinois Wildlife Action Plan, Bugwood.org); a young raccoon hangs upside down while gathering food (USDA Forest Service, Southern Research Station Archive, Bugwood.org); Chinese silvergrass is a nonnative invasive plant of southern forests having been introduced from Eastern Asia and sold as an ornamental (J. Miller, USDA Forest Service, Southern Research Station, Bugwood.org).

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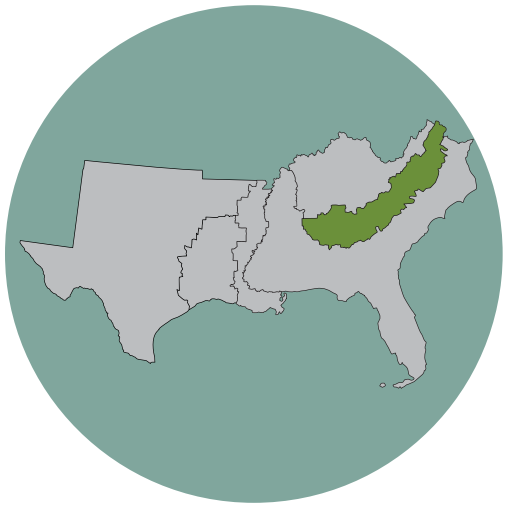

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PROLOGUE

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This report describes a set of likely forest futures and the management implications associated with each for the Piedmont, 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.

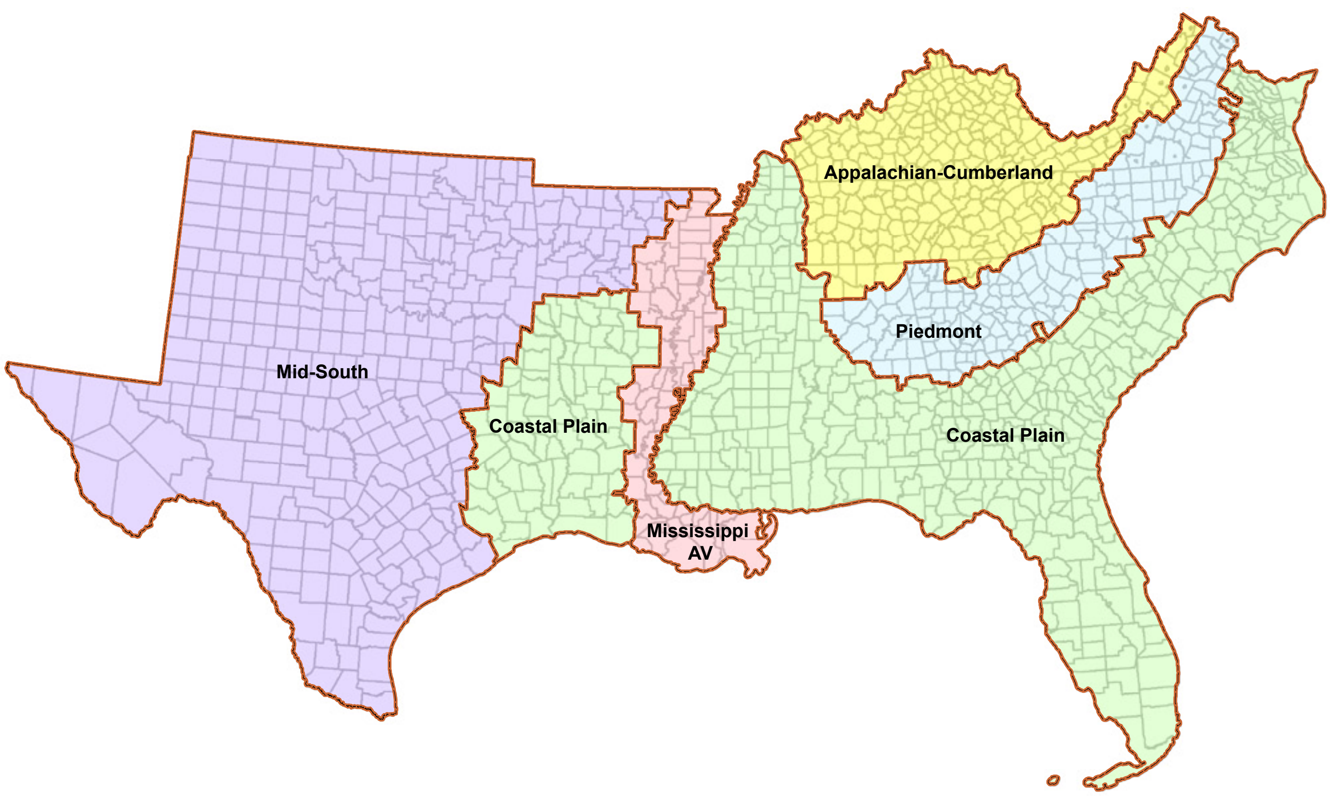

Figure P1—The five subregions of the U.S. South.

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).

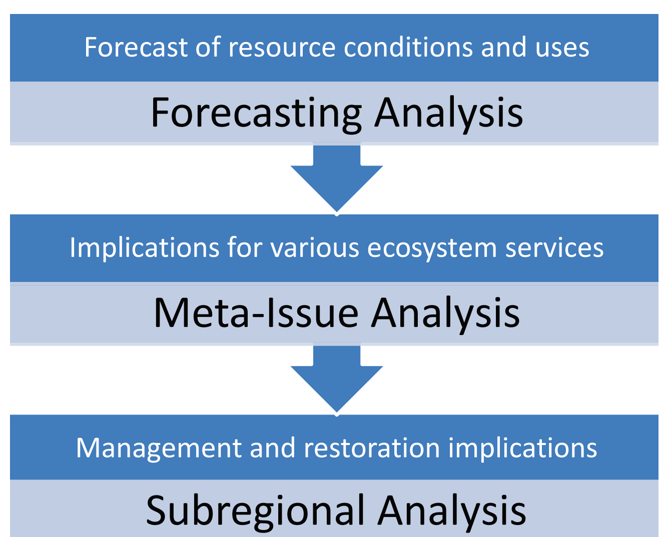

Figure P2—The three phases of the Southern Forest Futures Project.

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).

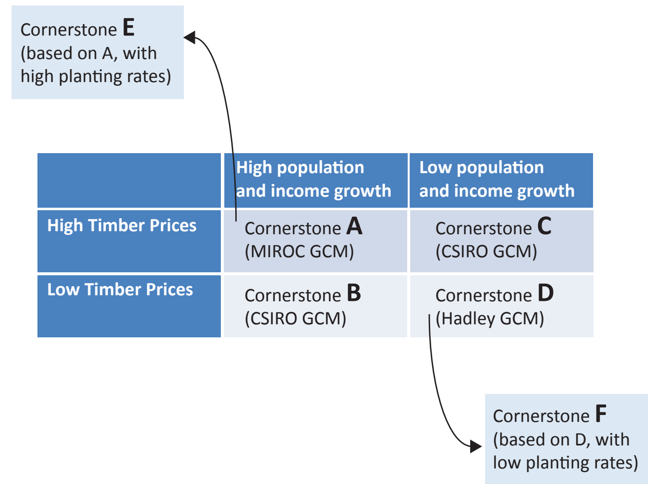

Figure P3—Six Cornerstone Futures, each of which represents a general circulation model (MIROC3.2, CSIROMK3.5, CSIROMK2, or HadCM3) paired with one of two emission scenarios (A1B representing low-population/high-economic growth, high energy use, and B2 representing moderate growth and use) and two timber 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).

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.

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 Piedmont. 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 Piedmont.

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, CSIROMK2, CSIROMK3.5, 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 Piedmont, a complex physiographic subregion of the U.S. South, encompasses parts of Virginia, North Carolina, South Carolina, Georgia, and Alabama. Anticipating the future and analyzing what the interaction of future changes might mean for the forests of the Piedmont and the services they provide can improve decisions by resource managers and policymakers that have long-term consequences. The authors extracted and analyzed detailed results from the Southern Forest Futures Project to provide a set of key findings and implications for the Piedmont. The general conclusion of this analysis is that Piedmont forests will likely decline over time in response to growing populations and urbanization. Over the next several decades the Piedmont will be faced with the effects of forest loss, including changes in water quality and water supply from forests, recreational opportunities, wildlife habitat, and increasing competition for traditional forest products industries.

Keywords: Climate, forest conservation, futuring, integrated assessment, Piedmont, Southern Forest Futures Project, sustainability, urbanization.

KEY FINDINGS

- Urbanization is the key driver leading to forest losses in the Piedmont.

- Forest losses will likely range from 6 to 21 percent depending on population growth and timber market trends.

- Most of the forest loss is forecast to occur in the upland hardwood type, more specifically in yellow-poplar stands.

- The extent of pine and oak-pine will likely remain the same, but these areas would experience some transition from natural stands to plantation pine.

- Forest product removals will likely remain at current levels even as forest area decreases.

- The Piedmont is expected to experience warmer temperatures (from 1.02 to 2.63 ºC increase).

- Predicted change in precipitation varies but generally is expected to decrease across the Piedmont; however, the southern part of the Piedmont (Piedmont Ridge, Valley, and Plateau section) would tend to have higher maximum precipitation, possibly because of more frequent storm events.

- The Piedmont has 528 native terrestrial vertebrates: 94 amphibians, 283 birds, 76 mammals, and 75 reptiles; species richness is highest in the Central Appalachian Piedmont (475) and Southern Appalachian Piedmont (444), reflecting both their large size and the diversity of habitats within them.

- The proportion of species at risk varies among taxonomic groups in the Piedmont: 53 percent of imperiled vertebrate species are amphibians, followed by reptiles (22 percent), mammals (19 percent), and birds (6 percent); the Southern Appalachian Piedmont (18) leads in the numbers of imperiled vertebrate species, followed by the Central Appalachian Piedmont (10) and the Piedmont Ridge, Valley, and Plateau (9).

- In the Piedmont, substantial urban growth and forest loss could reduce the diversity of amphibians, mammals, and plants, although species in inaccessible sites (such as rock outcrops) might be less at risk; management on public land could become more difficult because of the human population pressure in surrounding counties.

- Although some longleaf pine forests in the Piedmont will likely be lost, longleaf pine overall would actually expand from its current distribution.

- The heaviest infestation of invasive plant species occurs in the Piedmont Ridge, Valley, and Plateau section, where every county is infested with at least one invasive plant species.

- Diseases and harmful insects will likely have serious impacts on Piedmont forests; some species such as the emerald ash borer, laurel wilt, and thousand cankers disease are expanding and could threaten the ecological viability of their hosts throughout large areas of the Piedmont.

- Climate forecasts predict that the Piedmont's spring and autumn wildfire seasons will be extended.

- Smoke will likely increase restrictions on prescribed burning over large areas, especially in areas at or near the emissions threshold for air quality standards and in wildland-urban interface areas that have extensive transportation systems and vulnerable populations.

CHAPTER 1.
The Forests and People of the Piedmont

LOCATION AND AREA

One of five subregions of the Southern United States, the Piedmont (literally "foot of the mountain") comprises the area between the Appalachian Mountains to the north and west and the Coastal Plain to the south, west, and east. The Piedmont consists of three sections: (1) the Central Appalachian Piedmont within Virginia, North Carolina, and South Carolina; (2) the Southern Appalachian Piedmont within South Carolina, Georgia, and Alabama; and (3) the Ridge and Valley section within Georgia and Alabama (fig. 1). It generally extends about 600 miles from northeast to southwest and is about 125 miles across from the transition from the Appalachians to the fall line (the geographic boundary of the Piedmont where easily navigable waterways end).

The Central section is primarily located in Virginia and North Carolina, with two counties in South Carolina. The 37 Virginia counties are Loudoun, Arlington, Fairfax, Fauquier, Prince William, Rappahannock, Culpeper, Stafford, Madison, Spotsylvania, Orange, Greene, Albemarle, Louisa, Fluvanna, Hanover, Goochland, Powhatan, Chesterfield,

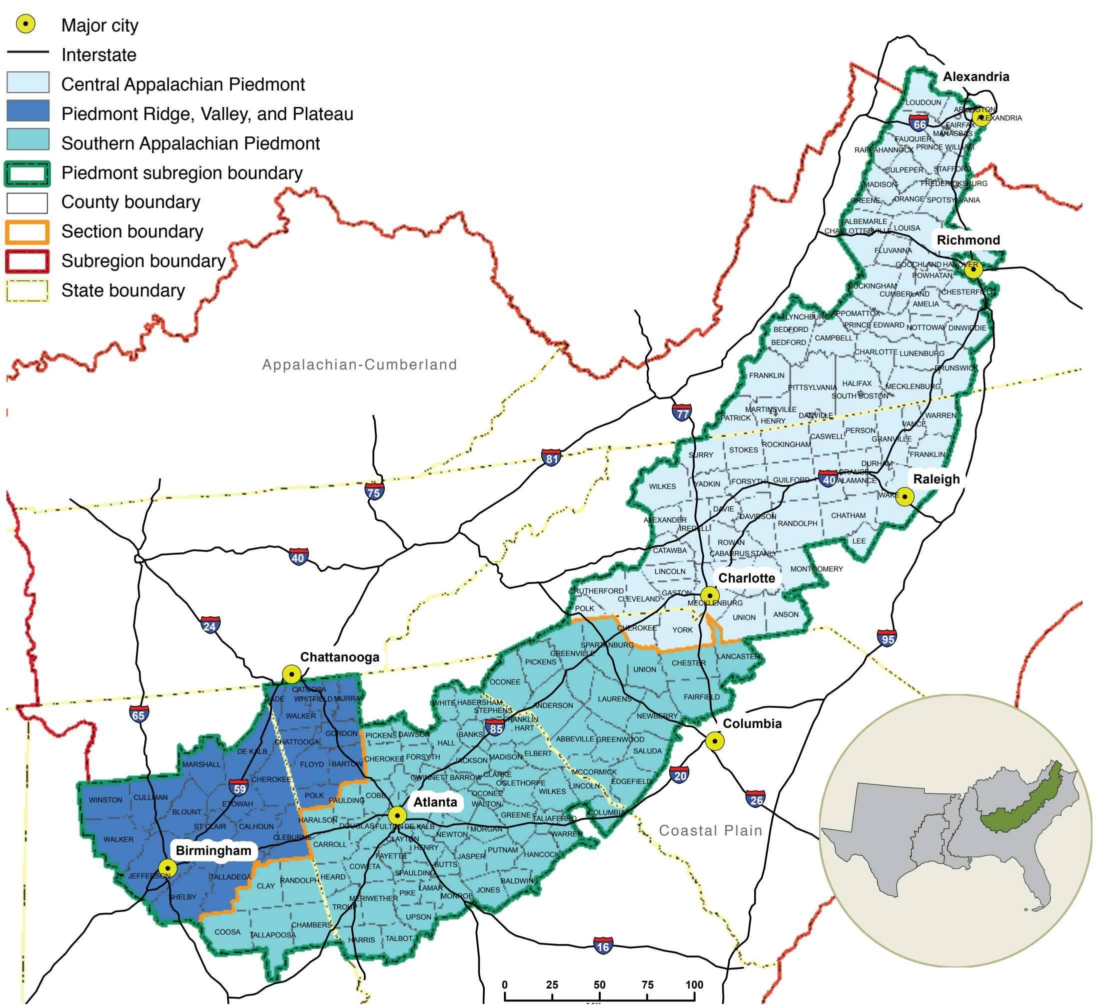


Figure 1—The Southern U.S. Piedmont.

Amelia, Cumberland, Buckingham, Appomattox, Prince Edward, Nottoway, Dinwiddie, Brunswick, Lunenburg, Charlotte, Campbell, Bedford, Franklin, Pittsylvania, Halifax, Mecklenburg, Henry, and Patrick. The 37 North Carolina counties are Warren, Vance, Granville, Person, Caswell, Rockingham, Stokes, Surry, Wilkes, Yadkin, Forsyth, Guilford, Alamance, Orange, Durham, Wake, Franklin, Lee, Chatham, Randolph, Davidson, Davie, Rowan, Iredell, Alexander, Catawba, Polk, Rutherford, Cleveland, Lincoln, Gaston, Mecklenburg, Cabarrus, Stanly, Union, Anson, and Montgomery. And finally, the South Carolina counties are Cherokee and York. This section covers 35,194 square miles.

The Southern section is primarily located in South Carolina and Georgia, with five counties in Alabama. The 16 South Carolina counties are Oconee, Pickens, Greenville, Spartanburg, Union, Chester, Lancaster, Fairfield, Newberry, Laurens, Anderson, Abbeville, Greenwood, Saluda, McCormick, and Edgefield. The 56 Georgia counties are White, Habersham, Stephens, Franklin, Hart, Banks, Madison, Elbert, Wilkes, Lincoln, Columbia, Warren, Taliaferro, Hancock, Greene, Oglethorpe, Clarke, Jackson, Hall, Forsyth, Dawson, Pickens, Cherokee, Cobb, Paulding, Haralson, Carroll, Douglas, Fulton, De Kalb, Gwinnett, Barrow, Oconee, Walton, Morgan, Putnam, Baldwin, Jones, Jasper, Newton, Rockdale, Clayton, Henry, Butts, Monroe, Lamar, Upson, Pike, Talbot, Harris, Troup, Meriwether, Spalding, Fayette, Coweta, and Heard. And finally, the Alabama counties are Randolph, Clay, Chambers, Tallapoosa, and Coosa. This section covers 29,918 square miles.

The Ridge and Valley section is located in Georgia and Alabama. The 10 Georgia counties are Dade, Catoosa, Whitfield, Murray, Walker, Chattooga, Gordon, Floyd, Bartow, and Polk; and the 14 Alabama counties are Marshall, De Kalb, Cherokee, Cleburne, Calhoun, Etowah, Winston, Cullman, Walker, Blount, Jefferson, Shelby, St. Clair, and Talladega. This section covers 13,016 square miles.

LANDFORMS AND SOILS

Geomorphology

The terrain of the Central and Southern sections is a moderately dissected plain with high or low hills (McNab and Avers 1994, McNab and others 2005) consisting of thick saprolite, continental sediments, and accreted terranes. Elevations range from 100 to 400 m, with local relief ranging from 30 to 90 m. The difference between the two sections is their underlying geomorphology. The Central section is "underlain by metamorphic formations of schists and phylites that have weathered to form thick saprolite and deep soils with heavy clay subhorizons" (McNab and others 2005). The Southern section is "underlain by highly metamorphosed crystalline rocks that have weathered to form deep, infertile clayey soils highly eroded from long, intensive cultivation" (McNab and others 2005).

The Ridge and Valley section consists of "highly folded, linear sandstone and limestone formulations resulting in topography of parallel, northeast-southwest trending, elongated synclinal valleys and rounded ridges, with gentle to moderate slopes" (McNab and others 2005). Part of this section also has "gently sloping tablelands of level-bedded sandstone formations and hilly to mountainous terrain consisting of shale and sandstone slopes forming deep canyons with steep connecting escarpments" (McNab and others 2005). Elevation ranges from 150 to 300 m, with local relief ranging from 90 to 150 m in the plains and 150 to 300 m in the high hills.

Lithography and Stratigraphy

For the Central and Southern sections, 60 percent of the rock units were formed during the Precambrian Era. Strata consist of "metamorphic complexes with compositions of schist and phylite, and mafic paragneiss" (McNab and Avers 1994). Thirty percent of the rock units were formed during the Paleozoic Era, with strata consisting of "about equal amounts of Cambrian eugeosynclinal and volcanic rocks" (McNab and Avers 1994). Ten percent of the rock units were formed during the Mesozoic Era, with strata consisting of "Triassic marine deposits (sandstone, siltstone, and shale)" (McNab and Avers 1994).

For the Ridge and Valley section, all of the rock units were formed during the Paleozoic Era. Strata consist of "a mosaic of marine deposits of Lower Cambrian clastic rocks (granites), and a mixture of marine deposits of Cambrian (carbonates and shales), Lower Ordovician (carbonates), and Mississippian (shales, limestone, and chert) ages" (McNab and Avers 1994).

Soils

Soils in the Central and Southern sections tend to be deep with a clay or loamy subsoil. Because of past intensive agricultural practices (especially the cultivation of cotton), many areas are severely eroded. Predominate soils include Udults, with Paleudults and Hapludults on gently sloping uplands. Hapludults, Rhodudults, Dystrochrepts, and Hapludalfs dominate the steeper slopes. Dystrochrepts, Udifluvents, and Fluvaquests are on alluvium (McNab and Avers 1994). The temperature regime is thermic, and the mineralogy is kaolinitic, mixed, or oxidic (McNab and Avers 1994).

The soils in the Ridge and Valley section tend to be Udults with some Ochrepts. Upland areas are dominated by Paleudults and underlain by limestone. Valleys are dominated by Hapludults and underlain by shale. Dystrochrepts dominate on side slopes and ridges compared to Hapludolls and Eutrochrepts in bottomlands. The moisture regime is udic, and the temperature regime is thermic or mesic. Depth of soils ranges from shallow on sandstone and shale to very deep on limestone formations, with almost all soils being well drained (McNab and Avers 1994).

HISTORICAL DEVELOPMENT

At the time of European contact the Piedmont was home to the Cherokee, Muskogee, Occaneechi, and other Native Americans. Desoto traveled through Georgia, South Carolina, North Carolina, Tennessee, and Alabama reporting that the Piedmont in Georgia was "well populated with Indians" (Sheppard 2001). These groups lived in settled communities and engaged in farming, hunting, and trade. They managed the landscape and used fire to clear areas for growing crops, promoting wildlife habitat, and encouraging desirable species such as canebrakes (Fowler and Konopik 2007). By the early 1700s, the remnants of clearings had begun to disappear into young pine (*Pinus* spp.) and oak (*Quercus* spp.) forests as introduced diseases increased mortality rates and population loss. Conflict between Native Americans and settlers culminated in the Indian Removal Act of 1830, opening the western part of the Piedmont to homesteading.

The pattern of European settlement of the South has always been influenced by transport connections—river transport between the interior and coastal ports and overland routes through the Piedmont connecting southern rural outposts and growing settlements to the population centers of the eastern seaboard and to the trade centers that emerged on navigable rivers along the fall line in the mid-to-late 1700s. The Fall Line Road was an early overland route that connected Augusta, GA to Fredericksburg, VA (today's I-20 and I-95); the Upper Road in the Piedmont passed through Charlotte roughly preceding the alignment of today's I-85.

After the Revolutionary War, migration increased significantly along these routes with the settlement of the Piedmont by Scots-Irish from northeastern areas. Because of the rolling terrain and distance to markets, the early development of the Piedmont was primarily limited to pioneer agriculture, resource trade, and small scattered communities. Forests were cleared to produce agricultural products that were transported to markets on rivers. Settlement progressed steadily from east to west starting in Virginia in 1700 and reaching the Alabama-Georgia border by 1826 (Brender 1974). As settlement expanded, agriculture shifted from subsistence and local trade to more intensive commodity production of crops, such as cotton in the Southern Piedmont and tobacco in Virginia and North Carolina. Trimble (1974) estimated that by the time of the Civil War most of the Piedmont was in moderately or highly erosive land use—with the equivalent of 38 percent of its acreage in row crop production. Commodity agriculture stimulated the expansion of transportation infrastructure to move goods to market. By the mid-1800s, southern railroads connected the east coast to the Mississippi River using various routes through the Piedmont. Atlanta was established in 1847 as a railroad "terminus" and quickly grew in response to the economic activity associated with rail connections. In 1856, the North Carolina Railroad connected Goldsboro, Raleigh, and Charlotte.

After the Civil War, southern development shifted towards industrialization with a vision of the "New South" that would produce the raw materials of industry as well as finished products. The fall line provided the water power needed to run the mills that processed food and fiber agricultural outputs, stimulating the growth of industrial cities at the southern edge of the Piedmont. In 1880, 160 cotton mills dotted the South; by 1890, the number had grown to more than 400. Tobacco followed a similar pattern in the Northern Piedmont as processing expanded with the invention of the cigarette-making machine in 1880. Continued agricultural development, however, faced a number of serious challenges from falling commodity prices, marginal farm productivity, arrival of the boll weevil (*Anthonomus grandis*), and declining economic conditions. A common problem in the Piedmont was the depletion of farm productivity by soil erosion and improper agricultural practices. After the peak of extensive agricultural land use in the 1920s, marginal and abandoned farms began reverting to pasture and forest. The 1940 Census of Agriculture counted nearly 400,000 acres of abandoned farmland in the Piedmont. Trimble (1974) cited an example in Georgia—Jasper County, which was 45 percent forest and pasture in 1919, had increased to 95 percent forest and pasture by 1967. Gemborys and Lund (1992) documented a similar trend in southern Virginia where open land decreased from 61 percent in 1917 to 12 percent in 1972 with a concomitant increase in forest cover from 26 to 70 percent. The recovery of forest cover followed natural succession with initial increases in pine and intolerant hardwoods leading to later successional oak-hickory (*Carya* spp.) forest cover over time.

FOREST USES AND HISTORY

Historically forest cover of the Piedmont was primarily oak-hickory transitioning to mixed pines and hardwoods on drier sites, closer to the fall line or west of the Ocmulgee River (Brender 1974). The derivation of Atlanta's ubiquitous "Peachtree" is actually "pitch tree," a reference to the southern pine that grew on the site when it was a Muskogee settlement called Standing Pitch Tree. Native American land use practices, including their application of fire, created clearings and favored pine development. Frost (1993) estimated that most of the Piedmont east of the Atlantic-Gulf divide (roughly central Georgia) would have been in a 4- to 6-year fire cycle, compared to a 7- to 12-year regime farther west.

Early European settlement and agricultural use cleared much of the original forest. In the late 1800s, the southern lumber industry dramatically expanded, with capital investment growing 550 percent in Alabama, Georgia, North Carolina, South Carolina, and Virginia from 1880 to 1900. The 1900 Census (Defebaugh 1906) reported 5.12 billion board feet of lumber production from the five states (about 14 percent of the U.S. total lumber production).

Agricultural abandonment and forest cutover lands reverted to forest cover following a pattern of succession from "old-field" pine stands to mixed pines and hardwoods (known as the South's second forest). Responding to significant concerns about the condition and utilization of these areas, U.S. agencies took steps to address the problem of degraded lands, support rural community and agricultural development, and acquire land for public forests as authorized by the Weeks Act. Most of the Piedmont national forests were established with land acquisitions of the early 1900s. New forest regeneration methods were also promoted to restore productivity. For example, research focused on methods to control hardwood invasion of pine plantations in the lower Piedmont (Brender and Nelson 1952) often cited the succession patterns in Piedmont forests from pine to hardwood as the natural driver of hardwood incursion. The development of forest regeneration for public and private-industry land resulted in expanded forest cover (the South's third forest) that continues to support forest-based industry, ecological communities, and public well-being.

Longleaf pine (*Pinus palustris*) is a signature ecosystem in the South, primarily associated with the Coastal Plain. However, the historical range of the longleaf ecosystem in the Piedmont also includes western Georgia, a transitional zone along the fall line, and the Ridge and Valley section (Frost 1993), where longleaf comprises about 140,000 acres. The Mountain Longleaf National Wildlife Refuge was established near Anniston, AL in 2003 to recognize the natural significance of this ecosystem and its need for conservation. In contrast to the Ridge and Valley section, the Southern and Central sections have a mixture of other pine species, such as shortleaf, loblolly (*Pinus taeda*), and slash (*Pinus elliottii*).

POPULATION, DEMOGRAPHY, AND ECONOMIC ACTIVITY

The most populous subregion of the South, the Piedmont includes major urban centers in a swath that stretches from Birmingham, AL through Washington, DC (fig. 1)—one of 10 major urban concentrations called "megapolitan" areas in the United States (Lang and Dhavale 2005) that are defined by a set of regional and functional connections. The Piedmont Atlantic Megaregion has been variously defined, but the urban core clearly builds around three interstate highways (I-20, I-85, and I-40) stretching from Birmingham, AL to Raleigh, NC (fig. 1). The upper end of the Piedmont in Virginia is actually included in the Northeast Megapolitan area because of trade, transport, and cultural connections.

To define the largest urban geographies, the U.S. Office of Management and Budget uses the term Core Based Statistical Area: one or more counties with an urban population of ≥10,000 plus adjacent areas that have a high degree of integration measured by commuting ties. Of the 177 counties in the Piedmont, 142 are classified as either metropolitan statistical areas (centered around an urban area >50,000 population) or micropolitan statistical areas (centered around an urban area between 10,000 and 50,000 population). Twelve Combined Statistical Areas (formed when adjoining statistical areas—any combination of metropolitan or micropolitan—meet the standards established for becoming a new area) include portions of the Piedmont. Eight of these are in the top 50 population centers of the United States—Atlanta, Charlotte, Raleigh, Greensboro, Greenville-Spartanburg, Washington-Alexandria, and Birmingham. The Atlanta metropolitan area is the ninth largest in the United States with a combined 2010 population of nearly 5.5 million. The Charlotte-Gastonia metropolitan area is 33rd with a population of 1.76 million.

Piedmont urbanization was partly caused by the migration of rural population to cities that occurred with the change from labor-intensive commodity agriculture to less intensive rural land use. The growth of primary manufacturing (textiles, iron and steel, and tobacco products) led the development of urban economies in the "New South." In the second half of the 20th century, another transition occurred with the decline of primary manufacturing (iron production in the 1950s and textiles in the 1990s) and the development of more diversified economies. In 2003 the top seven basic industries in the region were construction, manufacturing, retail trade, real estate, administrative and waste services, other services, and government (Conant and Ross 2005). Commodity flow on trucks and rail (fig. 2) averaged about 80 million tons per year along the I-85 corridor (Southworth and others 2010). Most of this appears to support economic activity within the Piedmont as traffic volumes decrease at its edges. The exception is significant commodity flow (>80 million tons per year) from north to south on I-75 through Atlanta; this most likely supports trade to other southern subregions and beyond.

Although the Piedmont is economically dynamic, poverty is still a critical issue. The American Community Survey

(U.S. Census Bureau 2011), which provides an estimate of poverty rates at the census tract level (fig. 3), found clear concentrations of poverty in inner cities as well as in rural areas. Some rural census tracts scattered throughout the Piedmont have >35 percent of the population living in poverty. Statistical tests comparing percent forest cover and poverty rate however found relatively low correlation coefficients.

A study of workforce issues in North Carolina summarized economic development challenges typical of the Piedmont (Corporation for a Skilled Workforce 2003). In a six-county area, about 20 percent of the adult population had less than a high school diploma. The economic base was shifting from manufacturing to service-oriented jobs. Most occupations did not require a high school diploma and had an annual salary of ≤ $25,000. Economic development requires a focus on retaining and attracting higher-wage and higher-skill jobs and supporting workforce development through education and training. Otherwise, labor will continue to migrate to better economic opportunities, generally a driver for increasing urbanization.

In general, the Piedmont is a diversifying and expanding human network (American Forests Urban Ecosystem Center 2010). Population growth has exceeded national averages because the area is attractive for its economic opportunities (jobs and cost of living) and for its standard of living (for example, the mild climate). Forestry is recognized as a unique element of the Piedmont economy but represents a relatively minor component of its total economic sector.

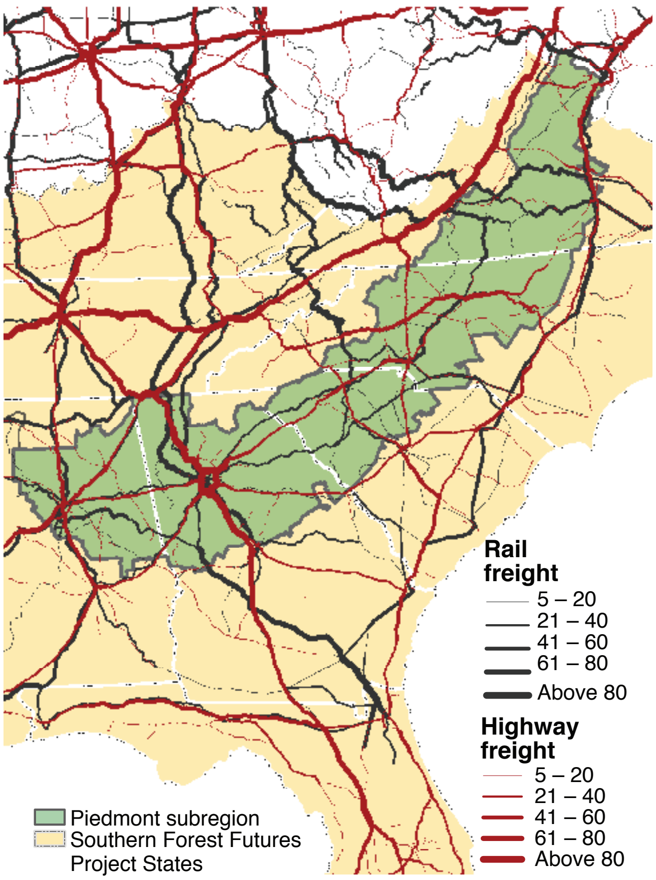


Figure 2—Commodity flows in the Southern U.S. Piedmont, 2010.

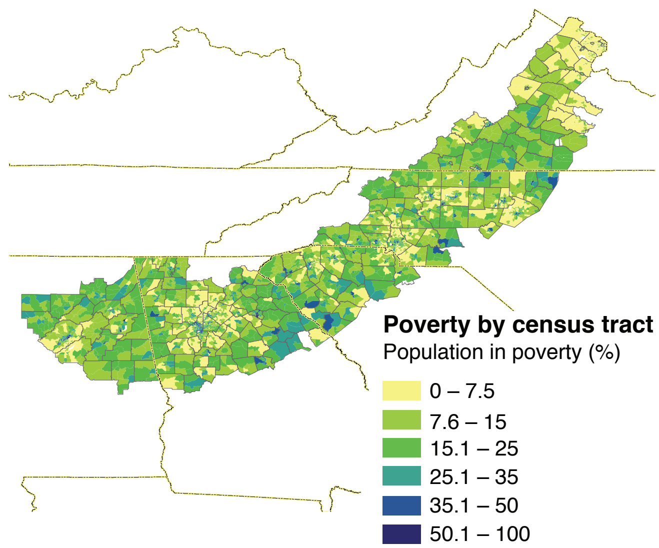


Figure 3—Percent of total population living in poverty in the Southern U.S. Piedmont by census tract, 2010 (Source: U.S. Census Bureau 2011).

CHAPTER 2.
Forest Conditions

CURRENT MAJOR FOREST TYPES AND VEGETATIVE COMMUNITIES

The Piedmont currently supports about 31 million acres of forest land (approximately 62 percent of total land area). These forests are 52 percent hardwoods (mostly upland hardwood) and 34 percent pine, with about 50 percent of the pine being planted (more prevalent in the Southern section), and about 14 percent a mixture of pines, oaks, and other hardwoods (fig. 4). The pine management type is dominated by loblolly pine at 83 percent, followed by Virginia pine (*Pinus virginiana*) at 11 percent. The remainder is in various other pine species (table 1), such as shortleaf pine at about 850,000 acres (mostly in the Central section and Southern section), and longleaf pine at about 140,000 acres (more often occurring in the Southern and Ridge and Valley sections). For the oak-pine management type, over half (57 percent) is in loblolly pine–hardwood, followed by Virginia pine–southern red oak (*Q. falcata*) at 22 percent and shortleaf pine–oak at 12 percent. The upland hardwoods are led by white oak (*Q. alba*)–red oak–hickory and mixed upland hardwoods (both at 22 percent), followed by sweetgum (*Liquidambar styraciflua*)–yellow-poplar (*Liriodendron tulipifera*) at 15 percent and yellow-poplar–white oak–northern red oak (13 percent). The lowland hardwood management type consists of mostly sweetgum –nuttall oak (*Q. nuttallii*)–willow oak (*Q. phellos*) at 27 percent, sugarberry (*Celtis laevigata*)– hackberry (*Celtis occidentalis*)–American elm (*Ulmus americana*)–green ash (*Fraxinus pennsylvanica*) at 23 percent, river birch (*Betula nigra*)–sycamore (*Platanus occidentalis*) at 17 percent, sweetbay (*Persea borbonia*)–swamp tupelo (*Nyssa biflora*)–red maple (*Acer rubrum*) at 12 percent, and sycamore–pecan (*Carya illinoinensis*)–American elm at 10 percent.

The forests in the Piedmont tend to be younger than other forests in the South. More than half (55 percent) are ≤40 years, and 24 percent are ≥61 years (fig. 5), a pattern followed by the sections of the Piedmont: 48 percent ≤40 years and 29 percent ≥61 years in the Central section, 61 percent ≤40 years and 19 percent ≥61 years in the Southern section, and 55 percent ≤40 years and 22 percent ≥61 years in the Ridge and Valley section. In all sections, age class distribution varies among the management types.

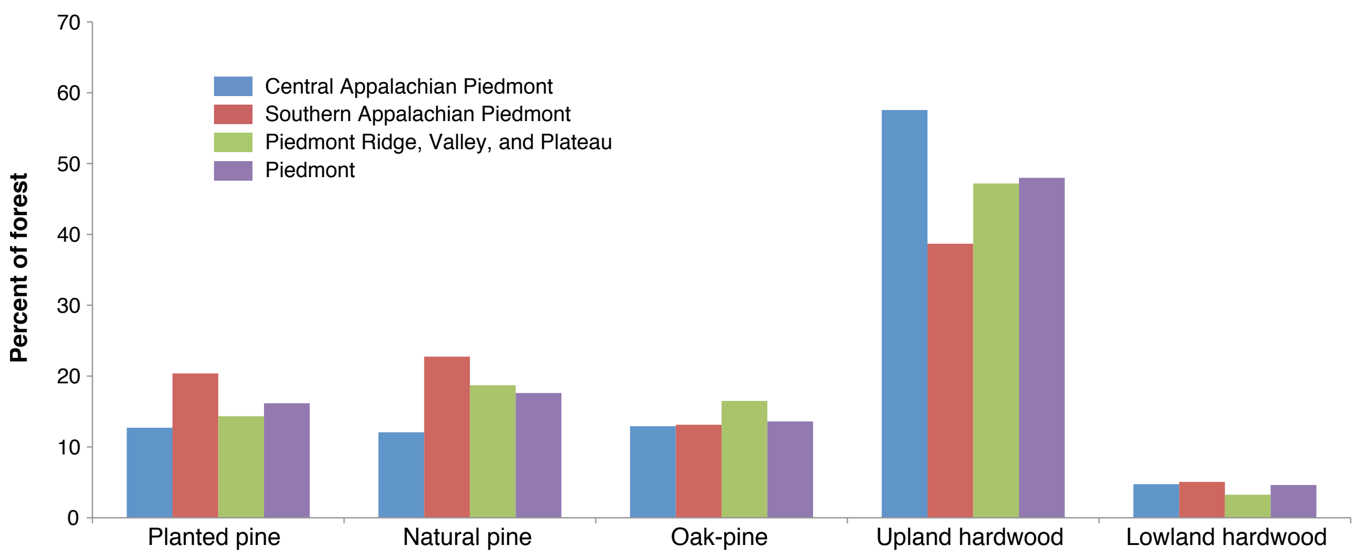


Figure 4—Composition of forests, 2010, in the Southern U.S. Piedmont and its sections (Source: Huggett and others 2013).

Table 1—Species and species group distribution in 2010, by area, in the forests of the Southern U.S. Piedmont and its sections—Central Appalachian Piedmont, Southern Appalachian Piedmont, and Piedmont Ridge, Valley, and Plateau

Species/species group	Central	Southern	Ridge and Valley	All Piedmont
		percent of total forested acres		
Eastern white pine	0.141	0.125	0.000	0.111
Eastern white pine–eastern hemlock	0.000	0.044	0.000	0.018
Eastern hemlock	0.060	0.040	0.181	0.072
Longleaf pine	0.003	0.367	0.859	0.296
Slash pine	0.000	0.034	0.000	0.014
Loblolly pine	16.254	39.593	26.595	27.669
Shortleaf pine	1.586	1.128	0.369	1.195
Virginia pine	5.714	1.083	4.438	3.577
Sand pine	0.000	0.092	0.000	0.038
Pitch pine	0.090	0.000	0.000	0.038
Eastern redcedar	0.713	0.333	0.309	0.488
Eastern white pine–northern red oak–white ash	0.518	0.106	0.000	0.261
Eastern redcedar–hardwood species	0.831	0.803	0.299	0.732
Longleaf pine–oak	0.000	0.361	0.571	0.244
Shortleaf pine–oak	1.125	1.513	2.892	1.578
Virginia pine–southern red oak	5.178	0.755	2.937	2.968
Loblolly pine–hardwood species	5.136	9.432	9.643	7.667
Other pine–hardwood species	0.031	0.078	0.000	0.045
Post oak–blackjack oak	0.737	1.959	2.457	1.529
Chestnut oak	2.716	0.818	5.317	2.357
White oak–red oak–hickory	11.684	7.851	14.395	10.538
White oak	4.217	2.349	1.538	2.997
Northern red oak	0.365	0.059	0.146	0.202
Yellow-poplar–white oak–northern red oak	9.013	3.851	3.986	6.035
Sassafras–persimmon	0.400	0.274	0.281	0.328
Sweetgum–yellow-poplar	7.679	7.823	4.702	7.247
Scarlet oak	0.347	0.324	0.148	0.304
Yellow-poplar	3.597	0.932	0.805	2.027
Black walnut	0.069	0.083	0.032	0.069
Black locust	0.136	0.000	0.000	0.057
Chestnut oak–black oak–scarlet oak	3.324	1.631	4.560	2.824
Cherry–white ash–yellow-poplar	0.000	0.011	0.000	0.000
Red Maple–oak	1.041	0.142	0.196	0.528
Mixed Upland hardwood	11.755	10.339	8.191	10.577
Swamp chestnut oak–cherrybark oak	0.036	0.057	0.253	0.080
Sweetgum–nuttall oak–willow oak	0.638	1.783	1.182	1.204
Sweetbay–swamp tupelo–red maple	0.534	0.658	0.164	0.525
River birch–sycamore	1.141	0.551	0.219	0.744
Cottonwood	0.000	0.000	0.129	0.021
Willow	0.019	0.175	0.028	0.086
Sycamore–pecan–American elm	0.507	0.487	0.276	0.461
Sugarberry–hackberry–American elm–green ash	1.049	0.999	0.915	1.006
Red maple–lowland species	0.470	0.151	0.031	0.265
Cottonwood–willow	0.000	0.042	0.000	0.018
Aspen	0.061	0.000	0.000	0.026
Other nonnative hardwood species	0.246	0.124	0.032	0.160
Nonstocked	0.823	0.651	0.924	0.768

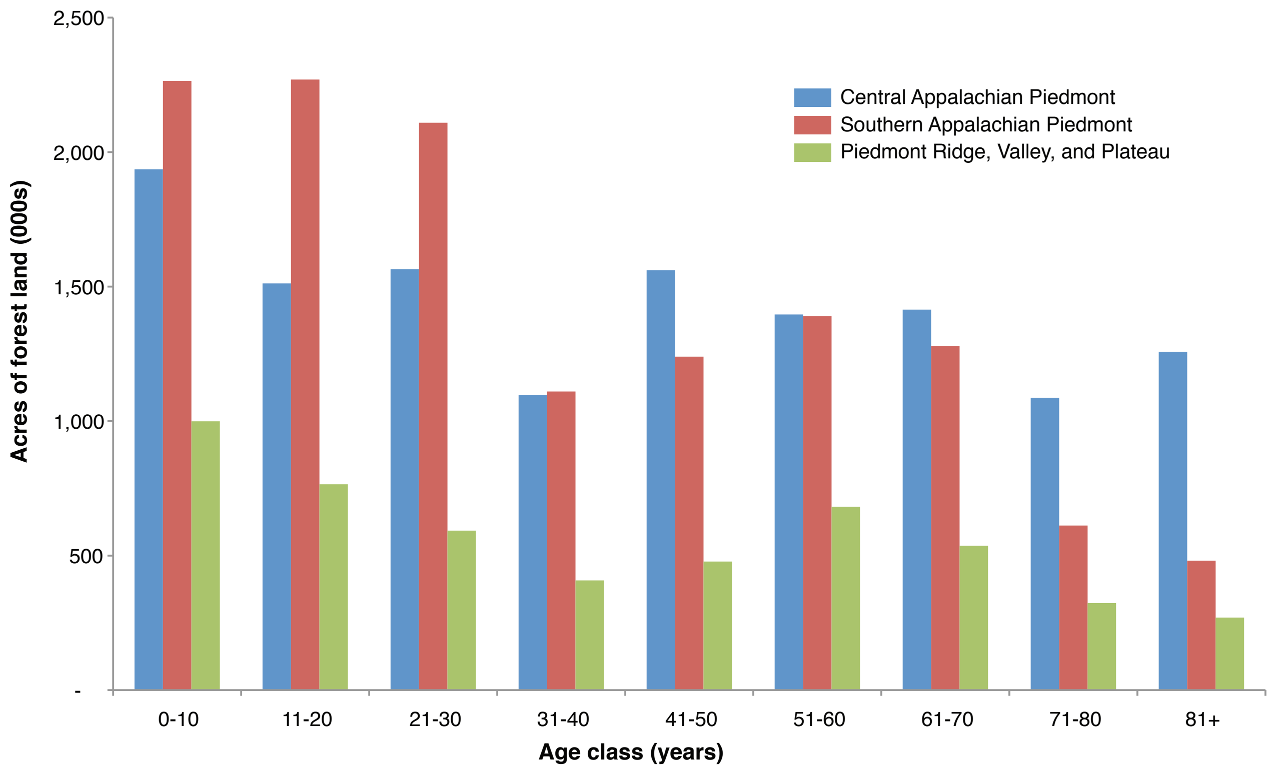


Figure 5—Age class distribution, 2010, of forests in the Southern U.S. Piedmont and its sections (Source: Huggett and others 2013).

In the Central section, most (86 percent) planted pine is ≤30 years, with 14 percent at 31 to 60 years (fig. 6). The natural pine and oak-pine types are fairly evenly distributed across age classes, except for those trees in the older (≥71 years) age classes. The hardwood management types also are relatively evenly distributed across age classes, with more trees in the older age classes.

In the Southern section, most (94 percent) planted pine is ≤30 years, with only 6 percent at 31 to 60 years (fig. 6). The natural pine and oak-pine types are skewed towards the younger age classes. Upland hardwoods are skewed towards the older age classes (≥41 years old), but >900,000 acres are ≤10 years. Lowland hardwoods tend to be relatively evenly distributed across age classes.

In the Ridge and Valley section, most (97 percent) planted pine is ≤30 years old, with only 3 percent at 31 to 60 years (fig. 6). The natural pine and oak-pine are skewed towards the younger age classes; however, almost 25 percent of the oak-pine is 51 to 60 years. Upland hardwoods are skewed towards the older age classes (≥41 years old), but almost 440,000 acres are ≤10 years. Lowland hardwoods tend to be skewed towards the younger and middle age classes.

From 1980 through 2007 losses of total forest-land area in the Piedmont were relatively minor (about 3 percent over a 27-year period) with the most change occurring in the Ridge and Valley section (table 2). However, within the total forested area, pine plantation area increased (1.8 million acres) along with corresponding reductions in other forest types. The trend of loss in Piedmont forest land was in contrast to an overall increase for the South.

FORECASTS OF FOREST AREA AND CONDITIONS

Huggett and others (2013) concluded that urbanization would clearly be the driving force for forest condition change in the Piedmont. Under Cornerstone B (high urbanization coupled with low timber prices), the Piedmont is projected to lose almost 17 percent of total forest area, dropping from 30.8 to 25.5 million acres (fig. 7). Most of these losses would occur in the upland hardwood type (fig. 8) and result from conversion to urban use. Pine forest types would experience a continued transition from natural pine to plantation pine with counteracting changes of about 2 million acres occurring in each. The smallest total forest loss (about 2 million acres) would occur under Cornerstone C (low urbanization coupled with high timber prices), again with losses concentrated in the upland hardwood forest type. Although changes in upland hardwood area would be predominantly caused by urbanization, the transition from natural pine to plantation pine would be driven by timber prices.

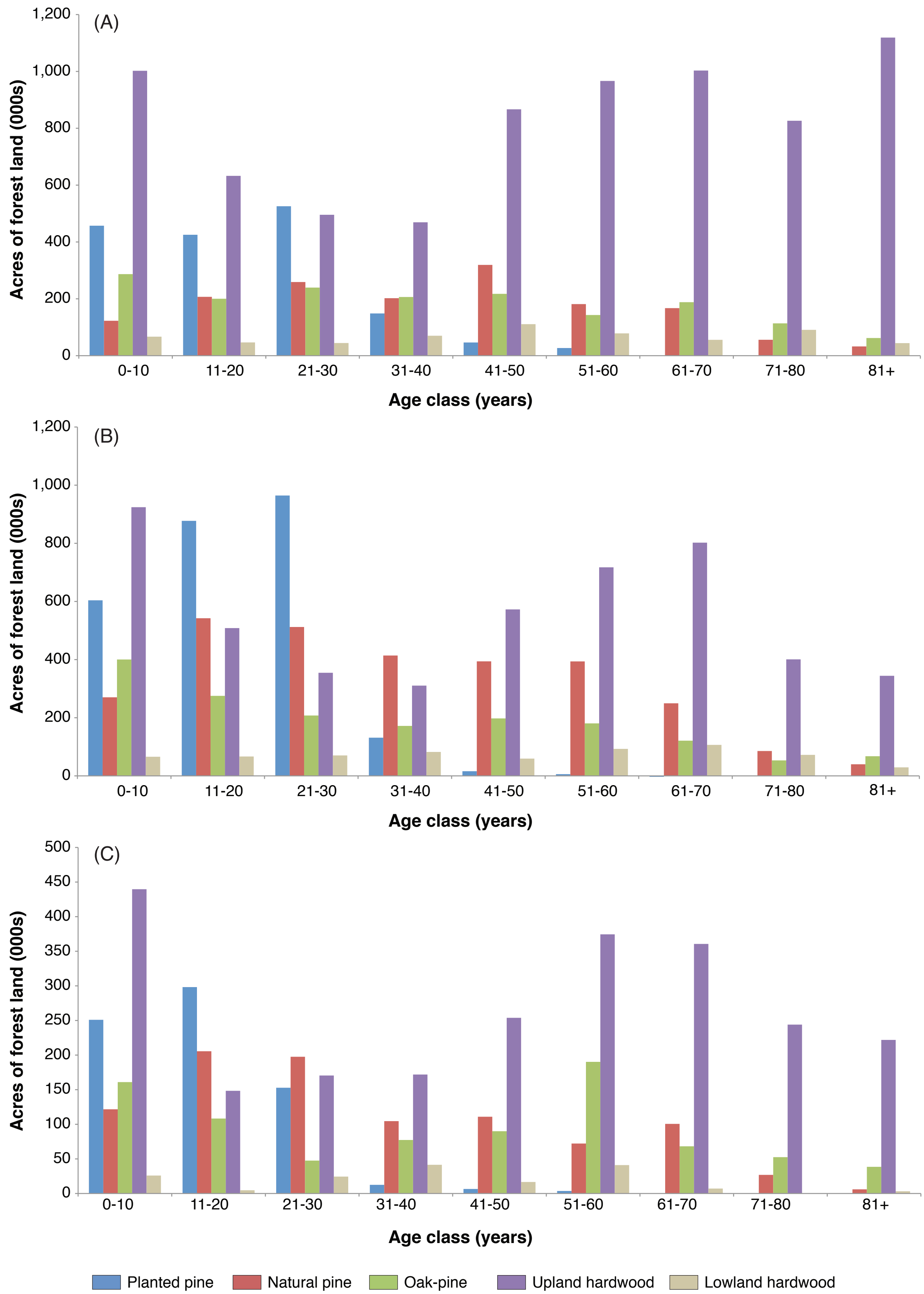


Figure 6—Age class distribution, 2010, of forests in the three sections of the Southern U.S. Piedmont (A) Central Appalachian Piedmont, (B) Southern Appalachian Piedmont, (C) Piedmont Ridge, Valley, and Plateau (Source: Huggett and others 2013).

Table 2—Forest land (1980s to 2007) in the Southern U.S. Piedmont and its sections—Central Appalachian Piedmont, Southern Appalachian Piedmont, and Piedmont Ridge, Valley, and Plateau

Geographic area	Early 1980s	Early 1990s	2007	Change 1980s to 2007	Average annual change
	------------*million acres*------------			------------*percent*------------	
Central	13.0	13.3	12.8	-1.410	-0.052
Southern	13.2	13.0	12.8	-3.220	-0.119
Ridge and Valley	5.4	5.2	5.1	-6.550	-0.243
All Piedmont	31.6	31.4	30.6	-3.050	-0.113
All South	183.7	187.3	207.9	13.180	0.488

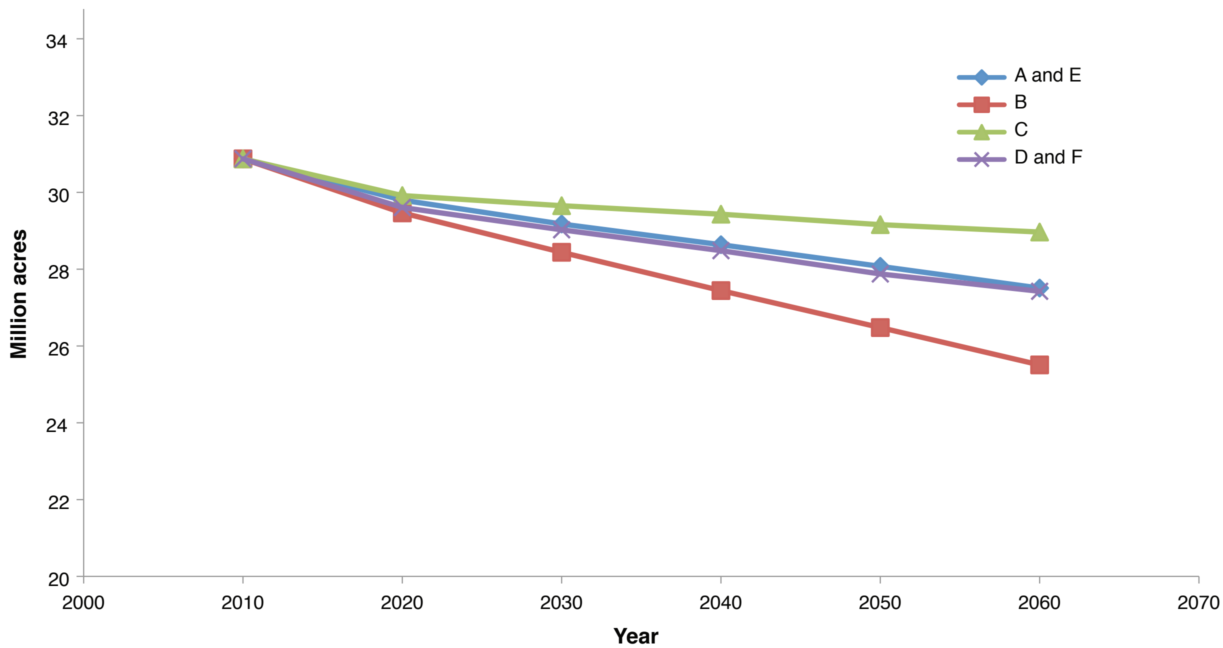


Figure 7—Projected changes in total forest area for the Southern U.S. Piedmont under six alternative scenarios (Wear and others 2013a)—moderate urbanization/increasing timber prices (Cornerstone A), high urbanization/decreasing timber prices (Cornerstone B), low urbanization/increasing timber prices (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 volumes would increase through 2020 and then level off (Cornerstone A) or continue to grow at a slower rate (Cornerstone D). In contrast hardwood growing stock levels under all futures would peak around 2030 and then decrease as the loss of hardwood forest acres cuts into total growing stock volume (fig. 9). However, even though growing stocks and forest area decrease, hardwood removals would remain at a relatively constant level (about 800 million cubic feet per year) throughout the projection period—sourced from conversion to urbanization rather than sustainable management and growth.

These general trends also define the shifts in age-class distribution in the various forest types. Upland hardwood stands are expected to shift to an older age class as stands mature and are converted to nonforest use. Natural pine stands will likely maintain a relatively constant area of older growth (restricted access or protected status) while middle-aged natural pine area decreases with a transition to younger planted pine through managed rotations.

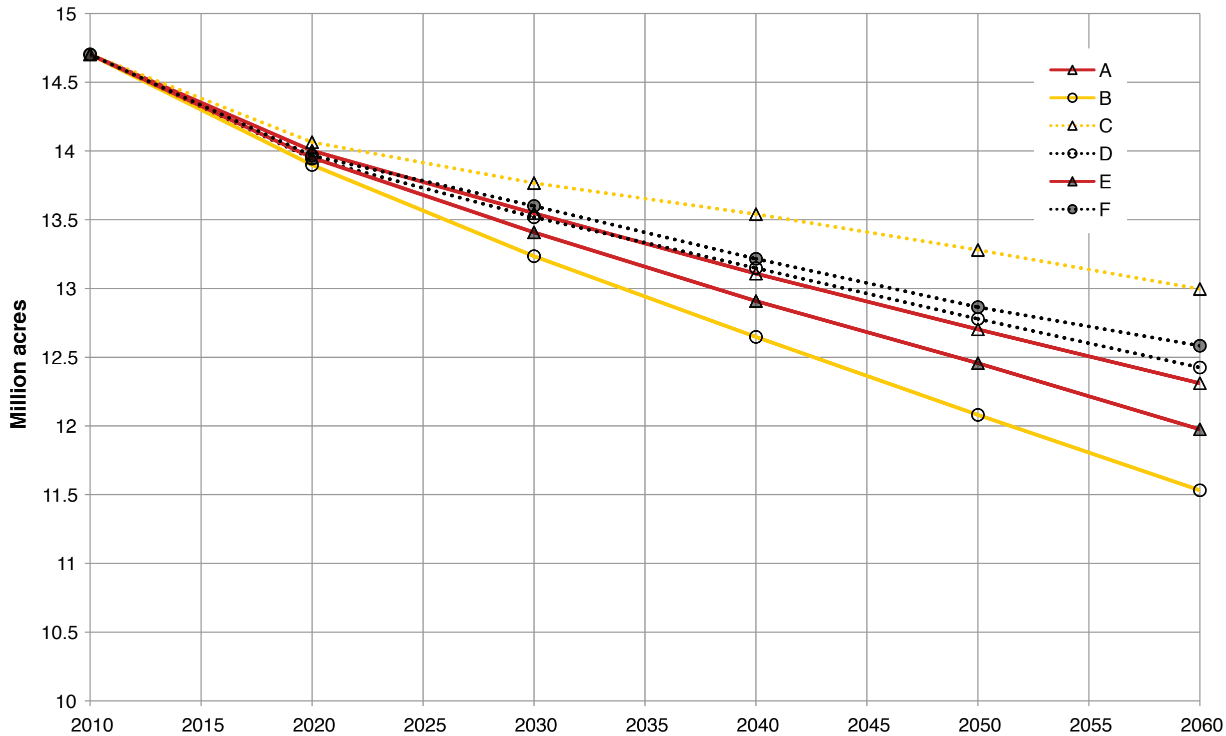


Figure 8—Projected changes in upland hardwood forest area in the Southern U.S. Piedmont under six alternative scenarios (Wear and others 2013a)—moderate urbanization/increasing timber prices (Cornerstone A), moderate urbanization/decreasing timber prices (Cornerstone B), low urbanization/increasing timber 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).

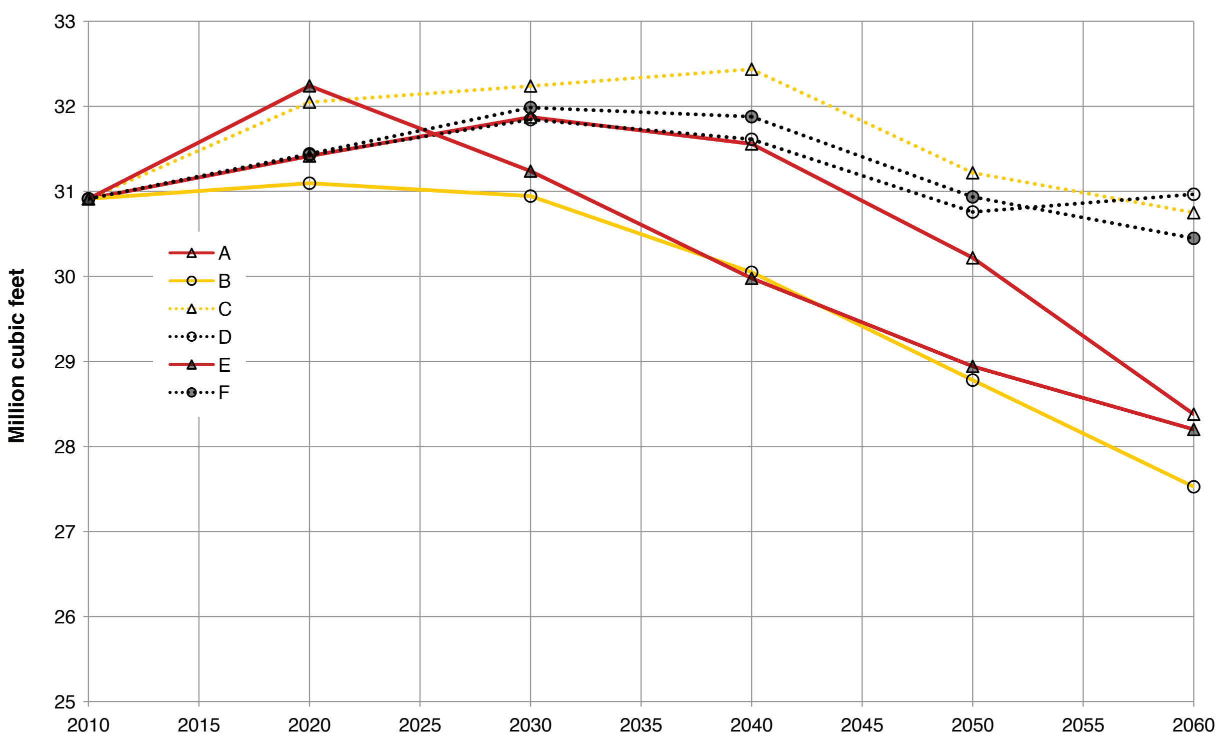


Figure 9—Projected hardwood growing stock levels for the Southern U.S. Piedmont under six alternative scenarios (Wear and others 2013a)—moderate urbanization/increasing timber prices (Cornerstone A), moderate urbanization/decreasing timber prices (Cornerstone B), low urbanization/increasing timber prices (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).

CHAPTER 3. Land Use and Ownership

LAND USE

Total land area of the Piedmont is about 80,000 square miles. The National Resources Inventory classifies five land-use categories using satellite landcover imagery (Wear 2013). Its 1997 data show that forest is the largest use category (38 percent). Every county except Fairfax (Washington metropolitan) and De Kalb and Cobb (Atlanta metropolitan) had some amount of forest cover ranging from 20 to 100 percent. The most heavily forested areas were in eastern central Alabama and along the fall line in Georgia and South Carolina (fig. 10). However, there are heavily forested counties across the Piedmont. Montgomery County in North Carolina, for example, covers 314 square miles and is 71 percent forest and only 4 percent urban.

The second largest land-use category in 2000 was urban (8 percent), which had a cover concentration that was the inverse of the forest cover areas. The highest values were in the Atlanta, Birmingham, Charlotte, Raleigh, and Washington metropolitan counties with other significant urban land use following the general route of I-85 through the center of the region (fig. 11). For example De Kalb County (metro Atlanta) in Georgia covers 171 square miles with 80 percent urban and 14 percent forest cover. Agricultural land use accounts for about 13 percent of total land cover (8 percent in pasture and 5 percent in cropland).

Wear (2013) concluded that the primary determinants of land use are population, personal income, and timber and crop prices. The two-stage structure of his model projects

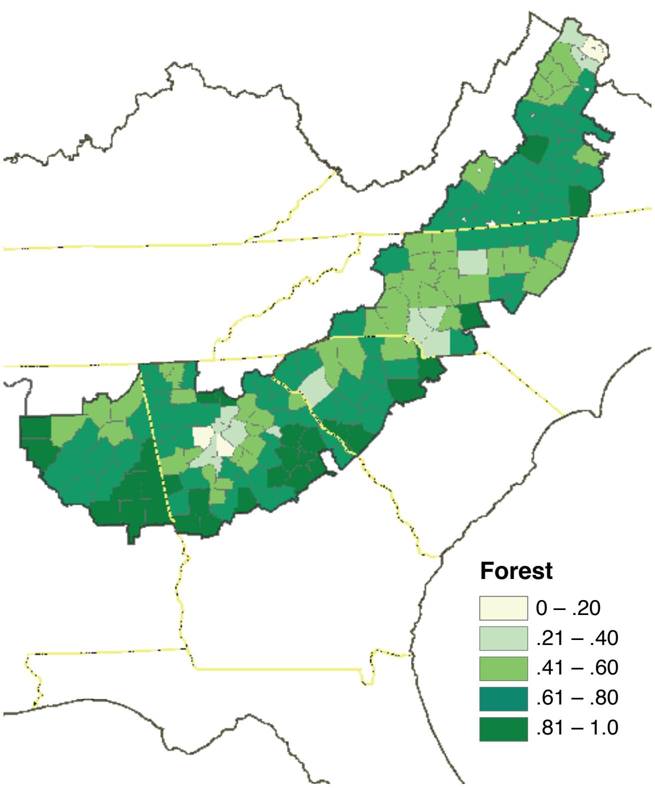


Figure 10—Forest cover, 2000, in the Southern U.S. Piedmont.

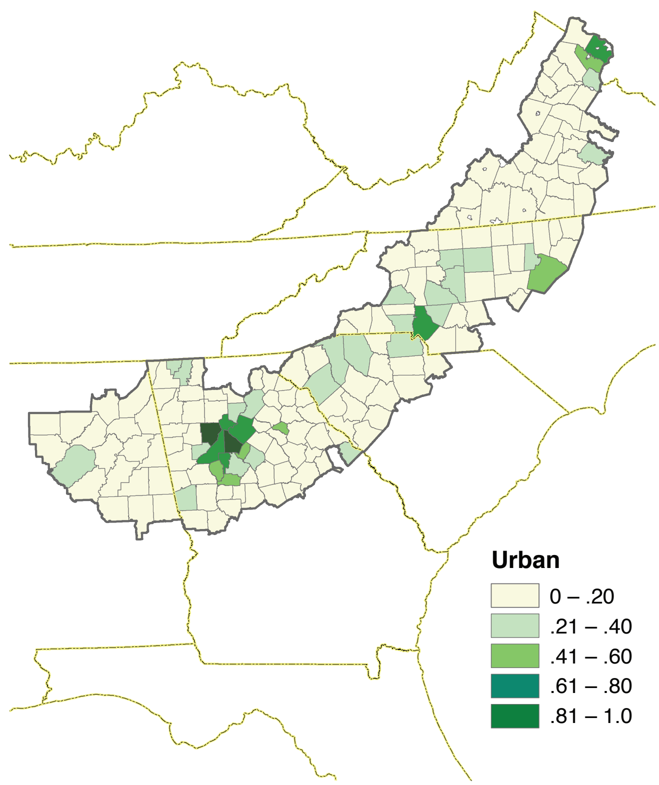


Figure 11—Urban land use, 2000, in the Southern U.S. Piedmont.

urbanization based on forecasts of population and income; however rural land uses are also influenced by the relative prices of timber and agricultural crops. Under all of the Cornerstone Futures, urbanization would increase in the Piedmont with a parallel loss of forest cover. Table 3 shows that urban area expansion does not vary with alternative timber price scenarios, only with assumptions about population and economic growth. However the loss of forest land area varies with timber prices. Decreasing timber prices are associated with greater forest loss regardless of urbanization trends.

Urban area in the Piedmont is projected to expand by 6 to 8 million acres (table 3). The high growth assumptions in Cornerstone A or B would result in more than doubling current urban area. The resulting loss of forest area depends on timber price assumptions and the level of urbanization predicted by each Cornerstone Future. With higher timber prices and only moderate urban pressure (Cornerstone C), less forest area (about 4 million forest acres) and more pasture and cropland area would be developed into urban use (table 3). In contrast, the combination of weak timber prices and high urbanization pressures (Cornerstone B) would result in a loss of about 6 million forest acres. Measured on a relative basis, the decrease in forest area represents a loss of 13 to 21 percent of the Piedmont forest, a higher relative change in forest cover than any other subregion of the South. Changes in forest land would be concentrated around urban areas especially in the Piedmont of Georgia and North Carolina (fig. 12).

FOREST OWNERSHIP

Southern forests are primarily privately owned. National Resources Inventory landcover data show 18.7 million acres of forest land in the Piedmont, only 1.2 million acres (6.5 percent) of which are national forests (USDA Forest Service 2011). Southwide data show that about 86 percent of forest land is privately held, about two-thirds of which is owned by families or individuals (Butler and Wear 2013). The remaining third is owned by corporate or organizational entities, mostly focused on timber management as a business enterprise.

Most private forest owners have small forest tracts (<9 acres), a circumstance that is often cited in conjunction with concerns about fragmentation. Fuller (2001) mapped landscape change in Virginia's rapidly urbanizing Loudon County from 1973 to 1999 and found a net gain in forest cover but also an increase in fragmentation. This result demonstrates that multiple dynamic factors are at work—urbanization reduces forest cover and increases

Table 3—Projected change in urban and forest cover in the Southern U.S. Piedmont, 1997 to 2060, under four alternative scenarios—moderate urbanization/increasing timber prices (Cornerstone A), moderate urbanization/decreasing timber prices (Cornerstone B), low urbanization/increasing timber prices (Cornerstone C), and low urbanization/decreasing timber prices (Cornerstone D)

Land use	Cornerstone	Change	
		million acres	*percent*
Urban	A or B	8.7	141.0
	C or D	6.1	99.0
Forest	B	-6.1	-21.3
	C	-3.8	-13.3

Source: Wear and others (2013a)

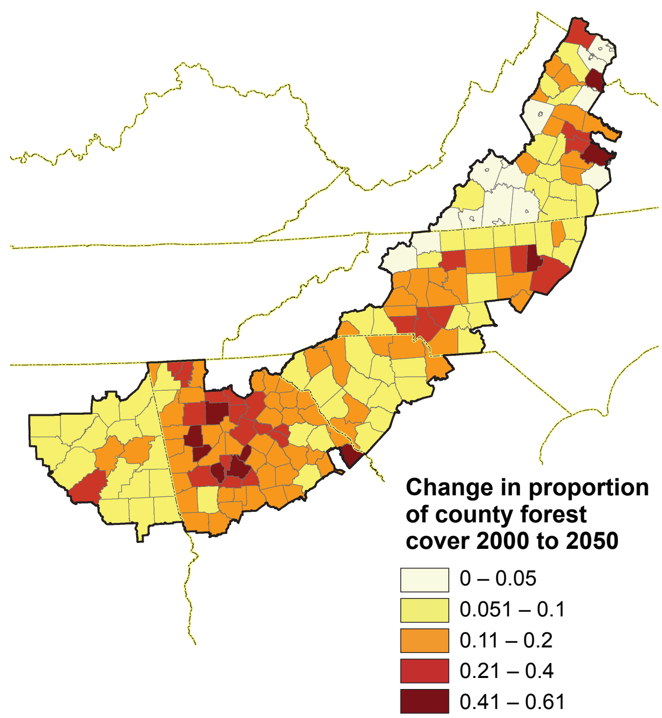


Figure 12—Projected change in the proportion of forest cover, 2000 to 2050, in the counties of the Southern U.S. Piedmont (borders indicated by a heavy black line).

fragmentation at the same time that forest cover is increasing in areas farther from the urban core. It also suggests that family forest owners have diverse ownership objectives and that timber production is not usually their primary objective. In the urban fringe, small forest tracts may be valued for their rural character. Further from urban areas, larger forest tracts can still be a source of income as well as recreation. Indeed, although most forest owners have small tracts, almost two-thirds of the forest land owned by family forest owners is in tracts >100 acres.

Another key trend in forest ownership has been the emergence of corporate forest ownership by investment groups—timber investment management organizations or real estate investment trusts. Before 1990, about 20 percent of southern forests were held by traditional forest products companies. Since then about 75 percent of that land has transitioned to an investment group. In the Piedmont, the remaining forest-industry holdings are primarily in the western section (Ridge and Valley) while investment-group ownership is more common in the Carolinas (Butler and Wear 2013).

The changes in land use described above show that the Piedmont will likely experience significant transition of forest and rural areas to more developed urban use. Land-use change models from the Piedmont in Virginia (Wickham and others 2000) suggest that the land demand gradient from urban to rural is strongly correlated with loss of forest land. The largest changes would occur at the interface or transition zone between urban and rural. Barlow and others (1998) however describe a more nuanced interaction at the transition zone from a study in Alabama and Mississippi. They concluded that the probability of a forest area being harvested decreases with proximity to urban areas. This could be a result of increasing real estate and amenity values, decreasing opportunity for long-term forestry investment, or parcelization and reduction in tract size. In addition, agricultural open space absorbed into the urban zone could experience afforestation (Fuller 2001). The result is the urban forest.

This conceptual model of forest change suggests that land use changes would occur as multiple transitions of ownership. Forests will likely transition from larger rural parcels (some corporate ownerships or larger family/individual ownerships) to smaller amenity-centered forest holdings (family/individual forest ownerships) and eventually to developed urban space (urban forest owners or nonforest ownership). Even though the ultimate conversion from forest to urban would occur at a narrow transition zone, the conversion process would be at work across the entire gradient. By 2050, 4 to 6 million acres of Piedmont forest would be fully converted to urban ownership. At the same time a similar amount of forest land would likely change hands through parcelization and conversion to less intensive management.

The general economic theory of land-use change also defines transitions of forest use and ownership that occur away from urban areas. Forest products markets will continue to function and forest owners will respond to opportunities to derive economic value from forest land—perhaps by intensifying management (for example, establishing plantations following harvests of natural stands). Projections show pine plantation area increasing in the Piedmont by 2 to 4 million acres. Because intensification of management requires capital resources and focused management plans, new plantation acres will likely be limited to larger private landownerships. New plantations could also occur with ownership change from family forest owners to corporate ownership. The development of more intensive forest management will likely occur in more rural regions of the Piedmont rather than near urban centers.

Private forest ownership ranges from corporations to families and individuals—each with a unique set of objectives and motives for owning and managing forest land. Ownership transitions occur when economic drivers shift the potential returns and someone finds a “higher value” use. In the next 40 years land-use change is expected to impact forest ownership across a significant portion of Piedmont forests, creating new small-parcel forest owners, shifting forest land into more intensive management holdings, and ultimately converting some to urban development.

CHAPTER 4.
Climate

The Piedmont climate is humid and subtropical, characterized by hot, humid summers and mild-to-cool winters. Summers are long and almost tropical—hot and humid, with daily averages above 25 ºC—with a growing season that lasts from 170 to 235 days. In winter, temperatures reach freezing only a few days each year and snowfall is rare, usually three inches or less.

BASELINE PERIOD

During a 10-year period (1997 to 2006), the average annual temperature in the Central section was 14.2 ºC, ranging from 11.9 to 16.4 ºC (McNulty and others 2013). The average annual temperature in the Southern section was warmer, with an annual temperature of 16.3 ºC (ranging from 14.1 to 17.6 ºC). The average annual temperature of the Ridge and Valley section was in between the other sections, with the average annual temperature of 15.9 ºC (ranging from 14.8 to 17.3 ºC).

During this same period, the average annual precipitation for the Central section was 1148.82 mm (ranging from 1034.39 to 1445.35 mm), drier than the Southern section at 1283.32 mm (ranging from 1129.77 to 1660.86 mm) and the Ridge and Valley section at 1400.51mm (ranging from 1321.63 to 1503.96 mm) (McNulty and others 2013).

Potential evapotranspiration is the amount of water that would be evaporated and transpired if sufficient amounts of water were available. It is higher in the summer, on sunnier days, and closer to the equator because more solar radiation provides the energy for evaporation. It is also higher on windy days because the evaporated moisture can be quickly moved from the ground or plant surfaces, allowing more evaporation to take place. From 1997 to 2006, average annual potential evapotranspiration was 2080.89 mm (ranging from 1861.51 to 2293.05 mm) for the Central section, 2266.52 mm (ranging from 2051.94 to 2419.96 mm) for the Southern section, and 2260.78 mm (ranging from 2142.08 to 2403.93 mm) for the Ridge and Valley section (McNulty and others 2013).

The average annual potential evapotranspiration is often compared to average annual precipitation, with the ratio between the two (potential evapotranspiration divided by precipitation) known as the aridity index. A numerical indicator of the degree of dryness of the climate at a given location, the aridity index classifies the type of climate in relation to water availability. For example, the atmospheric conditions that characterize a desert climate are those that create large water deficits, meaning that potential evapotranspiration is much higher than precipitation and that the aridity index is higher than in wetter climates. In the Piedmont, the aridity index is 0.552 for the Central section, 0.566 for the Southern section, and 0.619 for the Ridge and Valley section. According to the generalized climate classification scheme (table 4), all three sections are considered to be in the dry subhumid climate class, with the Ridge and Valley section wetter than the Southern section, which is wetter than the Central section.

CLIMATE FORECASTS

This section summarizes the climate predictions for the Piedmont that were developed by McNulty and others (2013). Four general circulation models were combined with emissions storylines developed by the Intergovernmental Panel on Climate Change to create an initial set of four Cornerstone Futures. General circulation models provide geographically and physically consistent estimates of regional climate change, while emissions storylines represent alternative demographic, socioeconomic, and environmental futures. Additional Cornerstone Futures were developed to reflect two levels of investment in pine plantations.

Table 4—Generalized climate classification scheme for global-aridity values

Aridity index (AI) value	Climate class
AI < 0.03	Hyper arid
0.03 < AI < 0.20	Arid
0.20 < AI < 0.50	Semi-arid
0.5 < AI < 0.65	Dry subhumid
AI > 0.65	Humid

Source: United Nations Environmental Programme (1997).

In the Piedmont, overall forecasted precipitation and temperature averages are expected to be drier and hotter, although not uniformly so, with variations across the three sections based on the four Cornerstones (tables 5 and 6).

Cornerstone A

Under Cornerstone A, the predicted decadal average precipitation across the Piedmont would decrease from 1263 mm in 2010 to 1065 mm in 2060, a decrease of 198 mm over the span of 50 years (table 5, fig. 13), which is the largest decrease of the four Cornerstones. More specifically, all of the Central section and Southern section and most of the Ridge and Valley section would be dry, with three western counties in the Ridge and Valley section being even drier (fig. 14). Maximum annual precipitation during the 50-year period would be 1001 to 1500 mm for the northern half and 1501 to 2000 mm for the lower half of the Central section; 1501 to 2000 mm for most of the Southern section, with five counties having 2001 to 3000 mm; and 1501 to 2000 mm for the northeastern two-thirds and 2001 to 3000 mm for the southwestern third of the Ridge and Valley section (fig. 15). Interestingly, the drier counties in the Ridge and Valley section are also part of the area with a higher maximum annual precipitation, perhaps because of an expected increase in storm events.

The predicted decadal average air temperature would increase from 16.16 to 18.79 ºC across the Piedmont, an increase of 2.63 ºC (table 6) that is the largest increase of the four Cornerstones (table 6, fig. 13). More specifically, all of the Central and Southern sections and five eastern counties in the Ridge and Valley section would have air temperature increases of 1.50 to 1.99 ºC. However, most of the Ridge and Valley section would have a temperature increase of 2.00 to 2.60 ºC (fig. 16). Across the Central section, the average maximum monthly temperature would range from 36 to 42 ºC, with the northern 33 counties at 36 to 37 ºC, the middle 34 counties at 38 to 49 ºC, and the southern nine counties at 41 to 42 ºC. Across the Southern section, the maximum annual air temperature would range from 38 to 47 ºC, with the northern 19 counties at 41 to 42 ºC, 3 northern counties at 38 to 40 ºC, the middle and western counties at 43 to 44 ºC, and the southern 13 counties at 45 to 47 ºC. Across the Ridge and Valley section, the maximum annual air temperature would range from 41 to 47 ºC, with the northern nine counties at 41 to 42 ºC, the middle 12 counties at 43 to 44 ºC, and the southern 3 counties at 45 to 47 ºC. As one moves southward through the Piedmont, the temperature gets higher (fig. 17).

Cornerstone B

Under Cornerstone B, the predicted decadal average precipitation across the Piedmont would decrease from 1484 mm in 2010 to 1345 mm in 2060, a decrease of 139 mm over the span of 50 years (table 5, fig. 13). More specifically, about two-thirds of the Central section, about half of the Southern section, and all of the Ridge and Valley section would be drier. About a third of the Central section and half of the Southern section would be wetter (fig. 14). Maximum annual precipitation during the 50-year period would be 1501 to 2000 mm for most of the Central section, about two-thirds of the Southern section, and two eastern counties in the Ridge and Valley section. The northern 10 counties of the Central section would have less maximum annual precipitation at 1001 to 1500 mm, and a third of the western counties in the Southern section and most of the Ridge and Valley section would have higher maximum annual precipitation at 2001 to 3000 mm (fig. 15). Again, as with Cornerstone A, the drier counties on the southern end of the Piedmont would also coincide with the area with a higher maximum annual precipitation.

Table 5—Predicted average precipitation for the Southern U.S. Piedmont as forecasted by four Cornerstone Futures

	Cornerstone[a] prediction of average precipitation (mm)			
Year	A	B	C	D
2010	1263	1484	1285	1379
2020	1285	1259	1326	1272
2040	1202	1273	1328	1331
2060	1065	1345	1324	1371
2090	1164	1395	1231	1388

[a] Each Cornerstone represents a general circulation model (MIROC3.2, CSIROMK3.5, CSIROMK2, and 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 is MIROC3.2 + A1B, B is CSIROMK3.5 + A1B, C is CSIROMK2 + B2, and D is HadCM3 + B2.

Source: McNulty and others (2013).

Table 6—Predicted average temperature for the Southern U.S. Piedmont as forecasted by four Cornerstone Futures

	Cornerstone[a] prediction of average temperature (°C)			
Year	A	B	C	D
2010	16.16	15.41	16.34	16.24
2020	16.73	16.02	16.72	16.05
2040	17.59	16.77	17.39	16.41
2060	18.79	17.05	17.84	17.26
2090	19.74	17.89	19.12	18.46

[a] Each Cornerstone represents a general circulation model (MIROC3.2, CSIROMK3.5, CSIROMK2, and 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 is MIROC3.2 + A1B, B is CSIROMK3.5 + A1B, C is CSIROMK2 + B2, and D is HadCM3 + B2.

Source: McNulty and others (2013).

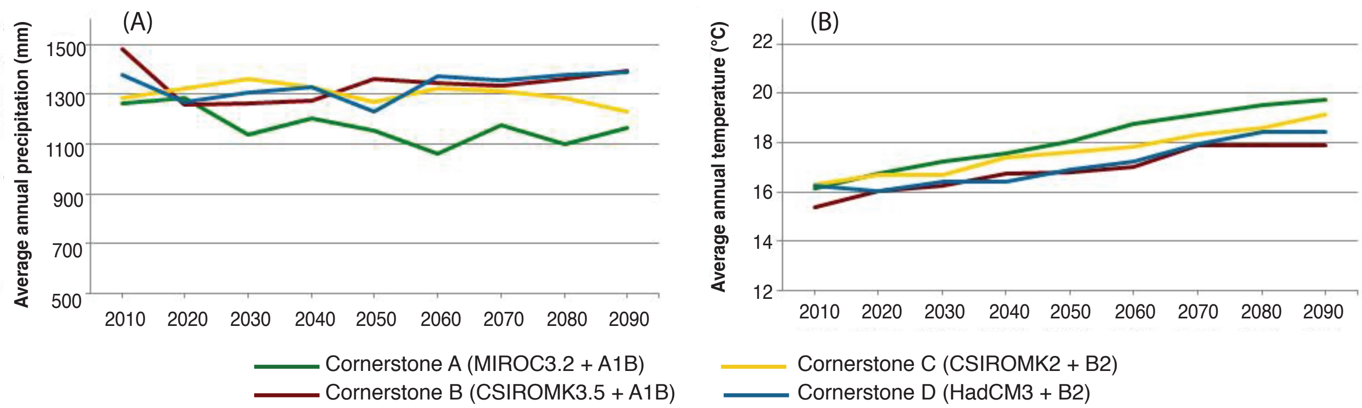


Figure 13—Predicted (A) average annual precipitation and (B) average annual air temperature for the Southern U.S. Piedmont, 2010 to 2090, as forecasted by four Cornerstone Futures; each Cornerstone represents a general circulation model (MIROC3.2, CSIROMK3.5, CSIROMK2, or HadCM3) paired with one of two emission scenarios (A1B representing low-population/high-economic growth, high energy use; B2 representing moderate growth and use) (Source: McNulty and others 2013).

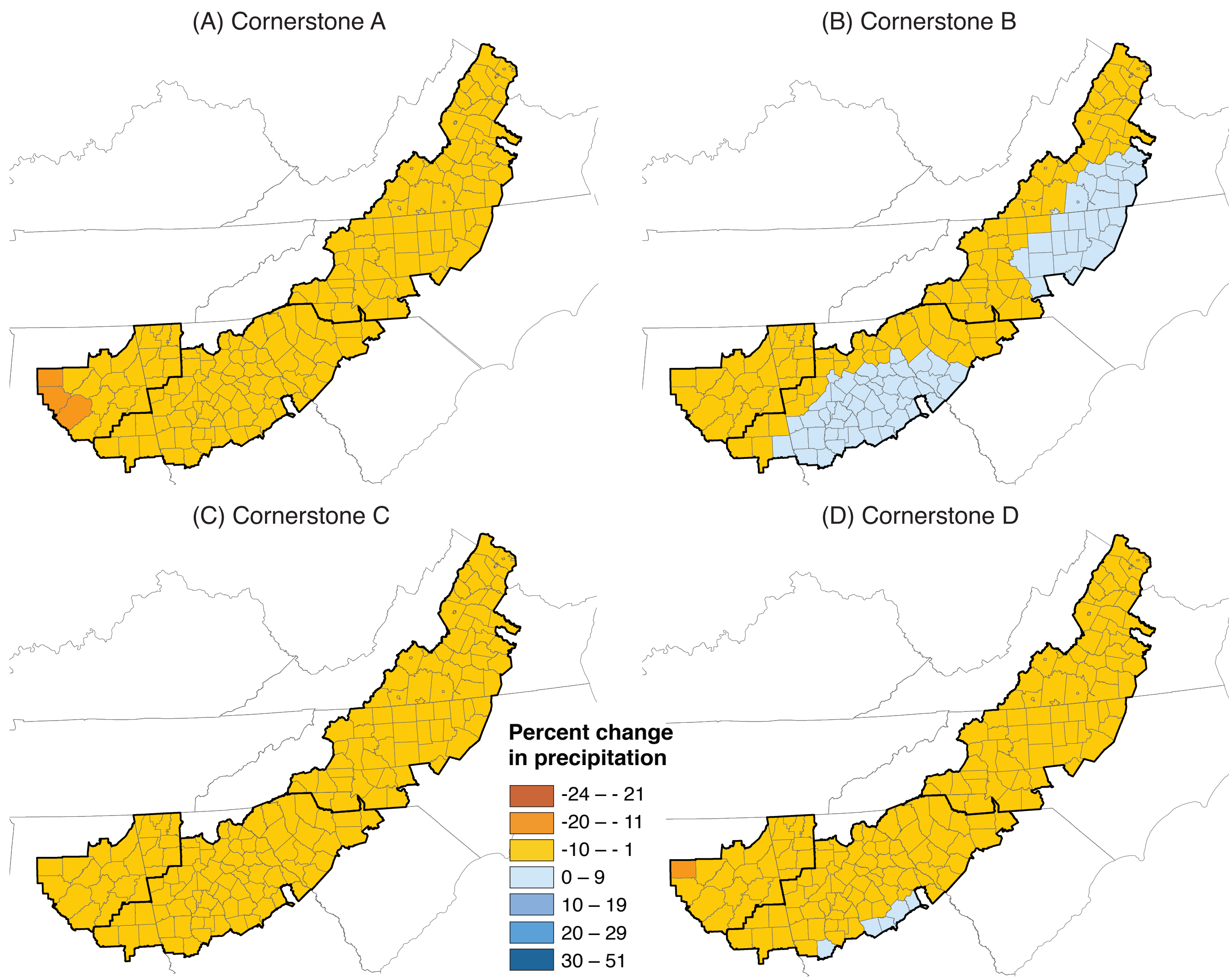


Figure 14—Predicted change in precipitation, 2010 to 2060, for the Southern U.S. Piedmont as forecasted by (A) Cornerstone A, (B) Cornerstone B, (C) Cornerstone C, and (D) Cornerstone D; each Cornerstone represents a general circulation model (MIROC3.2, CSIROMK3.5, CSIROMK2, or HadCM3) paired with one of two emission scenarios (A1B representing low-population/high-economic growth, high energy use; B2 representing moderate growth and use): A is MIROC3.2 + A1B, B is CSIROMK3.5 + A1B, C is CSIROMK2 + B2, and D is HadCM3 + B2 (Source: McNulty and others 2013).

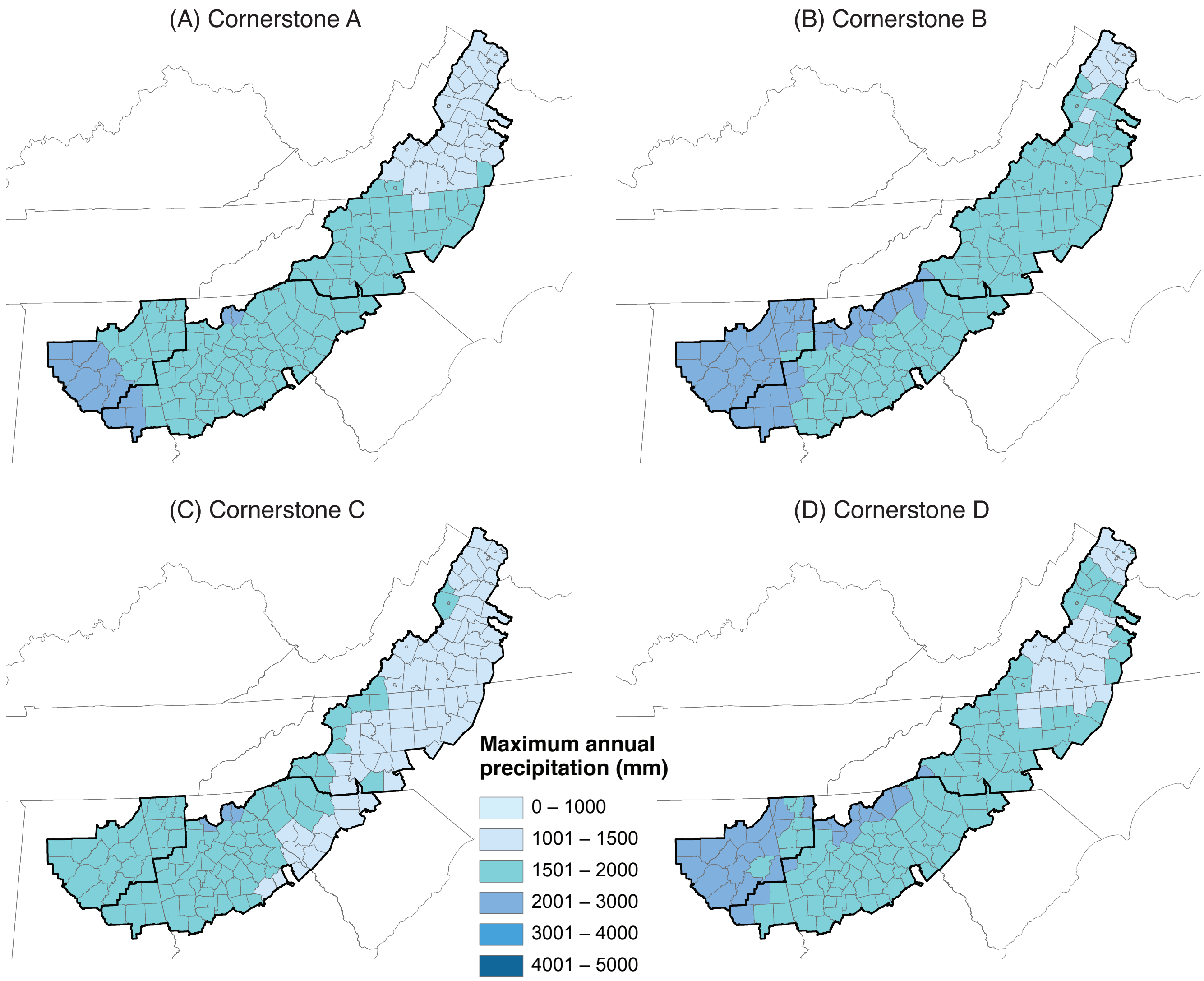


Figure 15—Predicted maximum annual precipitation, 2010 to 2060, for the Southern U.S. Piedmont as forecasted by (A) Cornerstone A, (B) Cornerstone B, (C) Cornerstone C, and (D) Cornerstone D; each Cornerstone represents a general circulation model (MIROC3.2, CSIROMK3.5, CSIROMK2, or HadCM3) paired with one of two emission scenarios (A1B representing low-population/high-economic growth, high energy use; B2 representing moderate growth and use): A is MIROC3.2 + A1B, B is CSIROMK3.5 + A1B, C is CSIROMK2 + B2, and D is HadCM3 + B2 (Source: McNulty and others 2013).

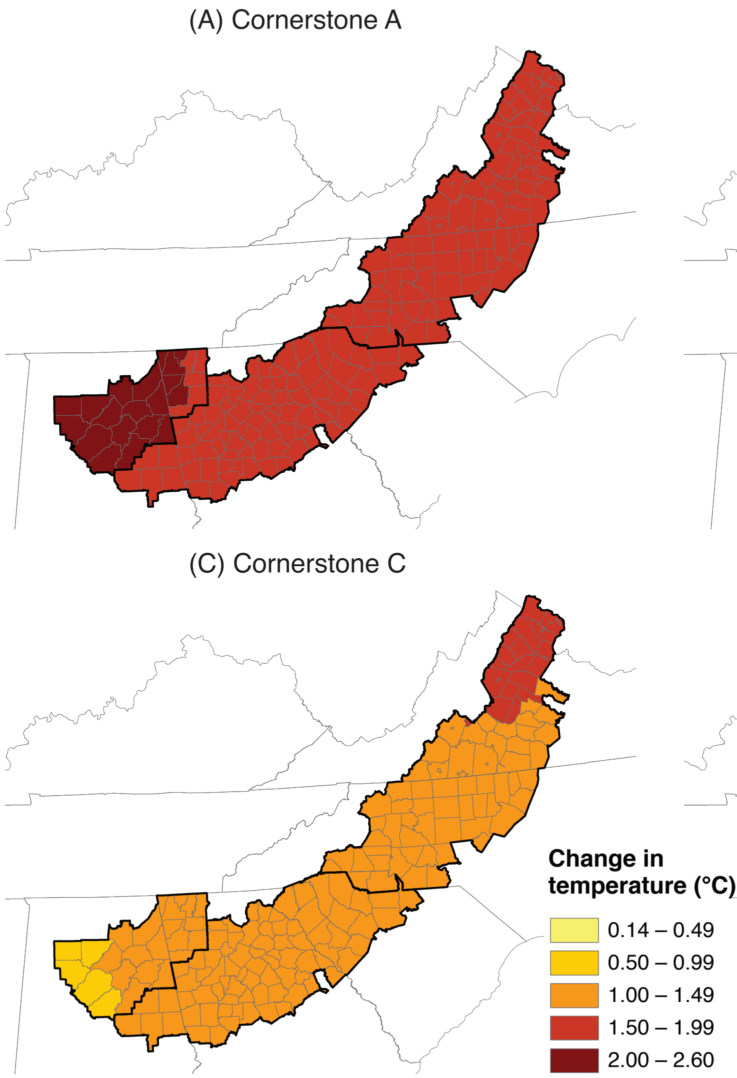


Figure 16—Predicted change in air temperature, 2010 to 2050, for the Southern U.S. Piedmont as forecasted by (A) Cornerstone A, (B) Cornerstone B, (C) Cornerstone C, and (D) Cornerstone D; each Cornerstone represents a general circulation model (MIROC3.2, CSIROMK3.5, CSIROMK2, or HadCM3) paired with one of two emission scenarios (A1B representing low-population/high-economic growth, high energy use; B2 representing moderate growth and use): A is MIROC3.2 + A1B, B is CSIROMK3.5 + A1B, C is CSIROMK2 + B2, and D is HadCM3 + B2 (Source: McNulty and others 2013).

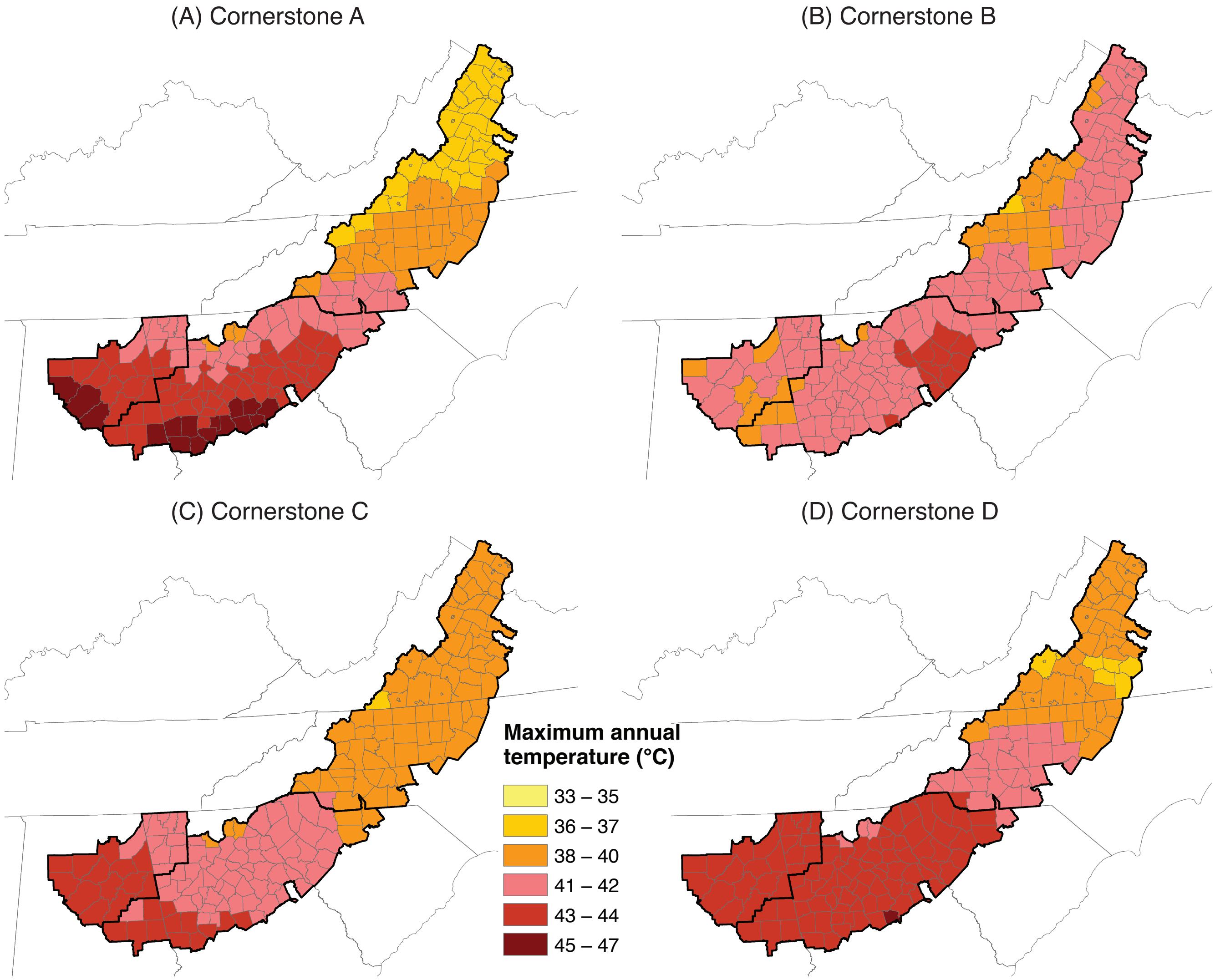


Figure 17—Predicted maximum annual air temperature, 2010 to 2060, for the Southern U.S. Piedmont as forecasted by (A) Cornerstone A, (B) Cornerstone B, (C) Cornerstone C, and (D) Cornerstone D; each Cornerstone represents a general circulation model (MIROC3.2, CSIROMK3.5, CSIROMK2, or HadCM3) paired with one of two emission scenarios (A1B representing low-population/high-economic growth, high energy use; B2 representing moderate growth and use): A is MIROC3.2 + A1B, B is CSIROMK3.5 + A1B, C is CSIROMK2 + B2, and D is HadCM3 + B2 (Source: McNulty and others 2013).

The predicted decadal average air temperature would increase from 15.41 to 17.05 ºC across the Piedmont, an increase in 1.64 ºC (table 6). More specifically, the northern two-thirds of the Central section would have an increase of 1.50 to 1.99 ºC, whereas the remainder of the Central section and all of the Southern and Ridge and Valley sections would only have an increase of 1.00 to 1.49 ºC (fig. 16). The maximum annual air temperature for most of the Central, Southern, and Ridge and Valley sections would be 41 to 42 ºC. One western county in the Central section would have a maximum annual air temperature of 36 to 37 ºC, but its adjacent counties would be warmer (38 to 40 ºC). In the Southern section, 6 counties on the southwestern border would have a maximum annual air temperature of 38 to 40 ºC, compared to 43 to 44 ºC for 12 eastern counties. Five scattered counties in the Ridge and Valley section would have a maximum annual air temperature of 38 to 40 ºC (fig. 17).

Cornerstone C

Cornerstone C predicts that the decadal average precipitation across the Piedmont would increase from 1285 mm in 2010 to 1324 mm in 2060, an increase of 39 mm over the span of 50 years (table 5, fig. 13). It is the only Cornerstone to predict an increase in the decadal average precipitation. However, when taking the model out to 2090, Cornerstone C actually predicts a decrease in precipitation. The whole Piedmont, with its three sections, would be uniformly dry over the next 50 years (fig. 14). However, the northern and eastern half of the Piedmont (most of the Central section and about 20 percent of the Southern section) would have a maximum annual precipitation of 1001 to 1500 mm, and the southwestern half of the Piedmont (most of the Southern section and all of the Ridge and Valley section) would have a maximum annual precipitation of 1501 to 2000 mm (fig. 15). As with Cornerstones A and B, the southwestern end of the Piedmont would be dry but with higher maximum annual precipitation.

The predicted decadal average air temperature would increase from 16.34 to 17.84 ºC across the Piedmont, an increase of 1.50 ºC (table 6). More specifically, most of the Piedmont would experience a temperature change of 1.00 to 1.49 ºC (fig. 16). The northern edge of the Central section would change 1.50 to 1.99 ºC, and the western edge of the Ridge and Valley section would change 0.50 to 0.99 ºC. As one moves southward through the Piedmont, the severity of temperature change would ease. Almost all of the Central section would have a maximum annual air temperature of 38 to 40 ºC, compared to 41 to 42 ºC for about 75 percent of the Southern section and the northeastern third of the Ridge and Valley section. The southern quarter of the Southern section and the remaining two-thirds of the Ridge and Valley section would have a maximum annual air temperature of 43 to 44 ºC (fig. 17).

Cornerstone D

Cornerstone D predicts that the decadal average precipitation across the Piedmont would decrease from 1379 mm in 2010 to 1371 mm in 2060, a decrease of 8 mm over the span of 50 years (table 5, fig. 13). This is the smallest decrease of any Cornerstone, basically remaining relatively flat over the next 50 years. Most of the Piedmont, with its three sections, would be uniformly dry, with the exceptions of five southern counties in the Southern section being wetter and one western county in the Ridge and Valley section being drier (fig. 14). About 65 percent of the Central section is predicted to have a maximum annual precipitation of 1501 to 2000 mm, with the northern 35 percent drier (1001 to 1500 mm). A single southwestern county would have a higher maximum annual precipitation (2001 to 3000 mm). Most of the Southern section would have a maximum annual precipitation of 1501 to 2000 mm, but 12 northwestern counties would have a maximum annual precipitation of 2001 to 3000 mm (fig. 15). Approximately 70 percent of the Ridge and Valley section would have a maximum annual precipitation of 2001 to 3000 mm, with 7 northeastern counties having less maximum annual precipitation of 1501 to 2000 mm. As with the others, Cornerstone D predicts that the southwestern end of the Piedmont will be dry, but will have a higher maximum annual precipitation.

The predicted decadal average air temperature would increase from 16.24 to 17.26 ºC across the Piedmont, an increase in 1.02 ºC (table 6) that is the smallest increase of the four Cornerstones (fig. 15). More specifically, almost all of the Piedmont would experience a temperature change of 0.50 to 0.99 ºC (fig. 16). The eastern 6 counties of the Central section would change only 0.14 to 0.49 ºC. Various areas of the Central section would have a maximum annual temperature ranging from 36 to 44 ºC. The southern third would have a maximum annual temperature of 41 to 42 ºC, compared to 38 to 40 ºC for most of the northern two-thirds. Six central counties would have a maximum temperature of 36 to 37 ºC and a single southern county would have a maximum annual temperature of 43 to 44 ºC. With the exception of 4 counties, the Southern section and all of the Ridge and Valley section would have a maximum annual temperature of 43 to 44 ºC; 3 northern counties would have a lower maximum annual temperature of 41 to 42 ºC, while a single southern county would have a higher maximum annual temperature of 45 to 47 ºC (fig. 17).

Summary

Cornerstone A is forecasted to be dry and hot, with an average annual precipitation range of 1001 to 3000 mm and an average annual temperature range of 36 to 47 ºC across the Piedmont. It predicts the lowest decadal average precipitation in 2060 (1065 mm) but the largest decrease (198 mm) in precipitation over the next 50 years. It also predicts the highest decadal average temperature in 2060 (18.79 ºC) with the largest temperature increase (2.63 ºC).

Cornerstone B is forecasted to be moderate and warm, with an average annual precipitation range of 1001 to 3000 mm and an average annual temperature range of 36 to 44 ºC across the Piedmont. Cornerstone B predicts the second highest decadal average precipitation (1345 mm) in 2060 with the second largest decrease (139 mm) in precipitation over the next 50 years. It also predicts the coolest decadal average temperature (17.05 ºC) in 2060 with the second highest temperature increase (1.64 ºC).

Cornerstone C is forecasted to be moderate and warm, with an average annual precipitation range of 1001 to 3000 mm and an average annual temperature range of 36 to 44 ºC across the Piedmont. It predicts the second lowest decadal average precipitation (1324 mm) with a slight increase (39 mm) in precipitation over the next 50 years. Cornerstone C is the only model to predict an increase in precipitation in 2060. Afterward, the trend would switch to one of decreasing precipitation into 2090. It predicts the second highest decadal average temperature (17.84 ºC) but the second lowest increase in temperature (1.50 ºC) over the next 50 years.

Cornerstone D is also forecasted to be moderate and warm, with an average annual precipitation range of 1001 to 3000 mm and an average annual temperature range of 36 to 47 ºC. It predicts the highest decadal average precipitation (1371 mm), with only a slight decrease (8 mm) in precipitation over the next 50 years and a slight increase (9 mm) when carried out to 2090. So, precipitation for Cornerstone D would stay relatively flat into the future. It also predicts the second lowest decadal average temperature (17.26 ºC) with the smallest increase in temperature (1.02 ºC) through 2060.

CHAPTER 5.
Wildlife and Forest Communities

Although not as diverse as some other areas of the South, the Piedmont is rich with native species—528 native terrestrial vertebrates (NatureServe 2011), of which 94 are amphibians, 283 are birds, 76 are mammals, and 75 are reptiles. Species richness, which varies by taxonomic group and geography in the Piedmont, is highest in the Central section (475) and Southern section (444), reflecting their relative size as well as the diversity of habitats that they support. The remaining, smaller section (Ridge and Valley) supports fewer vertebrate species (408). Figure 18 shows the geographic patterns that cross the four taxonomic groups listed above.

The most plentiful of the taxonomic groups, amphibians, are more plentiful in the Piedmont than in other southern subregions. Amphibians are the most abundant in the Central section (77), followed closely by the Southern section (74) and more distantly by the Ridge and Valley section (60). Bird richness is highest in the Central section (273), with the Southern section (234) and the Ridge and Valley section (232) being similar. Mammal richness is also highest in the Central section (69), followed closely by the Southern section (66) and more distantly by the Ridge and Valley section (58). Conversely, reptile richness is highest in the Southern section (70), with the Ridge and Valley section second (58) and the Central section (56) a close third.

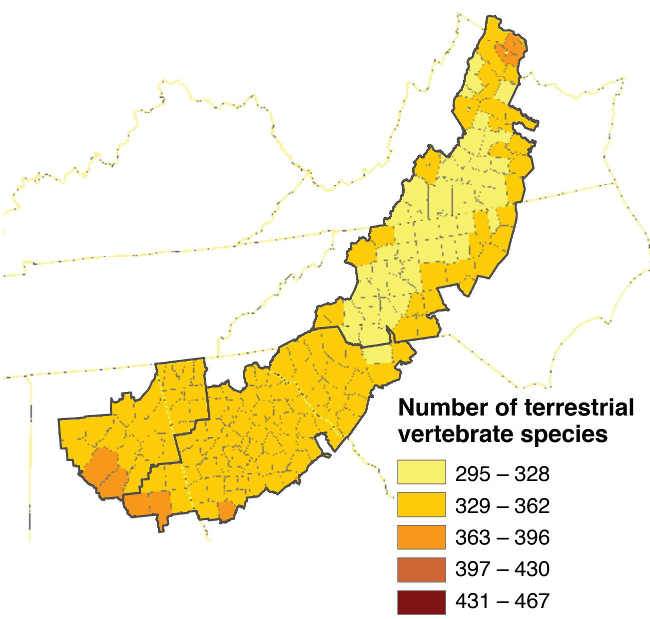


Figure 18—County-level counts of native terrestrial vertebrate species in the three sections (Central Appalachian Piedmont, Southern Appalachian Piedmont, and Piedmont Ridge, Valley, and Plateau) of the Southern U.S. Piedmont (Source: NatureServe 2011).

According to NatureServe (2011), the Piedmont supports 22 ecosystems, far fewer than the larger subregions of the South (153 in the Coastal Plain, 115 in the Mid-South, and 77 in the Appalachian-Cumberland highlands). As used here, the term ecosystem is defined as recurring groups of communities found in comparable environments in which similar ecological processes—such as fire or flooding—have a critical influence.

Six percent (32) of the terrestrial vertebrate species in the Piedmont are considered to be of conservation concern (table 7), seven of which are federally listed (table 8). The Piedmont has 188 plant species that are considered to be of conservation concern; of these, 28 are federally listed (table 8).

The proportion of vertebrate species at risk varies among taxonomic groups in the Piedmont: 53 percent are amphibians, followed by reptiles (22 percent), mammals (19 percent), and birds (6 percent). The Southern section (18) has the most, followed by the Central section (10) and Ridge and Valley section (9).

Figure 19 displays the distribution of vertebrate species of conservation concern across the Piedmont. In the Central section, a single county (Rutherford County in North Carolina) has 4 to 6 species of conservation concern, and 33 counties have 1 to 3 species. In the Southern section, a single county (Oconee County in South Carolina) has 7 to 9 species of conservation concern, four have 4 to 6 species, and 15 have 1 to 3 species. In the Ridge and Valley section a single county (Marshall County in Alabama) has 7 to 9 species of conservation concern, two have 4 to 6 species, and 16 have 1 to 3 species. Rutherford and Oconee Counties are adjacent to the Blue Ridge section of the Appalachian-Cumberland highlands, and Marshall County is adjacent to the Cumberland Plateau and Mountain section of the Appalachian-Cumberland highlands. These sections have a high number of species of

Table 7—Vertebrate species of global conservation concern in the sections—Central Appalachian Piedmont, Southern Appalachian Piedmont, and Piedmont Ridge, Valley, and Plateau—of the Southern U.S. Piedmont

Taxonomic group	Species	Global rank[a]	Piedmont section
Frogs	Carolina gopher frog (*Rana capito*)	G3	Southern, Ridge and Valley
Salamanders	Blue Ridge gray-cheeked salamander (*Plethodon amplus*)	G1	Central
	South Mountain gray-cheeked salamander (*Plethodon meridianus*)	G1	Central
	Shenandoah salamander (*Plethodon shenandoah*)	G1	Central
	Tennessee cave salamander (*Gyrinophilus palleucus*)	G2	Ridge and Valley
	Black Warrior waterdog (*Necturus alabamensis*)	G2	Ridge and Valley
	Peaks of Otter salamander (*Plethodon hubrichti*)	G2	Central
	Pigeon Mountain salamander (*Plethodon petraeus*)	G2	Ridge and Valley
	Big Levels salamander (*Plethodon sherando*)	G2	Central
	Green salamander (*Aneides aeneus*)	G3	All
	Hellbender (*Cryptobranchus alleganiensis*)	G3	Southern, Ridge and Valley
	Seepage salamander (*Desmognathus aeneus*)	G3	Southern, Ridge and Valley
	Neuse River waterdog (*Necturus lewisi*)	G3	Central
	Southern gray-cheeked salamander (*Plethodon metcalfi*)	G3	Southern
	Northern gray-cheeked salamander (*Plethodon montanus*)	G3	Southern
	Southern Appalachian salamander (*Plethodon teyahalee*)	G3	Southern
	Webster's salamander (*Plethodon websteri*)	G3	Southern, Ridge and Valley
Birds	Bachman's sparrow (*Aimophila aestivalis*)	G3	All
	Red-cockaded woodpecker (*Picoides borealis*)	G3	All
Bats	Indiana bat (*Myotis sodalis*)	G2	All
	Rafinesque's big-eared bat (*Corynorhinus rafinesquii*)	G3	Southern, Ridge and Valley
	Southeastern bat (*Myotis austroriparius*)	G3	Central, Ridge and Valley
	Gray bat (*Myotis grisescens*)	G3	Central, Ridge and Valley
	Eastern small-footed bat (*Myotis leibii*)	G3	All
Rodents	Allegheny woodrat (*Neotoma magister*)	G3	Central, Ridge and Valley
Snakes	Southern hog-nosed snake (*Heterodon simus*)	G2	Southern
Turtles	Barbour's map turtle (*Graptemys barbouri*)	G2	Southern
	Flattened musk turtle (*Sternotherus depressus*)	G2	Ridge and Valley
	Bog turtle (*Glyptemys muhlenbergii*)	G3	Central, Southern
	Gopher tortoise (*Gopherus polyphemus*)	G3	Southern
	Black-knobbed map turtle (*Graptemys nigrinoda*)	G3	Southern
	Alligator snapping turtle (*Macrochelys temminckii*)	G3	Southern, Ridge and Valley

[a] G1 = Critically Imperiled—At very high risk of extinction or elimination due to very restricted range, very few populations or occurrences, very steep declines, very severe threats, or other factors; G2 = Imperiled—At high risk of extinction or elimination due to restricted range, few populations or occurrences, steep declines, severe threats, or other factors; G3 = Vulnerable—At moderate risk of extinction or elimination due to a fairly restricted range, relatively few populations or occurrences, recent and widespread declines, threats, or other factors.

Source: NatureServe (2011).

Table 8—Terrestrial vertebrates and vascular plants that are federally listed as threatened or endangered in the sections—Central Appalachian Piedmont, Southern Appalachian Piedmont, and Piedmont Ridge, Valley, and Plateau—of the Southern U.S. Piedmont

Taxonomic group	Species[a]	Status	Piedmont section
Salamanders	Shenandoah salamander (*Plethodon shenandoah*)	E	Central
Birds	Wood stork (*Mycteria americana*)	E	Southern
	Red-cockaded woodpecker (*Picoides borealis*)	E	All
Bats	Indiana bat (*Myotis sodalis*)	E	All
	Gray bat (*Myotis grisescens*)	E	Central, Ridge and Valley
Turtles	Bog turtle (*Glyptemys muhlenbergii*)	T	Central, Southern
	Gopher tortoise (*Gopherus polyphemus*)	T	Southern
	Flattened musk turtle (*Sternotherus depressus*)	T	Ridge and Valley
Ferns	Black-spored quillwort (*Isoetes melanospora*)	E	Southern
	Merlin's-grass (*Isoetes tegetiformans*)	E	Southern
Conifers	Florida torreya (*Torreya taxifolia*)	E	Southern
Vines	Price's potato-bean (*Apios priceana*)	T	Ridge and Valley
	Alabama leather-flower (*Clematis socialis*)	E	Ridge and Valley
Herbs	Sensitive joint-vetch (*Aeschynomene virginica*)	T	Central
	Little amphianthus (*Amphianthus pusillus*)	T	Central, Southern
	Small-anther bittercress (*Cardamine micranthera*)	E	Central
	Smooth purple coneflower (*Echinacea laevigata*)	E	Central, Southern
	Schweinitz's sunflower (*Helianthus schweinitzii*)	E	Central, Southern
	Swamp-pink (*Helonias bullata*)	T	Southern
	Dwarf-flower heartleaf (*Hexastylis naniflora*)	T	Central, Southern
	Small whorled pogonia (*Isotria medeoloides*)	T	Central, Southern
	Mohr's Barbara's-buttons (*Marshallia mohrii*)	T	Ridge and Valley
	Harperella (*Ptilimnium nodosum*)	E	All
	Bunched arrowhead (*Sagittaria fasciculata*)	E	Southern
	Little River arrowhead (*Sagittaria secundifolia*)	T	Southern, Ridge and Valley
	Green pitcherplant (*Sarracenia oreophila*)	E	Ridge and Valley
	Mountain sweet pitcherplant (*Sarracenia rubra* ssp. *jonesii*)	E	Southern
	Large-flower skullcap (*Scutellaria montana*)	T	Ridge and Valley
	Fringed campion (*Silene polypetala*)	E	Southern
	Reflexed blue-eyed-grass (*Sisyrinchium dichotomum*)	E	Central, Southern
	Persistent trillium (*Trillium persistens*)	E	Southern
	Relict trillium (*Trillium reliquum*)	E	Southern
	Tennessee yellow-eyed-grass (*Xyris tennesseensis*)	E	Ridge and Valley
Shrubs	Michaux's sumac (*Rhus michauxii*)	E	Central, Southern
	Miccosukee gooseberry (*Ribes echinellum*)	T	Southern
	Virginia spiraea (*Spiraea virginiana*)	T	Ridge and Valley

T = threatened; E = endangered.

[a] Terrestrial vertebrate names follow NatureServe (2011); vascular plant names follow the U.S. Department of Agriculture Plants Database.

Source: Griep and Collins (2013).

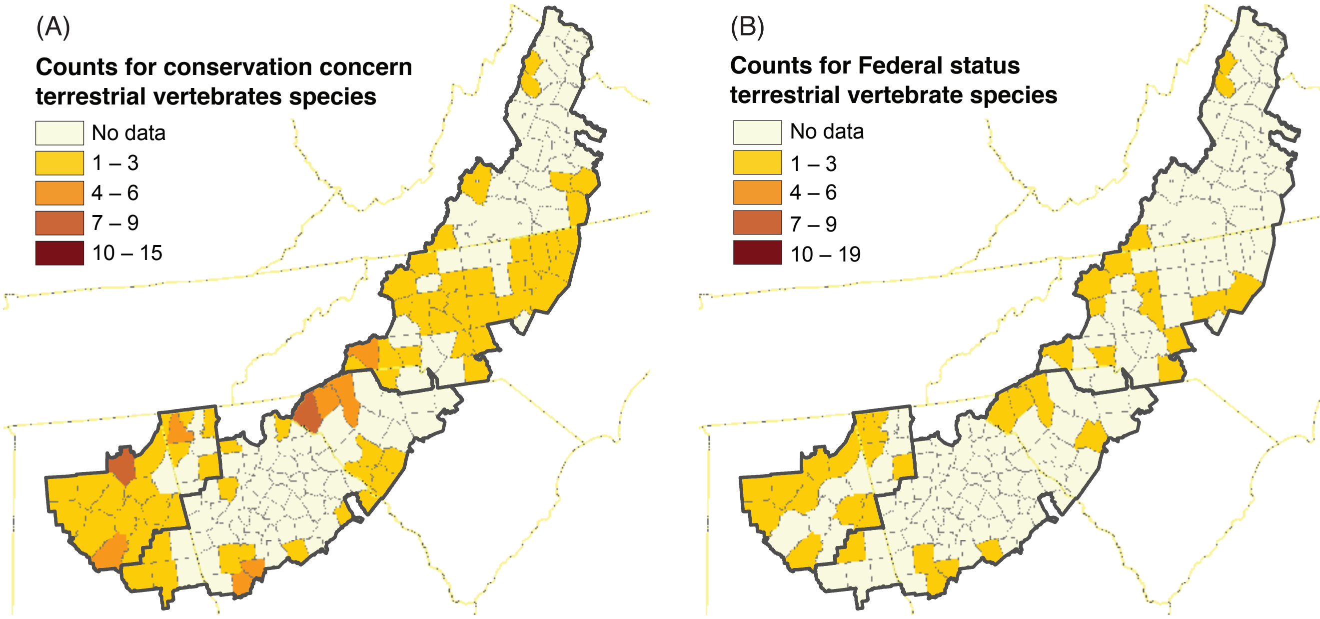


Figure 19—County-level counts in the three sections (Central Appalachian Piedmont, Southern Appalachian Piedmont, and Piedmont Ridge, Valley, and Plateau) of the Southern U.S. Piedmont for (A) terrestrial vertebrate species of conservation concern and (B) federally listed status terrestrial vertebrate species (Source: NatureServe 2011).

conservation concern, most likely because they are in the transition between northern and southern species ranges and ecotones. Of the counties in the Piedmont that contain federally listed threatened or endangered species, none has more than three such species (fig. 19).

Species, including those of conservation concern, are affected by habitat alteration, isolation, introduction of invasive species, environmental pollutants, commercial development, human disturbance, and exploitation. The conditions predicted by the forecasts would only magnify these stressors. Each species varies in its vulnerability to forecasted threats, and these threats vary by section. Key areas of concern arise where hotspots of vulnerable species coincide with forecasted stressors.

DISTRIBUTION AND STATUS OF INDIVIDUAL TAXONOMIC GROUPS

Differences among taxonomic groups that are not evident from the composite map shown in figure 18 are described in further detail.

Amphibians

Of the 94 species of amphibians that occur in the Piedmont, 60 percent are salamanders, with frogs and toads comprising the remaining 40 percent. More specifically, the distribution by section is 62 percent (Central), 58 percent (Southern), and 60 percent (Ridge and Valley). Amphibian diversity is highest in the Central section (77), followed closely by the Southern section (74), and more distantly by the Ridge and Valley section (60). As shown in figure 20, diversity tends to be higher in the counties along the outer edges of the sections, where there is transition into the Coastal Plain and Appalachian-Cumberland highlands.

Amphibians use a variety of habitats in the Piedmont; all are related to bodies of water or moist conditions. These habitats include ephemeral pools, seeps, bogs, caves, forests, floodplains and isolated wetlands, small ponds, and rock outcrops. For many species, moisture is a limiting factor. Several terrestrial species migrate to aquatic habitats for egg deposition, and many aquatic species use terrestrial habitat for dispersal of juveniles and other life-cycle events (Griep and Collins 2013). Leaf litter, fallen logs, moist soils, and other surface debris serve as refugia when conditions are drier. Amphibians are an increasingly important consideration in many issues of conservation concern, often used as indicators of ecosystem health (Rose and Harshbarger 1977, Southerland and others 2004, Welsh and Droege 2001). Threats include loss or degradation of habitat, such as through agricultural and urban development, exclusion of fire, contamination of water springs or ponds, introduction of fish into breeding ponds, and stream impoundment.

Only one species of salamander is federally listed as threatened or endangered in the Piedmont (table 8). The federally endangered Shenandoah salamander (*Plethodon shenandoah*) occurs in Virginia. Its range is limited to the highest peaks in Shenandoah National Park (NatureServe 2011). Griffis and Jaeger (1992) found that it might be

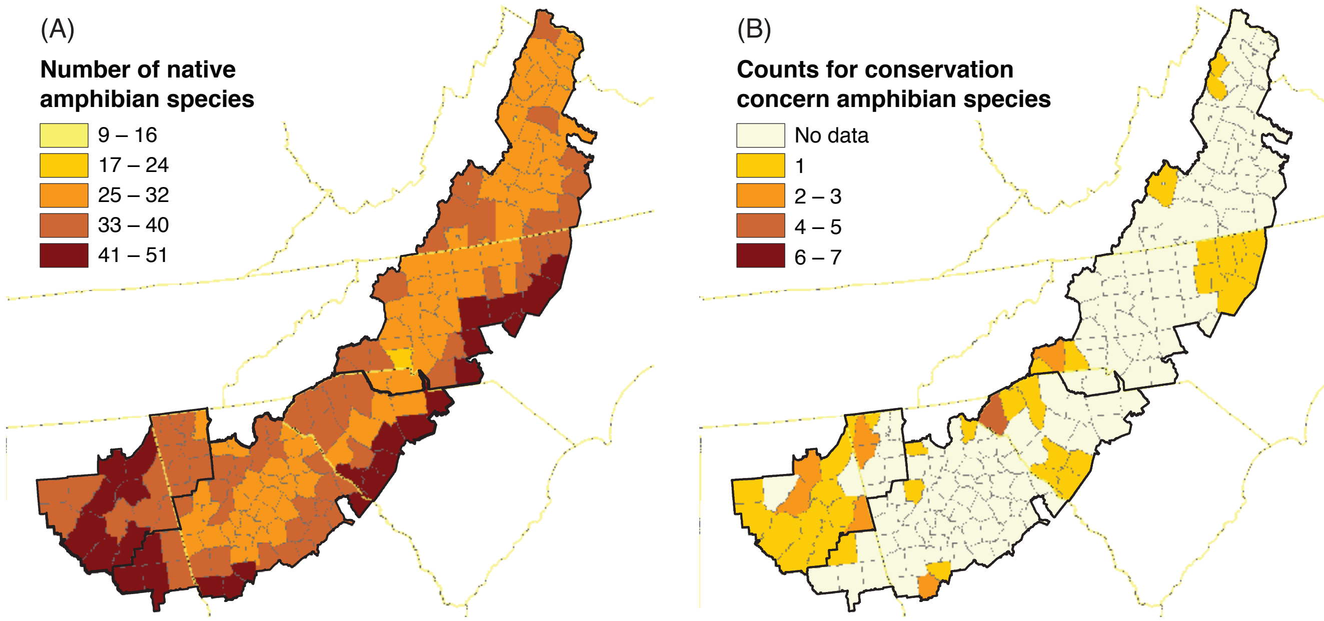


Figure 20—County-level counts in the three sections (Central Appalachian Piedmont, Southern Appalachian Piedmont, and Piedmont Ridge, Valley, and Plateau) of the Southern U.S. Piedmont for (A) of all native amphibian species and (B) amphibian species of conservation concern (Source: NatureServe 2011).

Table 9—Vertebrate species richness in the sections—Central Appalachian Piedmont, Southern Appalachian Piedmont, and Piedmont Ridge, Valley, and Plateau—of the Southern U.S. Piedmont

	Amphibians		Birds						Mammals				Reptiles				
Piedmont section	Frogs and toads	Salamanders	Perching birds	Raptors	Shorebirds	Wading birds	Waterfowl	Other birds[a]	Bats	Carnivores	Rodents	Other mammals[b]	Crocodilians	Lizards	Snakes	Turtles	Worm lizards
Central	29	48	133	17	25	10	27	61	13	12	24	20	0	10	33	13	0
Southern	31	43	128	13	17	13	29	43	15	12	22	17	0	11	38	21	0
Ridge and Valley	24	36	127	13	16	11	22	43	14	10	23	11	0	11	30	17	0

[a] Includes game birds and woodpeckers.

[b] Includes deer, rabbits, shrews, and moles.

Source: NatureServe (2011).

further restricted by competition with the common redback salamander (*Plethodon cinereus*). Also threatening the species are human-related factors, such as acid deposition and tree defoliation caused by introduced pest insects (U.S. Fish and Wildlife Service 1994).

Seventeen amphibian species (16 salamanders and a frog) are of conservation concern in the Piedmont (table 8): seven in the Central section (all salamanders) with 14 counties having 1 to 3 species each (fig. 20), and four—including the Carolina gopher frog (*Rana capito*)—in both the Southern and Ridge and Valley sections. In the Southern section, 11 counties have one species each, one has 2 to 3 species and one county (Oconee County in South Carolina) has 4 to 5 species (fig. 20). Oconee County is actually a part of the Southern Appalachian Mountains, where more species of salamanders exist and are more abundant than anywhere else in the world (Highlands Biological Station, Foundation, Nature Center, and Botanical Garden 2013) and where the plethodontid salamanders could have originated according to observations of species richness and diversity by Wilder and Dunn (1920). Of the 24 counties in the Ridge and Valley section, 16 have 1 to 3 amphibian species of concern (fig. 20).

Birds

Because of its moderate climate and diverse forests, the Piedmont supports abundant and diverse communities of breeding, wintering, and migrating birds. Its 283 avian species (NatureServe 2011) include perching birds, shorebirds, wading birds, waterfowl, and raptors. The Central section (273) has the highest bird diversity, with the Southern section (234) and the Ridge and Valley section (232) being very similar. Songbirds and other perching birds comprise about half of the bird species in the Piedmont: 49 percent of all birds in the Central section and 55 percent in the Southern and Ridge and Valley sections (table 9). Birds in the "other" category, which include several game birds and woodpeckers, comprise the next larger group: 22 percent in the Central section, 18 percent in the Southern section, and 19 percent in the Ridge and Valley section. All other bird groups collectively represent ≤10 percent in all sections.

Figure 21 shows the distribution of native bird species across the Piedmont. Bird distribution is influenced by a combination of local and landscape conditions. Local features include habitat composition, structural diversity, and successional stage. Landscape conditions include habitat patch size, interspersion of vegetative communities, edge length, interpatch distance, interior forest, adjacent land use, and spatial heterogeneity. Approximately 97 percent of the Piedmont counties have 201 to 226 species of birds; in the northern portion of the Central section, three counties have 227 to 251 species and three counties along the Potomac River have 252 to 276 species. The Potomac River flows into the Chesapeake Bay, the largest estuary in the United States. The higher diversity of birds in this area may be attributed to the diversity of habitats, including fresh, salt, and brackish water.

The only birds that are federally listed in the Piedmont (table 8) are the wood stork (*Mycteria americana*), which occurs in the Southern section, and the red-cockaded woodpecker (*Picoides borealis*), which occurs in all sections.

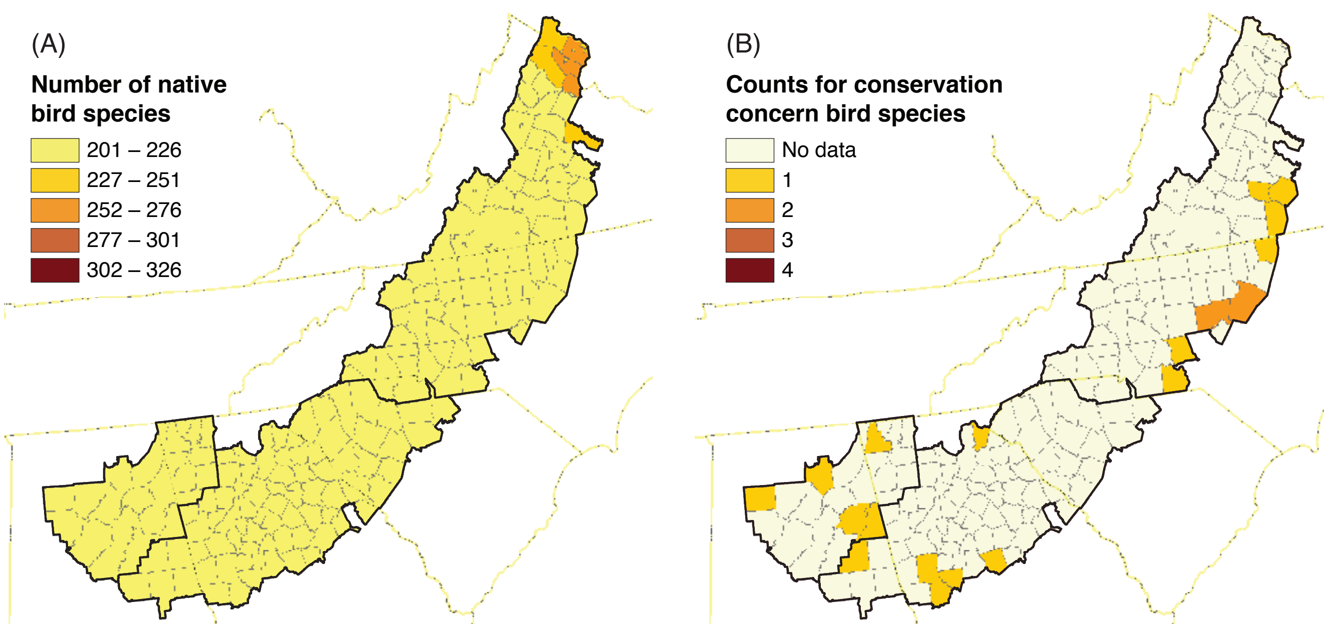


Figure 21—County-level counts in the three sections (Central Appalachian Piedmont, Southern Appalachian Piedmont, and Piedmont Ridge, Valley, and Plateau) of the Southern U.S. Piedmont for (A) all native bird species and (B) bird species of conservation concern (Source: NatureServe 2011).

Both are endangered, but the wood stork has a global ranking of "apparently secure" (G4). The wood stork is threatened by changes in water regimes such as from the drainage of wetlands or the loss of habitat from development (Van Meter 1989). Reproductive failure resulting from prolonged drought, unseasonably heavy rainfall, or nest predation have also reduced populations in some areas (Van Meter 1989). The red-cockaded woodpecker is threatened by loss of habitat, forest fragmentation, competition with other species for cavities, and catastrophic events (Walters 1991).

Two avian species are of conservation concern (table 7), Bachman's sparrow (*Aimophila aestivalis*) and the red-cockaded woodpecker. Figure 21B shows the distribution of these species across the Piedmont. Eight counties in the Central section have 1 to 2 species, six counties in the Southern section have one species, and five counties in the Ridge and Valley section have one species.

Mammals

Terrestrial and freshwater habitats in the Piedmont are home to 76 native mammals (NatureServe 2011) including rodents, bats, and carnivores. Rodents (approximately 36 percent of the mammal species) comprise the largest group, with representative species including squirrels, voles, mice, beavers, and groundhogs. The NatureServe category of "other mammals" (25 percent) includes deer, rabbits, shrews, and moles. Bats comprise 22 percent of the mammal species. Carnivores, which comprise the smallest group (17 percent), include foxes and other canids, weasels, and skunks. The relative absence of large, native carnivores reflects the history of European settlement (Griep and Collins 2013). The American black bear (*Ursus americanus*) is the largest carnivore currently inhabiting the Piedmont.

Mammals are associated with specific habitats that offer suitable forage and refuge; their patterns of use vary with seasonal food availability. Areas that are diverse in composition, structure, and ecological successional stage as well as the transition zones that separate them enhance prey density and other food opportunities.

The distribution of mammal diversity across the Piedmont is fairly homogeneous (fig. 22). Most of the counties in the three sections have 38 to 48 mammal species. However, higher diversity (49 to 59 species) exists in the 6 Central section counties, 9 Southern section counties, and 2 Ridge and Valley section counties. Most of these counties border the Blue Ridge section of the Appalachian-Cumberland highlands. Their diversity may be attributed to the range in elevation, from the mountains through the foothills, which creates habitat gradients for a variety of species.

The two species of mammals listed as threatened or endangered (table 8) are the Indiana bat (*Myotis sodalis*) and the gray bat (*Myotis grisescens*). Human disturbance to hibernating and maternity colonies in caves is a major factor in bat declines (Griep and Collins 2013). More recently, the introduction of white-nose syndrome and its associated fungus (*Geomyces destructans*) has caused extensive mortality in cave-hibernating bats in the Eastern United States (Frick and others 2010). This disease was first documented in New York in 2006, and it has spread rapidly

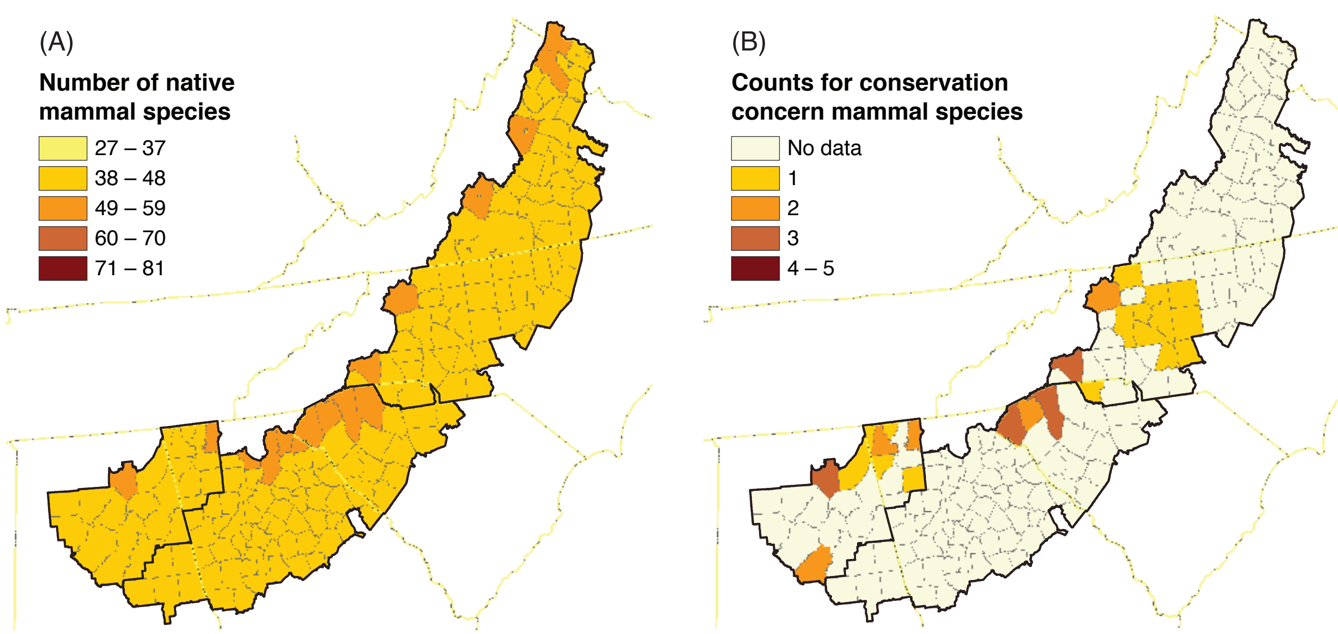


Figure 22—County-level counts in the three sections (Central Appalachian Piedmont, Southern Appalachian Piedmont, and Piedmont Ridge, Valley, and Plateau) of the Southern U.S. Piedmont for (A) all native mammal species and (B) mammal species of conservation concern (Source: NatureServe 2011).

into 21 other States and five Canadian provinces. Both the Indiana and gray bats have already been affected in other subregions of the South, and white-nose syndrome was confirmed in Pickens County, South Carolina in March 2013.

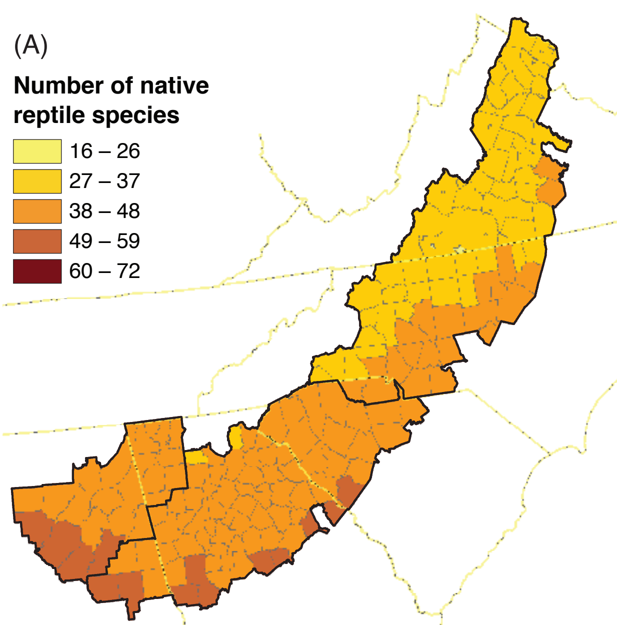
Six mammal species are imperiled or vulnerable in the Piedmont (table 8): the Indiana bat, gray bat, Rafinesque's big-eared bat (*Corynorhinus rafinesquii*), southeastern bat (*Myotis austroriparius*), eastern small-footed bat (*Myotis leibii*), and Allegheny woodrat (*Neotoma magister*). The Central and Ridge and Valley sections both have the Allegheny woodrat and four or five of the five imperiled bat species, and the Southern section has three of the bat species. In the Central section, one county has three species, one county has two species, and 11 counties have one species. For the Southern section, 2 counties have three species and one county has two species. In the Ridge and Valley section, one county has three species, 3 counties have two species, and 5 counties have one species.

Reptiles

The Piedmont supports 75 reptile species (NatureServe 2011), including snakes (about 55 percent), turtles (about 27 percent), and lizards (about 18 percent); but no crocodilians or worm lizards. The majority of snakes in the Piedmont are nonvenomous, but pit vipers and coral snakes do occur.

The Southern section, which leads in reptile richness with 70 species, also has the most snakes with 38 species and turtles with 21 species (table 9). Following are the Ridge and Valley section with 58 species and the Central section with 56 species; these sections also have higher numbers of snakes, followed by turtles. Only 11 species of lizards reside in the Southern section and Ridge and Valley section and 10 in the Central section. Twenty-one of the 76 counties of the Central section have 38 to 48 species of reptiles, and the remaining counties have 27 to 37 species (fig. 23). Two northwestern counties in the Southern section have 27 to 37 species, and 10 have 49 to 59 species; the remaining 65 counties have 38 to 48 species. Four southwestern counties in the Ridge and Valley section have 49 to 59 species of reptiles; the remaining 20 counties have 38 to 48 species. Most of the counties in the Southern section and Ridge and Valley section with 49 to 59 reptile species border the Coastal Plain—the Eastern Atlantic section for the Southern section and the Middle Gulf-Eastern section for the Ridge and Valley section. These areas could provide habitat gradients along the fall line that increase reptile diversity.

As with amphibians, the ecological importance of lizards has become recognized in the past decade as resource objectives focus on biodiversity conservation, landscape perspectives, and ecosystem functioning. Reptiles occupy a variety of habitats including mesic and xeric hardwood forests, sandhills, grasslands, prairies, barrens, outcrops, beaches and dunes, and agricultural and urban areas (Griep and Collins 2013). Rivers, streams, swamps, lakes, and marshes figure prominently in aquatic turtle occurrence. For many reptile species, leaf litter and fallen logs provide shelter and foraging opportunities, and friable soils are an important habitat component.



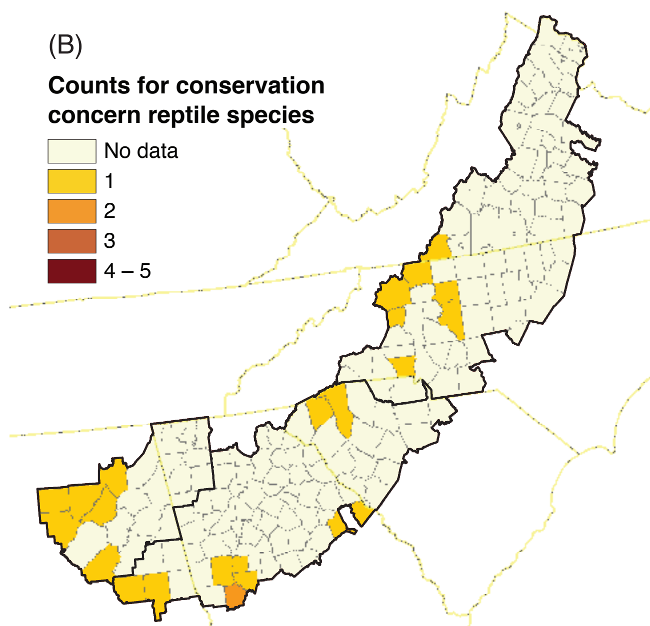


Figure 23—County-level counts in the three sections (Central Appalachian Piedmont, Southern Appalachian Piedmont, and Piedmont Ridge, Valley, and Plateau) of the Southern U.S. Piedmont for (A) all native reptile species and (B) reptile species of conservation concern (Source: NatureServe 2011).

Table 10—Number of counties in each section (Central Appalachian Piedmont, Southern Appalachian Piedmont, and Piedmont Ridge, Valley, and Plateau) of the Southern U.S. Piedmont with percent survey plots occupied by 1 to 4 nonnative invasive plants

	Number of counties reporting various percentages of survey plots occupied						
Piedmont section	<4	4.1 to 11	11.1 to 20	20.1 to 31	31.1 to 43	43.1 to 58	>58.1
Central	19	27	20	10	0	0	0
Southern	3	14	33	22	4	1	0
Ridge and Valley	0	3	7	4	6	3	1

Three species of reptiles are federally listed as threatened in the Piedmont (table 8)—the bog turtle (*Glyptemys muhlenbergii*) in the Central and Southern sections, the gopher tortoise (*Gopherus polyphemus*) in the Southern section, and the flattened musk turtle (*Sternotherus depressus*) in the Ridge and Valley section. Their ectothermic physiology and seasonal inactivity mean that growth rates are relatively slow and maturity occurs at advanced ages, factors that exacerbate environmental risks (Griep and Collins 2013). Threats to these species include illegal and unregulated collecting, urban and agricultural development, and degradation of wetland habitats.

Seven reptile species are of conservation concern in the Piedmont (table 7): the southern hog-nosed snake (*Heterodon simus*), Barbour's map turtle (*Graptemys barbouri*), black-knobbed map turtle (*Graptemys nigrinoda*), and gopher tortoise in the Southern section; the flattened musk turtle in the Ridge and Valley section; the bog turtle in the Central and Southern sections; and the alligator snapping turtle (*Macrochelys temminckii*) in the Southern and Ridge and Valley sections. The Southern section leads in the number of reptile species of conservation concern with six, compared to two for the Ridge and Valley section, and the one for the Central section. The Ridge and Valley section has six counties with 1 to 3 species of concern (fig. 23). The southwestern portion of the Central section has seven counties that contain 1 to 2 species, and the Southern section has one county (Talbot County in Georgia) with 3 to 4 and nine counties with 1 to 2 species. The higher diversity of rare reptiles in Talbot County, which actually crosses into the Coastal Plain, may be explained by the presence of three ecoregions: (1) the Southern Outer Piedmont, (2) Pine Ridge Mountains, and (3) Sand Hills (Georgia Department of Natural Resources 2005). These ecoregions add considerable diversity to the habitats that occur in the county.

Many reptiles are long lived, late maturing, and have restricted geographic ranges. For map turtles, those limits magnify the risk from degradation of aquatic habitats, disease, or illegal collection. Lizards with insular populations and restricted ranges are at risk to habitat loss. Malicious killing, biocides, and the pet trade contribute to snake imperilment.

Vascular Plants

The Piedmont supports thousands of native vascular plants in 22 different ecological systems, from Interior Longleaf Pine, Southern Appalachian Montane Pine Forest, and Southern Piedmont Granite Flatrock and Outcrop to Southern Piedmont Large Floodplain Forest and Atlantic Coastal Plain Streamhead Seepage Swamp, Pocosin and Baygall (Griep and Collins 2013). Representatives of vascular plants include trees and shrubs, herbs, vines, conifers and their relatives, and ferns and their relatives. Herbs comprise the vast majority of native vascular plants in the Piedmont.

Twenty-eight plants are federally listed as endangered or threatened (table 8) in the Piedmont—2 ferns, 1 conifer, 2 vines, 3 shrubs, and 20 herbs. The ferns, the black-spored quillwort (*Isoetes melanospora*) and Merlin's-grass (*Isoetes tegetiformans*), are both found in unique, temporary pools in Southern Piedmont Granite Flatrock and Outcrop ecosystems of the Southern section. The vines, Price's potato-bean (*Apios priceana*) and Alabama leather-flower (*Clematis socialis*), are both found in the Ridge and Valley section. Of the shrubs, Michaux's sumac (*Rhus michauxii*) is found in the Central and Southern sections, Miccosukee gooseberry (*Ribes echinellum*) is found in the Southern section, and Virginia spiraea (*Spiraea virginiana*) is found in the Ridge and Valley section (table 8).

The Southern section leads in the number of federally listed plants with 19, followed by the Central section with 10, and the Ridge and Valley section with 9 (table 8). In the Central section, one county (Mecklenburg County in North Carolina) has 4 to 6 federally listed species that mostly tend to thrive in habitats kept open by disturbance, and 44 counties have 1 to 3 species (fig. 24). In the Southern

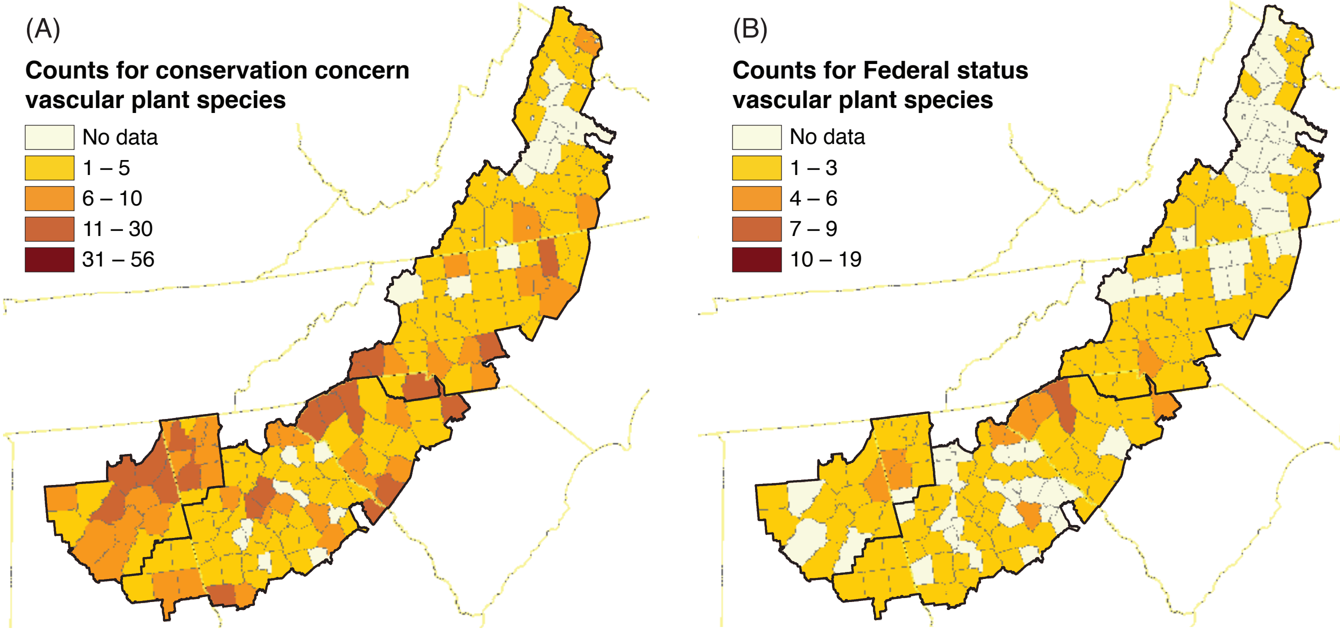


Figure 24—County-level counts in the three sections (Central Appalachian Piedmont, Southern Appalachian Piedmont, and Piedmont Ridge, Valley, and Plateau) of the Southern U.S. Piedmont for (A) vascular plant species of conservation concern and (B) federally listed status vascular plant species (Source: NatureServe 2011)

section, one county (Greenville County in South Carolina) has 7 to 9 federally listed species, and 45 counties have 1 to 3. In the Ridge and Valley section, three counties have 4 to 6 federally listed species, and 17 counties have 1 to 3.

The Piedmont has 188 vascular plants that are of conservation concern. Again, the majority of these plants are herbs. Counties with higher numbers (11 to 30 species) of plants of conservation concern also tend to have at least two, and up to five, federally listed species (fig. 24). In the Central section, five counties have 11 to 30 species of conservation concern, 11 counties have 6 to 10, and 47 counties have 1 to 5. In the Southern section, nine counties have 11 to 30 species of conservation concern, 15 counties have 6 to 10, and 44 counties have 1 to 5. In the Ridge and Valley section, six counties have 11 to 30 species of conservation concern, 12 counties have 6 to 10, and six counties have 1 to 5.

SPECIES EXTIRPATION IN THE PIEDMONT

According to NatureServe (Griep and Collins 2013), several birds and mammals have been extirpated from the Piedmont: the passenger pigeon (*Ectopistes migratorius*), Carolina parakeet (*Conuropsis carolinensis*), red wolf (*Canis rufus*), American bison (*Bos bison*), Appalachian Bewick's wren (*Thryomanes bewickii altus*), Bachman's warbler (*Vermivora bachmanii*), gray wolf (*Canis lupus*), Eastern cougar (*Puma concolor cougar*), and elk (*Cervus canadensis*). The extirpation of large carnivores such as the gray wolf and large herbivores such as elk and bison reflects the history of European settlement (Griep and Collins 2013). Wolves were regarded as threats to livestock and personal safety, whereas elk and bison were sources of food and clothing. The decline of the red wolf has been attributed to indiscriminate predator control, extensive land clearing, and coyote (*Canis latrans)* hybridization (Griep and Collins 2013). Some carnivores, such as the Eastern cougar, were relegated to relatively remote areas in response to overharvesting and habitat alteration, destruction, and fragmentation.

Several species of vascular plants have become extinct as well. These include Alexander's rock aster (*Eurybia avita*), Godfrey's stitchwort (*Mimartia godfreyi*), bigleaf scurfpea (*Orbexilum macrophyllum*), and purple fringeless orchid (*Plantanthera peramoena*). Habitat alteration or destruction caused by development, heavy disturbance, over collecting, competition with nonnative invasive species, and altered hydrology has contributed to the demise of these species.

OUTLOOK FOR ANIMALS AND PLANTS AT RISK

Forecasts of substantial urban growth (10 to 25 percent), with substantial losses of forest habitat and fragmentation, could impair the relatively high richness of the amphibians (59 to 76 species per section) and mammals (49 to 58 species per section) that inhabit the Piedmont (Griep and Collins 2013). Several species of concern occur in the Central section (14), Southern section (18), and Piedmont Ridge and Valley (17), including the Black Warrior waterdog (*Necturus alabamensis*), gray bat, Peaks of Otter salamander (*Plethodon hubrichti*), and Shenandoah Mountain salamander. The urban growth predicted for Atlanta (>25 percent) and the expansion along I-85 northward into South Carolina toward Greenville could threaten plants of upland forests and openings, such as American ginseng (*Panax quinquefolius*). However, most of the at-risk plant species (>75 percent) in the fast-growing De Kalb and Gwinnett Counties around Atlanta either are associated with granite outcrops and surrounding communities that may be inaccessible for development or are on protected lands.

Areas with concentrations of sensitive plant species or plant communities—including the Blue Ridge escarpment and foothills of the Southern section and the southern extensions of the Cumberland Plateau and Mountains section and adjacent Ridge and Valley section—are predicted to have a 3 to 20 percent increase in urban area and forest loss (Griep and Collins 2013). The escarpment and foothills area, primarily in northwestern South Carolina, includes mountain outcrops (such as those in Table Rock and Caesars Head State Parks), gorges, lakes (such as Jocassee, Keowee, and Hartwell), the Chattooga Wild and Scenic River, and the growing urban area around Greenville. Beyond protected public lands, development threatens plants such as the imperiled Oconee-bell (*Shortia galacifolia*) in ravines and shady stream banks. Plants at risk from habitat loss in the Ridge and Valley section include the endangered Alabama leather-flower (*Clematis socialis*), which occurs along roadsides and recently logged forests.

OUTLOOK FOR LONGLEAF PINE FORESTS

During the meetings held in the spring of 2008 to solicit input on important issues for Piedmont forests, particular emphasis was placed on longleaf pine. Although longleaf pine communities are typically limited to the Coastal Plain, widely dispersed stands of interior or upland longleaf pine can be found in the Piedmont.

The longleaf community supports several vertebrates (Griep and Collins 2013). Bachman's sparrow breeds in dense, grassy areas that have scattered trees. Other avifauna include Henslow's sparrow, brown-headed nuthatch (*Sitta pusilla*), and pine warbler (*Dendroica pinus*). Characteristic mammals include the southern short-tail shrew (*Blarina carolinensis*), eastern mole (*Scalopus aquaticus*), Seminole bat (*Lasiurus seminolus*), and long-tailed weasel (*Mustela frenata*). Longleaf pine communities also support numerous amphibians and reptiles, including the eastern spadefoot (*Scaphiopus holbrookii*), pine snake (*Pituophis melanoleucus*), pine woods treefrog (*Hyla femoralis),* sand skink (*Neoseps reynoldsi*)*,* and southern hog-nosed snake.

Longleaf pine forests traditionally have been managed with prescribed fire to promote regeneration and timber yield (Griep and Collins 2013). Restoration is underway, and many of these forests are managed primarily to promote biodiversity. Cornerstone A (high economic growth and high demand for wood products) predicts the most change in longleaf pine forests. Currently in the Piedmont (fig. 25A),

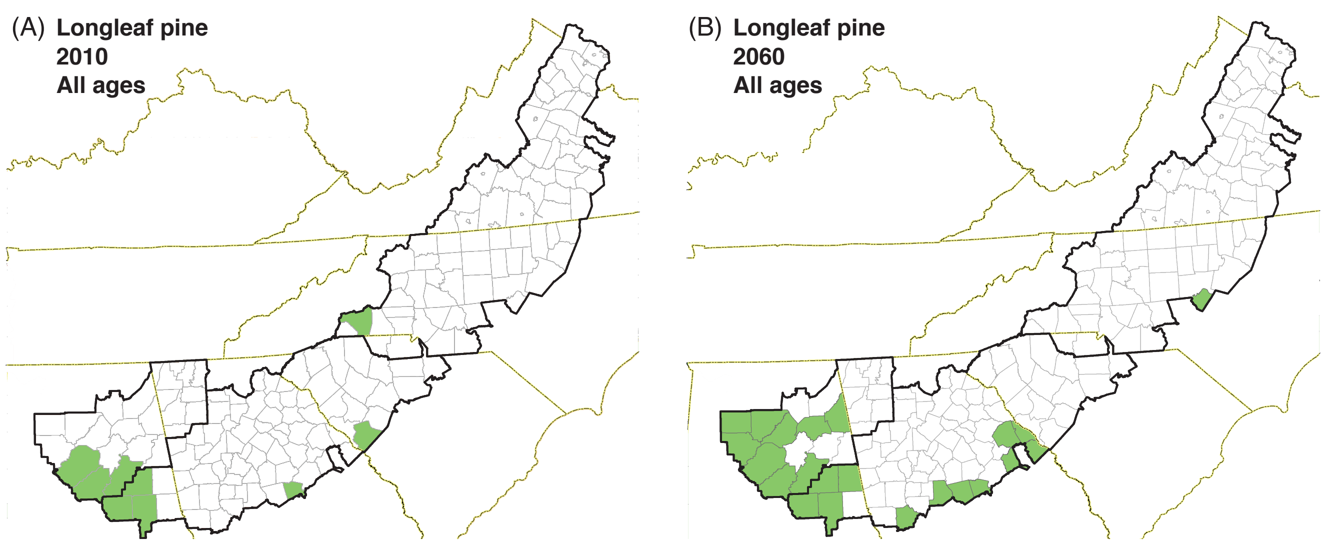


Figure 25—Longleaf pine distribution (all ages) in the three sections—Central Appalachian Piedmont, Southern Appalachian Piedmont, and Piedmont Ridge, Valley, and Plateau—of the Southern U.S. Piedmont under the high-urbanization/high-timber-prices forecast of Cornerstone A in (A) 2010 and (B) predicted for 2060; each of the six Cornerstone Futures represents a combination of two emission scenarios (A1B representing low-population/high-economic growth, high energy use; B2 representing moderate growth and use), high-low timber prices, and increased-decreased tree planting [Source: Wear and others 2013a].

longleaf pine occurs in one county in the Central section (Rutherford County in North Carolina), five counties in the Southern section (Edgefield County in South Carolina; Baldwin County in Georgia; and Coosa, Clay, and Tallapoosa Counties in Alabama), and three counties in the Ridge and Valley section (Jefferson, Shelby, and Talladega Counties in Alabama).

Figure 25B displays the forecast of longleaf pine distribution in the Piedmont as predicted for 2060. Overall, the range of longleaf pine is expected to expand, although where it occurs will likely change (fig. 26). The Central section will likely maintain one North Carolina county with longleaf pine, albeit through a 1 to 50 percent expansion in Lee County and the complete loss of the species in Rutherford County. In the Southern section, Edgefield County in South Carolina is expected to lose all longleaf pine, Clay County Alabama is expected to lose 51 to 99 percent, and Coosa County and Tallapoosa County in Alabama are expected to lose 1 to 50 percent; an offsetting 1 to 50 percent increase is expected for eight counties in Georgia and one in Alabama (Randolph County). In the Ridge and Valley section, Shelby County in Alabama is expected to lose 51 to 99 percent of its longleaf pine; however, in Alabama, longleaf is expect to expand by 1 to 50 percent in seven counties and >100 percent in Jefferson County. Although six counties in the Piedmont will likely lose longleaf pine (with two losing 100 percent), three counties will likely increase their longleaf acreage and longleaf will likely migrate into 15 counties, thus increasing the range of upland longleaf pine in the Piedmont. This shift in the range of longleaf pine may be a result of where urbanization will increase across the Piedmont subregion.

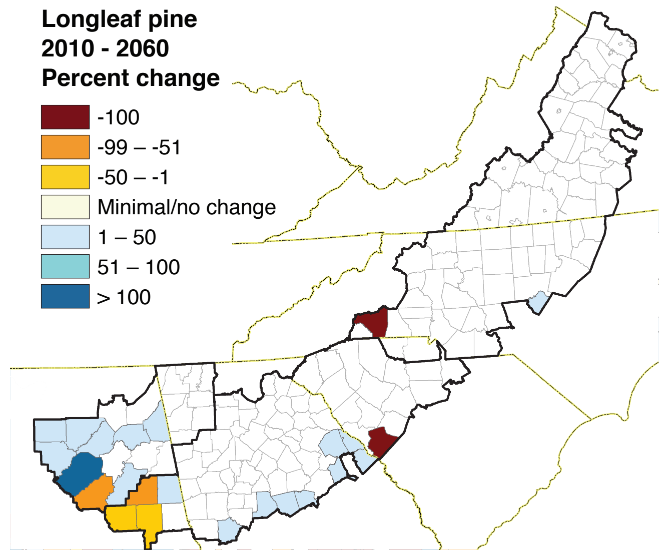


Figure 26—Predicted change, 2010 to 2060, in longleaf pine distribution (all ages) in the three sections (Central Appalachian Piedmont, Southern Appalachian Piedmont, and Piedmont Ridge, Valley, and Plateau) of the Southern U.S. Piedmont under the high-urbanization/high-timber-prices forecast of Cornerstone A; each of the six Cornerstone Futures represents a combination of two emission scenarios (A1B representing low-population/ high-economic growth, high energy use; B2 representing moderate growth and use), high-low timber prices, and increased-decreased tree planting [Source: Wear and others 2013 a].

CHAPTER 6.
Nonnative Invasive Plants

Miller and others (2013) described the nonnative plants of the South, how they were introduced into the United States, their vectors for spread, possible impacts, how to treat them, and methodology for analysis and data sources. The purpose of this report is to discuss the invasive plants currently occupying the Piedmont, the expected spread of the top five invasive species based on the Cornerstone Futures, and the positive actions that could slow the expected spread. Survey data from the U.S Forest Service, Forest Inventory and Analysis program, were used to display current occupation (as of 2010) by county and State. A caveat with the use of this approach is that the data presented in this report are based solely on forested plots and may not give the complete picture of infestation. Nonforested areas were not surveyed for invasive plants by any agency, although nonforested areas are shown in model projected maps.

In the Piedmont, most counties have survey plots that are occupied by 1 to 4 invasive species (table 10, fig. 27)—a legacy of Federal and State efforts to correct the disruprive land uses of the early 20th century. From the 1920s through the 1960s, Federal programs encouraged the planting of invasive species on erodible and eroding soils on the over-farmed lands in the Southern section of northern Georgia. The abundance of invasive plants in South Carolina stems from a long-standing State tradition of producing, promoting, and planting them for soil stabilization and wildlife habitat improvement (Miller and others 2013).

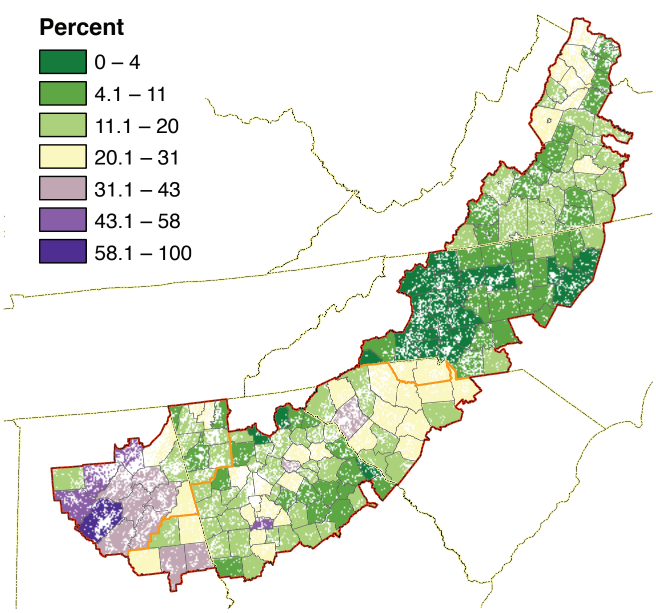


Figure 27—Southern U.S. Piedmont counties with survey plots occupied by one-to-four nonnative invasive plants, 2010 (Source: Forest Inventory and Analysis, Southern Research Station, U.S. Forest Service).

In the Central section, 19 counties (all in North Carolina) have ≤4 percent of survey plots occupied by 1 to 4 invasive species, 27 counties have 4.1 to 11 percent, 20 counties have 11.1 to 20 percent, and nine counties have 20.1 to 31 percent. In the Southern section, three counties have ≤4 percent of survey plots occupied by 1 to 4 invasive species, 14 counties have 4.1 to 11 percent, 33 counties have 11.1 to 20 percent, 22 counties have 20.1 to 31 percent, four counties have 31.1 to 43 percent, and one county has 43.1 to 58 percent. The Ridge and Valley section is the most heavily infested section of the Piedmont; it has no counties with ≤4 percent of survey plots occupied with 1 to 4 invasive species. Three counties have 4.1 to 11 percent of survey plots occupied, seven counties have 11.1 to 20 percent, four counties have 20.1 to 31 percent, six counties have 31.1 to 43 percent, three counties have 43.1 to 58 percent of survey plots occupied, and one county (Jefferson County in Alabama) has 58.1 to 100 percent. Counties with the highest occupations occur in the long inhabited and highly disturbed mining regions of north central Alabama.

Of the >380 recognized invasive plants that occupy the South, the following species are the most prevalent in the Piedmont. Plant detection is based on survey plot data within counties, but that does not preclude the possibility that these plants may be found outside the survey plots.

TREES

Tallowtree

Tallowtree (*Triadica sebifera*) has the highest occupation of any nonnative tree in the South, where it mostly occurs in the Coastal Plain. However, it has started creeping into the Piedmont, where it has been detected (<1,000 acres) in one county (Union County in North Carolina) in the Central section. As of 2010, it had not been detected in any other county within survey plots.

Tree-of-Heaven

Although tree-of-heaven or ailanthus (*Ailanthus altissima*) is most abundant outside the Piedmont (Nashville in the Cumberland Plateau of Tennessee), a secondary infestation occurs along the Shenandoah Valley in Virginia where the Piedmont meets the Northern Ridge and Valley section of the Appalachian-Cumberland highlands (fig. 28). That area of the Central section has the most acres with tree-of-heaven (1,000 to 10,000). The Central section as a whole has the highest occupation of tree-of-heaven, with four counties having 5,000 to 10,000 acres, 16 counties having 1,000 to 5,000 acres, 35 counties having <1,000 acres, and only 21 counties having no acres. The Southern section has two counties with 1,000 to 5,000 acres occupied, seven counties with <1,000 acres, and 68 counties with no acres. The Ridge and Valley section has four counties with <1,000 acres occupied and 20 counties with no acres.

Chinaberrytree

Chinaberrytree (*Melia azedarach*) has the highest occupation across the Coastal Plain with scattered outliers elsewhere in the South (fig. 28). In the Piedmont, chinaberry has been detected in only two counties (<1,000 acres) in the Central section. In the Southern section, one county has 1,000 to 5,000 acres occupied, 20 counties have <1,000 acres, and 56 counties have no acres. Most of the detections in the Southern section have been along the border with the Coastal Plain. In the Ridge and Valley section, only two counties have <1,000 acres occupied; the remaining 22 counties have no acres.

Silktree

Silktree or mimosa (*Albizia julbrissin*) is found scattered throughout the Piedmont, mostly along highways. In the Central section, 15 counties have <1,000 acres occupied and 61 counties have no acres. In the Southern section, two counties have 1,000 to 5,000 acres occupied, 33 counties have <1,000 acres, and 42 counties have no acres. In the Ridge and Valley section, the heaviest infestations are found around Birmingham with two counties having 5,000 to 10,000 acres occupied and three counties having 1,000 to 5,000 acres. Fourteen counties in the Ridge and Valley section have <1,000 acres occupied and only five counties have no acres (fig. 28).

Princesstree

Princesstree or paulownia (*Paulownia tomentosa*) occurs as scattered forest infestations in all States except Texas. As shown in figure 28, heaviest infestations occur around cities with numerous ornamental plantings in Tennessee (Lexington-Lynchburg), North Carolina (Forest City), Alabama (Florence and Tuscaloosa), Mississippi (Vicksburg), and Virginia (Richmond and Charlottesville). In the Central section, three counties have 1,000 to 5,000 acres occupied (especially around Forest City, Richmond, and Charlottesville), 17 counties have <1,000 acres, and 56 counties have no acres. The Southern section has 11 counties with <1,000 acres occupied and 66 counties with no acres. The Ridge and Valley section has one county with 1,000 to 5,000 acres occupied (around Birmingham), four counties with <1,000 acres, and 19 counties with no acres.

SHRUBS

Invasive Privets

At least eight species of invasive privets (*Ligustrum* spp.) are found throughout the Piedmont (fig. 29A). In the Central section, two southeastern counties have 10,000 to 50,000 acres occupied, 11 counties have 5,000 to 10,000 acres, 29 counties have 1,000 to 5,000 acres, 31 counties have <1,000 acres, and three counties have no acres. Privet has been detected in all survey plots in the Southern section: 14 counties have 10,000 to 50,000 acres occupied, 26 counties have 5,000 to 10,000 acres, 26 counties have 1,000 to 5,000 acres, and 11 counties have <1,000 acres. The largest infestation of privet occurs in the Ridge and Valley section, with one county (Jefferson County in Alabama) around Birmingham having 50,000 to 100,000 acres occupied, 12 counties having 10,000 to 50,000 acres, four counties having 5,000 to 10,000 acres, five counties having 1,000 to 5,000 acres, and two counties having <1,000 acres.

Invasive Roses

More than 21 nonnative roses (*Rosa* spp.) are invading ecosystems in the South, and one of them—multiflora rose (*R. multiflora*)—is the most pervasive in the Eastern United States (Miller and others 2013). Nonnative roses are found in most States in the South, but the heaviest infestations are in Kentucky and Virginia throughout the Cumberland Plateau and Appalachian Mountains. In the Piedmont, nonnative roses are most prevalent in the Central section, where two counties have 5,000 to 10,000 acres occupied, 34 counties have 1,000 to 5,000 acres, 37 counties have <1,000 acres, and only three counties have no acres (fig. 29B). The Southern section has four counties having 1,000 to 5,000 acres occupied, 37 counties having <1,000 acres, and 36 counties having no acres. The Ridge and Valley section has two counties having 1,000 to 5,000 acres occupied, nine counties having <1,000 acres, and 13 counties with no acres.

Bush Honeysuckles

At least six species of invasive bush honeysuckles (*Lonicera* spp.) have been introduced into the United States; they form solid understory infestations in central Kentucky, Tennessee, and Virginia as well as across the Midwest and Northeast

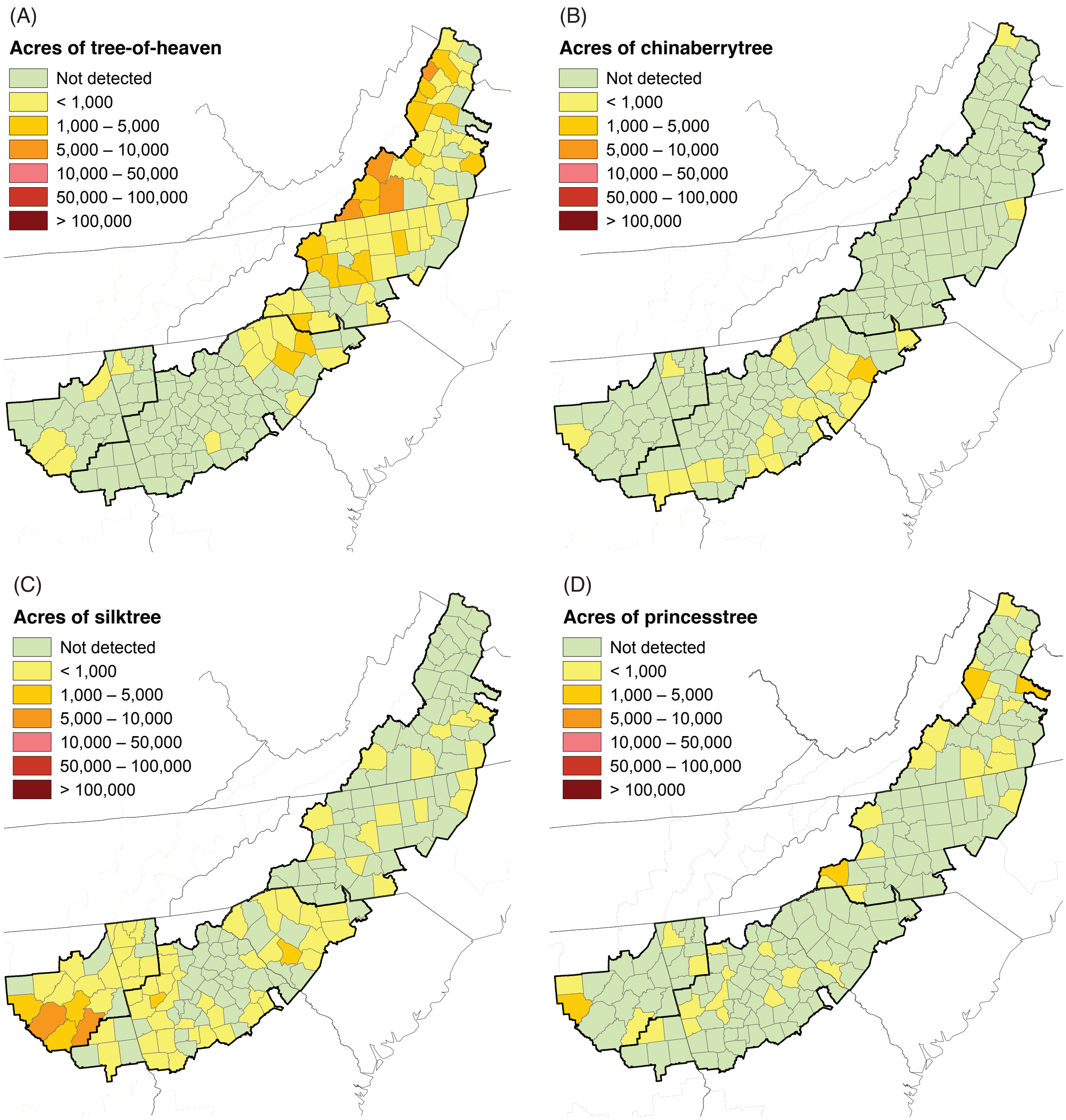


Figure 28—Current cover, 2010, of four nonnative invasive trees in the Southern U.S. Piedmont: (A) tree-of-heaven, (B) chinaberry (C) silktree, and (D) princesstree (Source: Forest Inventory and Analysis, Southern Research Station, U.S. Forest Service).

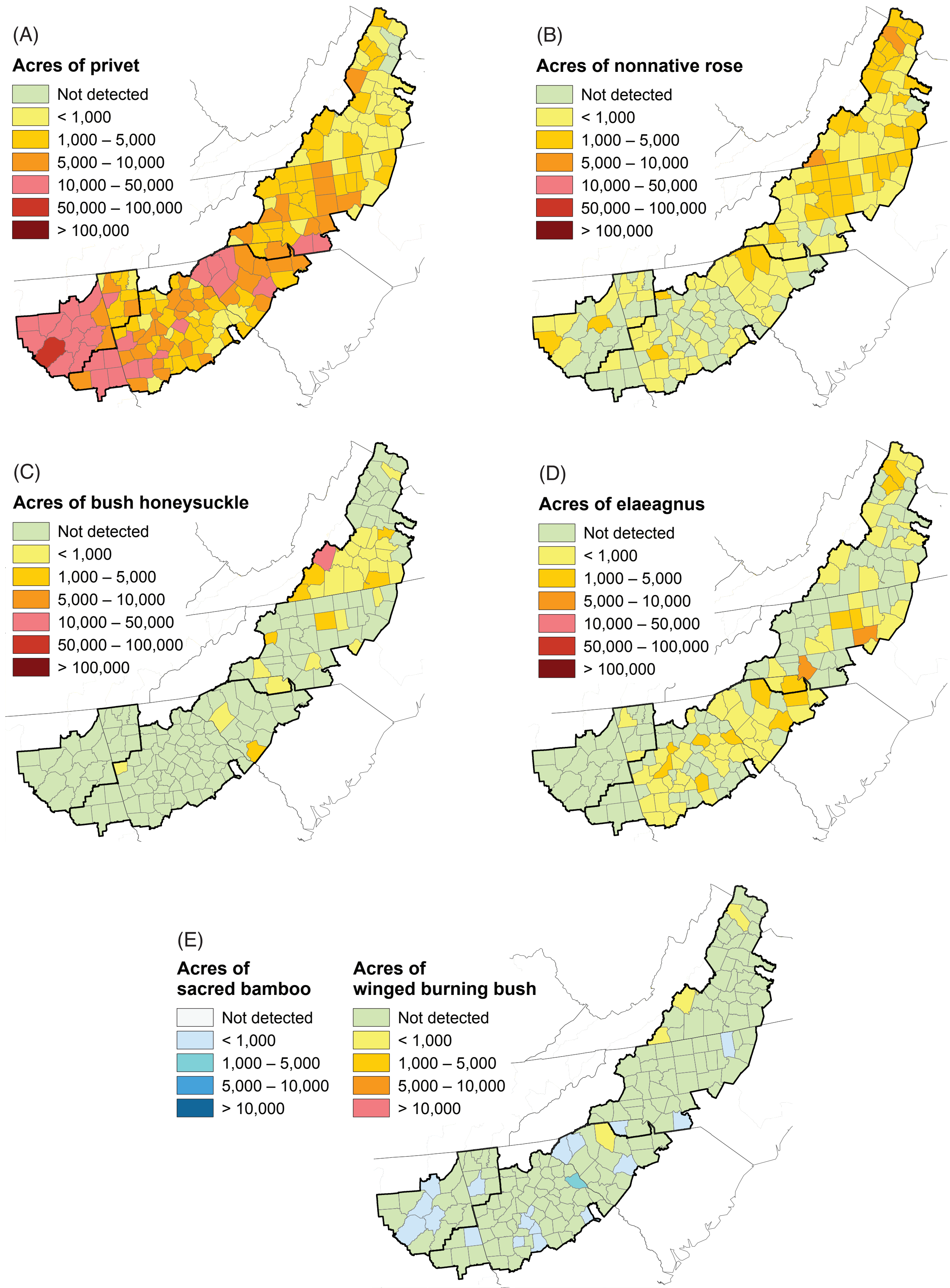


Figure 29—Current cover, 2010, of six nonnative invasive shrubs in the Southern U.S. Piedmont: (A) privets; (B) roses; (C) bush honeysuckles; (D) autumn olive, silverthorn, and Russian olive; and (E) sacred bamboo and winged burning bush (Source: Forest Inventory and Analysis, Southern Research Station, U.S. Forest Service).

(Miller and others 2013). Although bush honeysuckle infestations have been reported in southern Georgia and as far west as Houston, the highest levels are in the Cumberland Plateau and Mountains, the Interior Low Plateau, and Central sections of the Appalachian-Cumberland highlands (Miller and others 2013). In the Central section, one county (Bedford County in Virginia) has 10,000 to 50,000 acres occupied, six counties have 1,000 to 5,000 acres, 20 counties have <1,000 acres, and 49 counties have no acres (fig. 29C); the heaviest infestations are in southern Virginia. In the Southern section, only one county (Edgefield County in South Carolina) has 1,000 to 5,000 acres occupied, two counties have <1,000 acres, and 74 counties have no acres. No plants have been detected in the Ridge and Valley section.

Invasive Elaeagnus

Autumn olive (*Elaeagnus umbellata*), silverthorn or thorny olive (*Elaeagnus pungens*), and the infrequently occurring Russian olive (*Elaeagnus angustifolia*) occur in all sections of the Piedmont (fig. 29D). In the Central section, four counties have 5,000 to 10,000 acres occupied, three counties have 1,000 to 5,000 acres, 24 counties have <1,000 acres, and 45 counties have no acres. The Southern section has seven counties with 1,000 to 5,000 acres occupied, 35 counties with <1,000 acres, and 35 counties with no acres; this is the highest occurrence of elaeagnus in the South—the legacy of government nurseries that once supplied it for wildlife plantings (Miller and others 2013). In the Ridge and Valley section, two counties have <1,000 acres occupied and 22 counties have no acres.

Sacred Bamboo

In the South, sacred bamboo or nandina (*Nandina domestica*) has widely escaped to varying degrees in all States except Virginia and Kentucky (Miller and others 2013). In the Central section, three counties have <1,000 acres occupied, all in North Carolina (fig. 29E); the remaining 73 counties have no acres. In the Southern section, one county (Elbert County in Georgia) has 1,000 to 5,000 acres occupied, 10 counties have <1,000 acres, and 66 counties have no acres. In the Ridge and Valley section, five counties have <1,000 acres occupied and 19 counties have no acres.

Winged Burning Bush

Winged burning bush (*Euonymus alatus*) infestations are concentrated in central Kentucky and along the Shenandoah Valley in Virginia. In the Piedmont, winged burning bush has only been detected, with <1,000 acres occupied, in three counties in the Central section and one county (Spartanburg County in South Carolina) in the Southern section. Otherwise, all counties in all sections have no detection of winged burning bush (fig. 29E).

VINES

Japanese Honeysuckle

Japanese honeysuckle (*Lonicera japonica*) is considered to be the most rampant invasive species in the South, threatening forests in all States (Miller and others 2013). It infests all counties in the Piedmont to some degree. In the Central section, 54 counties have 10,000 to 50,000 acres occupied, 18 counties have 5,000 to 10,000 acres, and four counties have 1,000 to 5,000 acres. In the Southern section, five counties (three in South Carolina and two in Alabama) have 50,000 to 100,000 acres occupied, 34 counties have 10,000 to 50,000 acres, 16 counties have 5,000 to 10,000 acres, 20 counties have 1,000 to 5,000 acres, and only two counties have <1,000 acres. In the Ridge and Valley section, five counties have 50,000 to 100,000 acres occupied, 12 counties have 10,000 to 50,000 acres, six counties have 5,000 to 10,000 acres, and only one county has <1,000 acres; the highest levels of occupation of Japanese honeysuckle in the whole South are located in east central Alabama (fig. 30A).

Kudzu

Kudzu (*Pueraria montana*) is one of the most notorious of southern invasive plants (Miller and others 2013). Though kudzu occurs throughout the South, infestations are most numerous in Mississippi and Alabama; these States once promoted the use of this species and even provided incentive funds for planting (Miller and others 2013). In the Piedmont, heavier infestations occur in the Southern and Ridge and Valley sections. In the Central section, four counties have 1,000 to 5,000 acres occupied, seven counties have <1,000 acres, and 65 counties have no acres. In the Southern section, two counties (Tallapoosa County and Chambers County in Alabama) have 5,000 to 10,000 acres occupied, 11 counties have 1,000 to 5,000 acres, 16 counties have <1,000 acres, and 48 counties have no acres. In the Ridge and Valley section, one county (Jefferson County in Alabama) has 5,000 to 10,000 acres occupied, five counties have 1,000 to 5,000 acres, nine counties have <1,000 acres, and nine counties have no acres (fig. 30B).

Invasive Wisterias

Invasive wisterias (*Wisteria* spp.) occur in scattered dense infestations throughout the South, most of which are in the Coastal Plain and Piedmont. In the Piedmont, invasive wisterias are very localized and scattered throughout all sections (fig. 31).

Invasive Ivies

English ivy (*Hedera helix*), Atlantic Ivy or Irish ivy (*Hedera hibernica*), and colchis or Persian ivy (*Hedera colchica*) occur in scattered infestations in the Coastal Plain and Piedmont. In the Piedmont, invasive ivies are very localized and scattered throughout all sections (fig. 31).

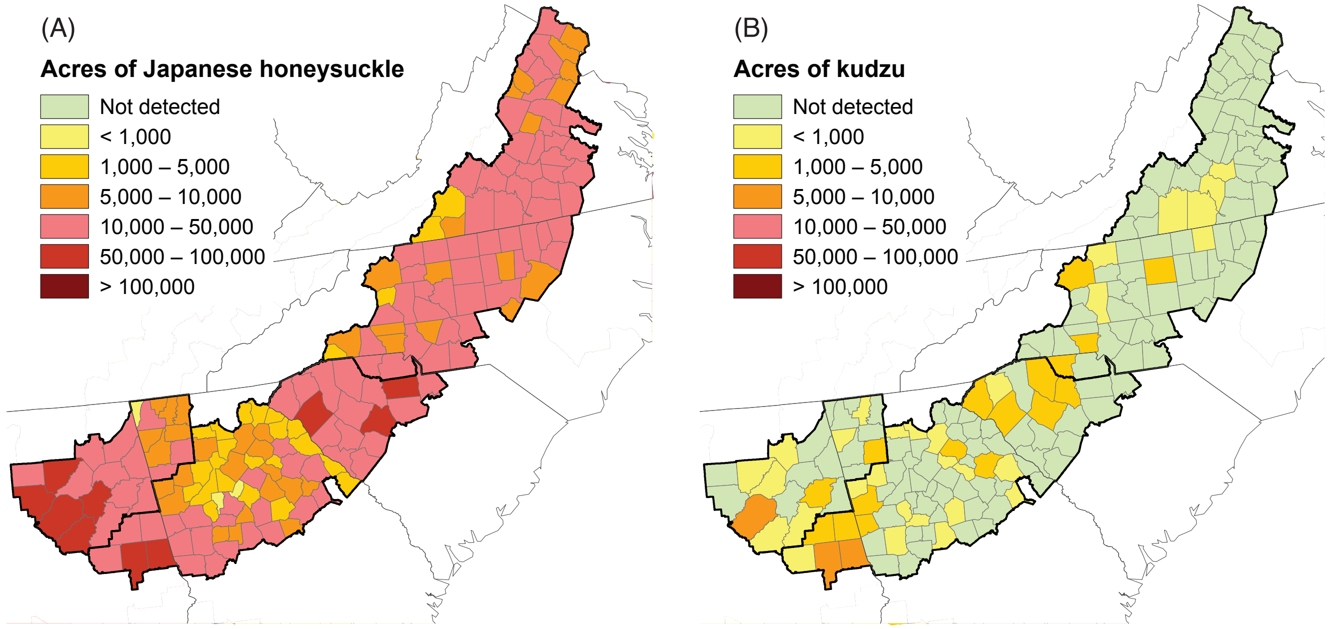


Figure 30—Current cover, 2010, of two nonnative invasive vines in the Southern U.S. Piedmont: (A) Japanese honeysuckle and (B) kudzu (Source: Forest Inventory and Analysis, Southern Research Station, U.S. Forest Service).

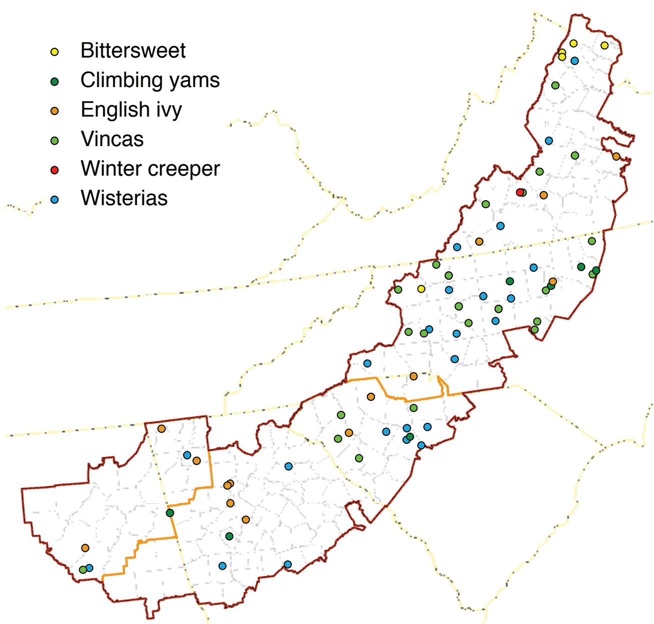


Figure 31—Current incidence, 2010, of Oriental bittersweet, invasive wisterias, periwinkles, invasive ivies, winter creeper, and invasive climbing yams in the Southern U.S. Piedmont (Source: Forest Inventory and Analysis, Southern Research Station, U.S. Forest Service).

Vincas, Periwinkles

Periwinkles (*Vinca* spp.) occur as scattered infestations that vary across the South, with the highest concentrations in Virginia, Kentucky, North Carolina, and Mississippi. In the Piedmont (fig. 31), invasive vincas are localized and scattered throughout the Central section where it occurs most often, in the Southern section where it occurs in South Carolina, and in the Ridge and Valley section where it occurs in one county (Shelby County in Alabama).

Invasive Climbing Yams

One species of nonnative climbing yam, Chinese yam or cinnamon vine (*Dioscorea oppositifolia*), is invading southern forests from the north, and two others—air yam (*Dioscorea bulbifera*) and water yam (*Dioscorea alata*)—are moving northward from the Coastal Plain and Florida (Miller and others 2013). Chinese yams are found scattered throughout the South with the most common infestations occurring in western Tennessee and the less common ones in Virginia; air and water yams occur along the Gulf of Mexico and throughout Florida (Miller and others 2013). In the Piedmont (fig. 31), climbing yams are scattered in North Carolina (Central section); in Newberry County in South Carolina and Fayette County in Georgia (Southern section); and on the boundary between Alabama and Georgia (Ridge and Valley section).

Winter Creeper

Winter creeper or climbing euonymus (*Euonymus fortunei*) has been detected mainly in the Cumberland Plateau in Kentucky and Tennessee. Piedmont detection (fig. 31) has been limited to the Central section, with only one occurrence in one county (Campbell County in Virginia).

Oriental Bittersweet

Oriental bittersweet (*Celastrus orbiculatus*) forms thickets and infestations on disturbed sites, mainly in the Southern Appalachian Mountains (Miller and others 2013). At present, escaped oriental bittersweet can only be found around small towns and cities in North Carolina and Virginia, with outliers in Mississippi. In the Piedmont (fig. 31), it only occurs in a few northern Virginia counties (Central section).

GRASSES

Nepalese Browntop

Nepalese browntop or Japanese stiltgrass (*Microstegium vimineum*) is the most widely distributed invasive grass in eastern U.S. forests, and scattered infestations emigrating from the Northeast have begun to appear in every State across the South (Duerr and Mistretta 2013) with heavier infestations in the Appalachian-Cumberland highlands and all sections of the Piedmont.

In the Central section of the Piedmont, two counties have >10,000 acres occupied, nine counties have 5,000 to 10,000 acres, 24 counties have 1,000 to 5,000 acres, 23 counties have <1,000 acres, and 18 counties have no acres. In the Southern section, one county (Newberry County in South Carolina) has >10,000 acres occupied, five counties have 5,000 to 10,000 acres, 20 counties have 1,000 to 5,000 acres, 23 counties have <1,000 acres, and 28 counties (mostly in Georgia) have no acres. In the Ridge and Valley section, four counties have 1,000 to 5,000 acres occupied, nine counties have <1,000 acres, and 11 counties have no acres (fig. 32A).

Tall Fescue

Because tall fescue (*Schedonorus phoenix*) is a cool season grass, infestations are most severe in the forests of Kentucky, Virginia, and central Tennessee. Satellite populations are present throughout much of the South, with most congregated in the Coastal Plain of Mississippi and the Piedmont of South Carolina (Miller and others 2013).

In the Central section of the Piedmont, two counties have 5,000 to 10,000 acres occupied, 15 counties have 1,000 to 5,000 acres, 23 counties have <1,000 acres, and 36 counties (mostly in the southern half of the Central section) have no acres (fig. 32B). In the Southern section, one county (Butts County in Georgia) has 5,000 to 10,000 acres occupied, 14 counties have 1,000 to 5,000 acres, five counties have <1,000 acres, and 57 counties have no acres; the largest infestation occurs in South Carolina. In the Ridge and Valley section, five counties have 1,000 to 5,000 acres occupied, five counties have <1,000 acres, and 14 counties have no acres.

Cogongrass

Cogongrass (*Imperata cylindrica*) is one of the most aggressive, colony-forming invasive grasses in the South, occurring in eight States along the Gulf of Mexico. The epicenter of cogongrass infestations remains near the point of initial introductions in coastal Alabama and nearby Mississippi with another in central Florida (Miller and others 2013). In the Piedmont, cogongrass has only been detected (<1,000 acres) in one county (Clay County in Alabama) in the southern portion of the Southern section (fig. 32A).

Golden and Other Invasive Bamboos

Nonnative bamboos (*Phyllostachys* spp. and *Bambusa* spp.) form dense stands that are scattered throughout the South, with golden bamboo being the most widely occurring species. In the Piedmont, one county (Wake County in North Carolina) in the Central section and one county (Spalding County in Georgia) in the Southern section have 1,000 to 5,000 acres occupied; two counties (Cleveland County and Gaston County in North Carolina) in the Central section, one county (Haralson County in Georgia) in the Southern section, and one county (Etowah County in Alabama) in the Ridge and Valley section have <1,000 acres occupied (fig. 32C).

Chinese Silvergrass

A locally invasive plant, Chinese silvergrass (*Miscanthus sinensis*) has only been found in scattered locations with an epicenter in eastern Kentucky (Miller and others 2013). In the Central section of the Piedmont, silvergrass has been detected in one county (Halifax County in Virginia) with <1,000 acres occupied (fig. 32C).

OTHER SPECIES

Invasive Lespedezas

Although invasive lespedezas (*Lespedeza* spp.) occupy all subregions in the South, Chinese lespedeza (*Lespedeza cuneata*) is the most prevalent (Miller and others 2013). In the Central section, three counties have 5,000 to 10,000 acres with invasive lespedezas, 14 counties have 1,000 to 5,000 acres, 28 counties have <1,000 acres, and 31 counties have no acres. In the Southern section, three counties have 10,000 to 50,000 acres occupied (with an epicenter of infestation for the whole South occurring in the Greenville-Spartanburg area in South Carolina), two counties have 5,000 to 10,000 acres, 14 counties have 1,000 to 5,000 acres, 43 counties have <1,000 acres, and 15 counties have no acres. In the Ridge and Valley section, one county has 5,000 to 10,000 acres occupied, five counties have 1,000 to 5,000 acres, nine counties have <1,000 acres, and nine counties have no acres (fig. 33A).

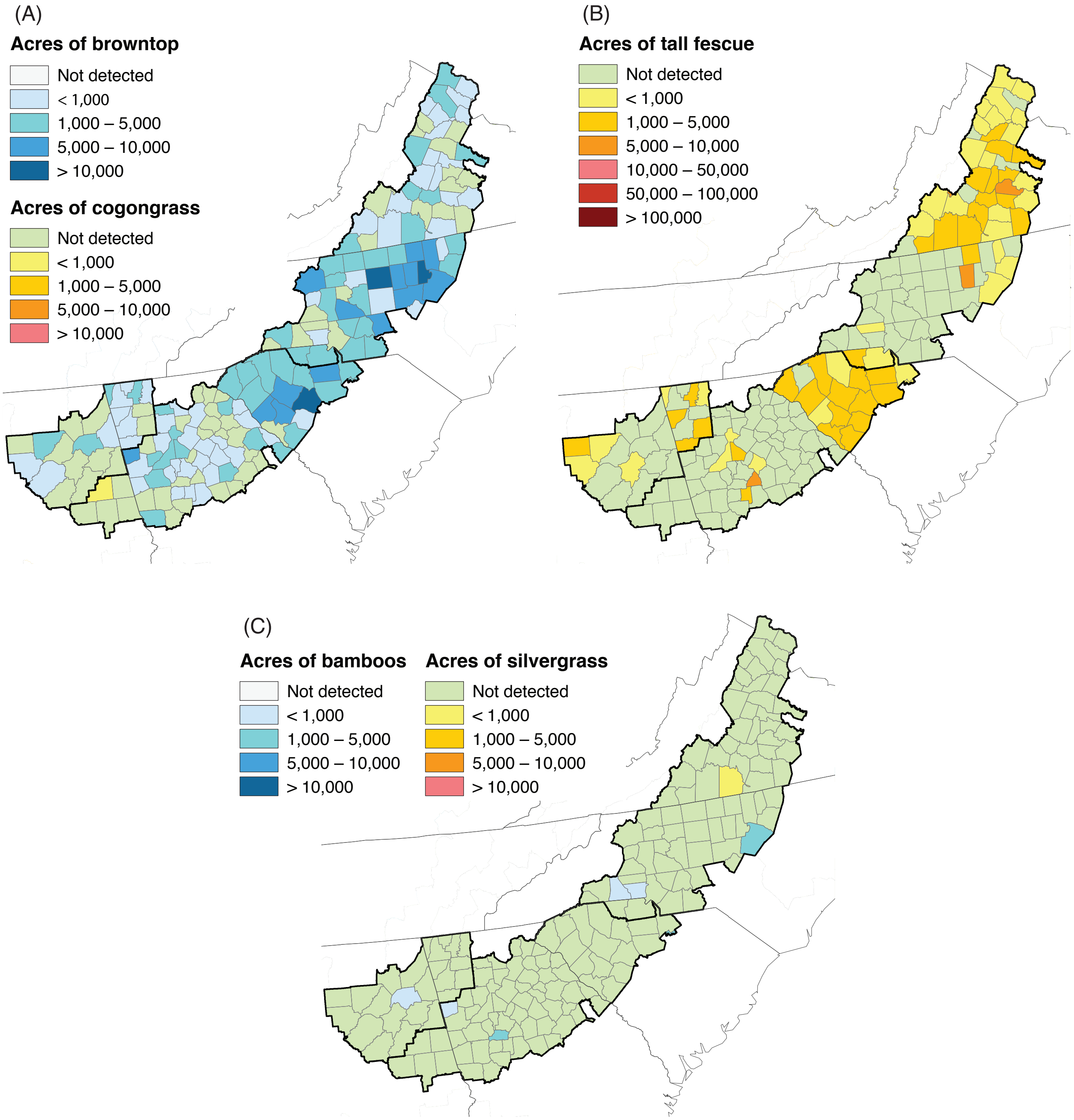


Figure 32—Current cover, 2010, of five nonnative invasive grasses in the Southern U.S. Piedmont (A) Nepalese browntop and congongrass, (B) tall fescue, and (C) bamboo and Chinese silvergrass (Source: Forest Inventory and Analysis, Southern Research Station, U.S. Forest Service).

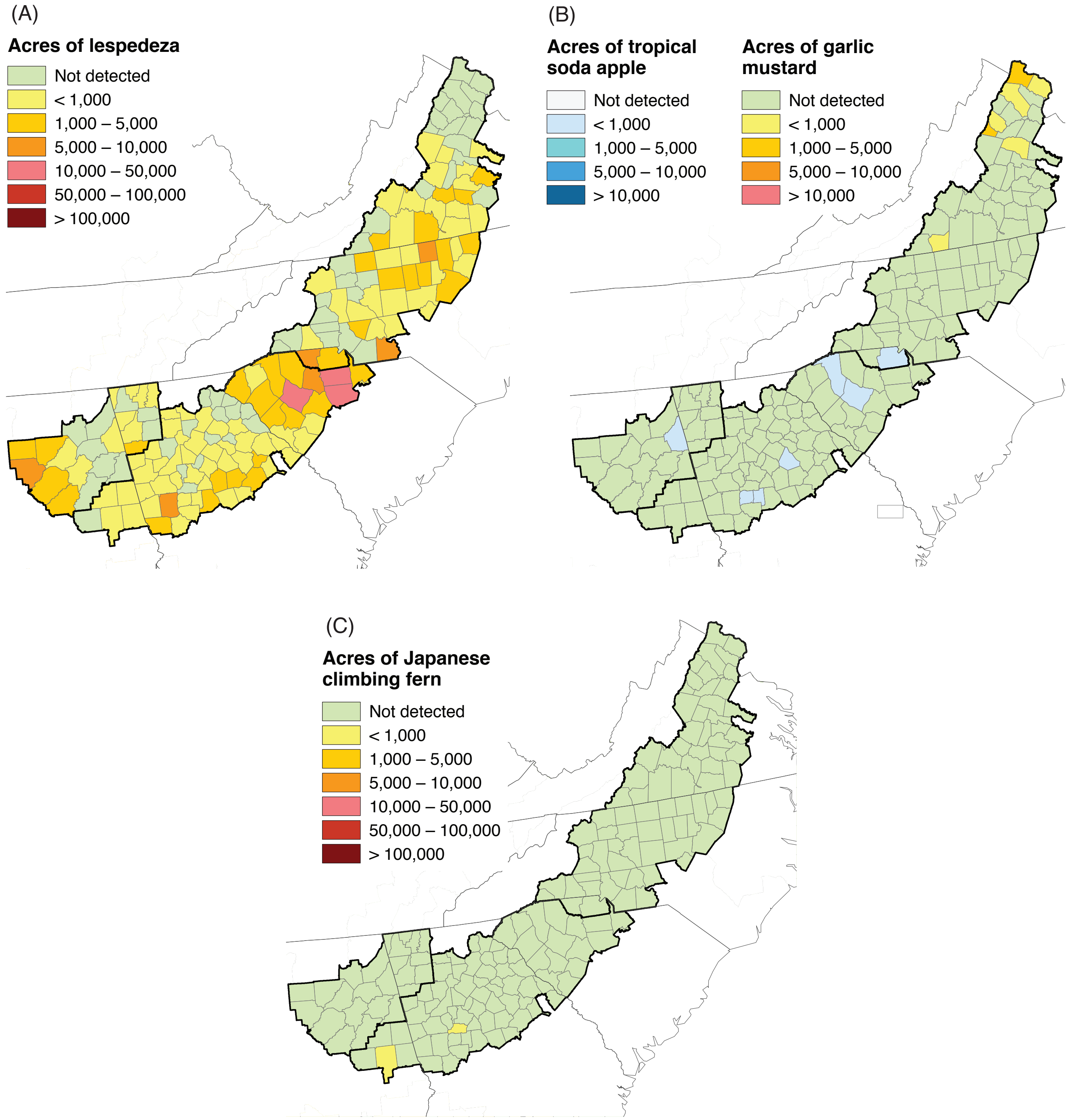


Figure 33—Current cover, 2010, in the Southern U.S. Piedmont for nonnative invasive: (A) lespedezas, (B) tropical soda apple and garlic mustard, and (C) Japanese climbing fern (Source: Forest Inventory and Analysis, Southern Research Station, U.S. Forest Service).

Garlic Mustard

Garlic mustard (*Alliaria petiolata*) occurs in small-to-extensive colonies under forest canopies and along roadsides in the Central Appalachian Mountains and throughout the Northeastern United States (Miller and others 2013). In the Piedmont, two counties (Loudoun County and Madison County in Virginia) have 5,000 to 10,000 acres occupied and six other Virginia counties have <1,000 acres. (fig. 33B).

Tropical Soda Apple

Tropical soda apple (*Solanum viarum*), which has mostly infested the Coastal Plain, has also migrated into the Southern Piedmont (Miller and others 2013). Tropical soda apple has only been detected in one county (York County in South Carolina) in the Central section and one county (Cherokee County in Alabama) in the Ridge and Valley section (fig. 33B). However, plants have been detected in five counties in the Southern section, all with <1,000 acres occupied.

Japanese Climbing Fern

Japanese climbing fern (*Lygodium japonicum*) is rapidly becoming one of the most common invasive plants in coastal areas along the Gulf of Mexico (Miller and others 2013). In the Piedmont, it has only been detected in two counties (Spalding County in Georgia and Tallapoosa County in Alabama) in the southern portion of the Southern section, with <1,000 acres occupied (fig. 33C).

MODEL PREDICTIONS OF CURRENT AND FUTURE POTENTIAL HABITAT

The following is a discussion about five invasive plants of high threat in the South and predictions of their likely spread in the Piedmont over the next 50 years, based on a status quo scenario and the six Cornerstone Futures.

Tallowtree

Under the status quo scenario, the spread of tallowtree across the Piedmont would be low, with some areas of moderate spread (fig. 34) around metropolitan Washington, Atlanta, and Birmingham and around some of the larger cities in Virginia (Richmond), North Carolina (Raleigh-Durham), and South Carolina (Greenville).

Under Cornerstone A (and E), urbanization would increase, and the potential for spreading would become moderate, with further expansion around Atlanta and new infestations around some cities in Georgia (Augusta) and North Carolina (Charlotte and Raleigh). Under Cornerstone B, the potential spread would remain fairly low for most of the Piedmont with less expansion (moderate potential) around Atlanta. Under Cornerstone C, the potential for spreading would be greatest with moderate potential occurring around Washington, Richmond, Raleigh-Durham, Charlotte, Birmingham, and Greenwood, SC; along the I-85 corridor through the upstate of South Carolina to Atlanta; from Atlanta along the I-20 corridor to Augusta; and from Atlanta along the I-75 corridor towards Chattanooga, TN. Under Cornerstone D (and F), forested area would decrease with the growth of metropolitan areas around major cities, but the potential for spread of tallowtree would remain low.

Silktree

Under the status quo scenario, the potential spread of silktree would be mixed, with high potential occurring around cities and along roads and low potential in the forested areas that separate high potential areas (fig. 35).

Under Cornerstone A (and E), although urbanization would increase, the potential spread of silktree would decrease somewhat (from high towards moderate) around cities and road corridors. The forests that separate high or moderate areas would still have low potential for invasion. Under Cornerstone B, the potential for spread would be similar to Cornerstone A (and E), the exception being Birmingham (Ridge and Valley section) where the potential would be more moderate; the potential would still be low in the forests that separate high and moderate areas. Under Cornerstone C, the potential for spread would be high along road networks, and some metropolitan areas (Atlanta, Charlotte, Durham, and Richmond) would have more moderate potential spread; again, forested areas that separate cities would have low potential for spread. Finally, Cornerstone D (and F) would be similar to Cornerstone C, with even higher potential for spread along road corridors and metropolitan areas.

Nonnative Roses

Under the status quo scenario, the potential invasion of nonnative roses is mostly high in the Central section, with moderate potential in a few scattered areas and low potential in the southeastern corner (fig. 36). In the Southern section, the potential for spread would be mostly high in upstate South Carolina (with some areas of moderate potential) and mostly moderate in the Atlanta metropolitan area (with some areas of high potential northeast of the city); two thirds of the section, mainly along the border with the Coastal Plain, would have low potential. The Ridge and Valley section would have high potential along its northern border and south of Chattanooga and moderate potential around Birmingham, AL.

Under Cornerstone A (and E), the high potential invasion areas in the Central section would occur in Virginia around Harrisonburg to Charlottesville and in North Carolina around Boone; moderate potential would occur along I-85 between metropolitan Washington and Richmond along I-85 from Charlotte northward to the Virginia State line, up I-77 and

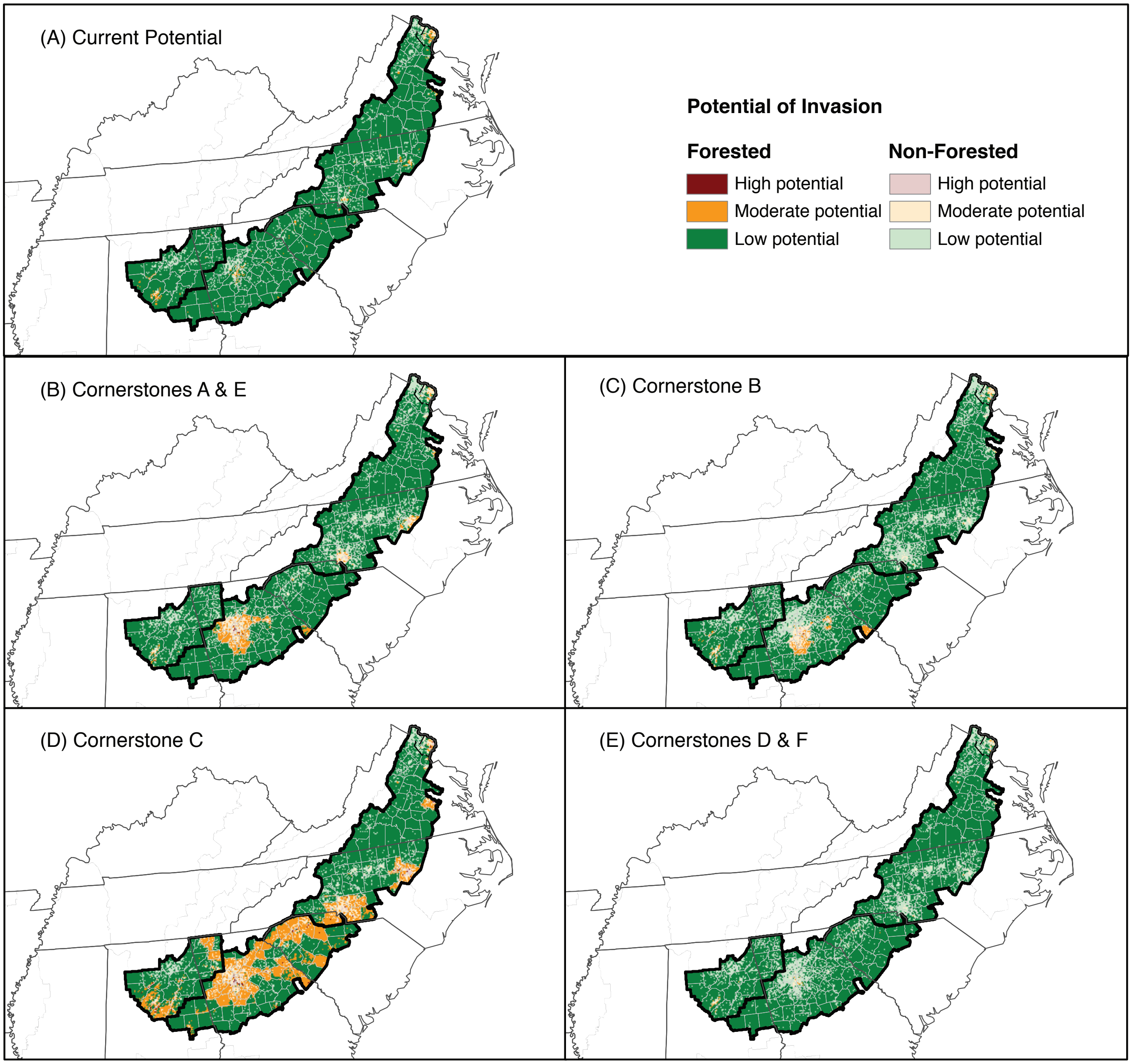


Figure 34—Potential for tallowtree occupation into 2060 assuming (A) continuation of current climate conditions, (B) maximal warming and drying predicted under Cornerstones A and E, (C) moderate warming and minimal drying predicted under Cornerstone B, (D) minimal warming with increased rainfall predicted under Cornerstone C and (E) cooling and drying predicted under Cornerstones D and F; each Cornerstone 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 and E are MIROC3.2 + A1B, B is CSIROMK3.5 + A1B, C is CSIROMK2 + B2, and D and F are HadCM3 + B2 (Source: McNulty and others 2013).

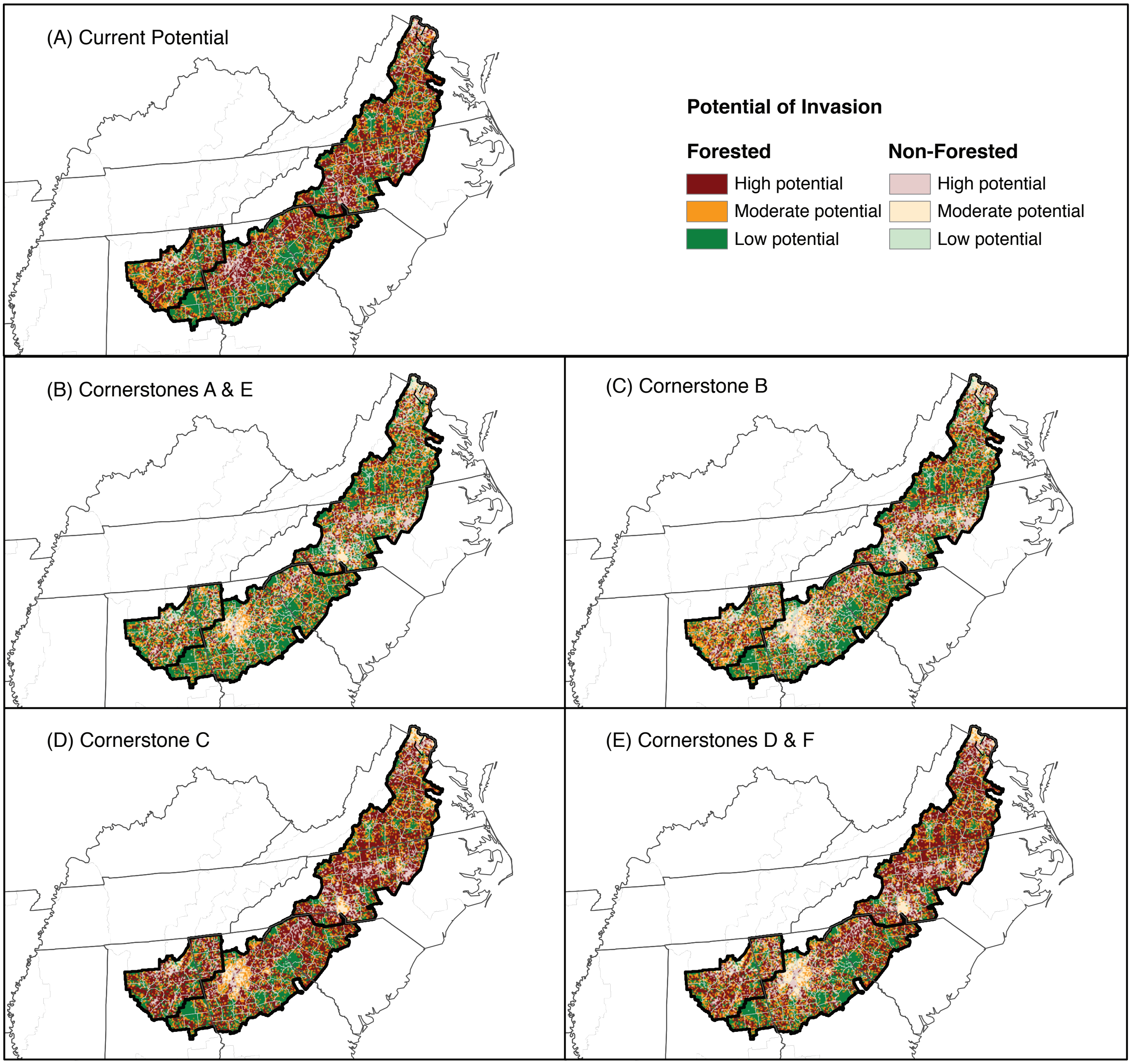


Figure 35—Potential for silktree occupation into 2060 assuming (A) continuation of current climate conditions (B) maximal warming and drying predicted under Cornerstones A and E, (C) moderate warming and minimal drying predicted under Cornerstone B, (D) minimal warming with increased rainfall predicted under Cornerstone C, and (E) minimal warming and drying predicted under Cornerstones D and F; each Cornerstone 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 and E are MIROC3.2 + A1B, B is CSIROMK3.5 + A1B, C is CSIROMK2 + B2, and D and F are HadCM3 + B2 (Source: McNulty and others 2013).

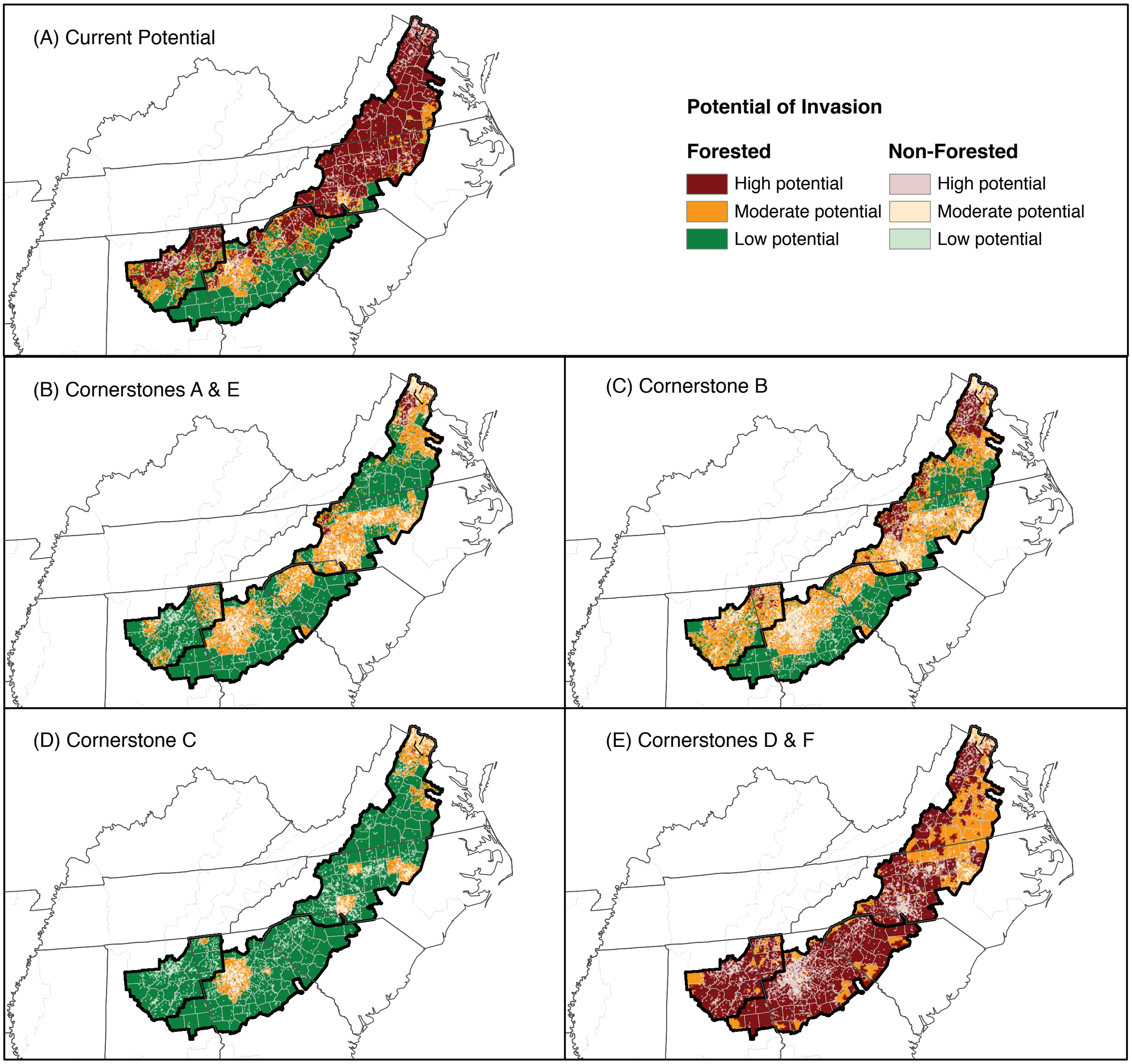


Figure 36—Potential for nonnative invasive rose occupation into 2060 assuming (A) continuation of current climate conditions, (B) maximal warming and drying predicted under Cornerstones A and E, (C) moderate warming and minimal drying predicted under Cornerstone B, (D) minimal warming with increased rainfall predicted under Cornerstone C, and (E) minimal warming and drying predicted under Cornerstones D and F; each Cornerstone 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 and E are MIROC3.2 + A1B, B is CSIROMK3.5 + A1B, C is CSIROMK2 + B2, and D and F are HadCM3 + B2 (Source: McNulty and others 2013).

along I-40 east to Winston-Salem, Greensboro, Durham, and Raleigh. In the Southern section, moderate potential areas of spread would include upstate South Carolina, along I-85 to the Atlanta metropolitan area, and Augusta. In the Ridge and Valley section, moderate potential would occur around Birmingham, the Bankhead National Forest, and along I-75 towards Chattanooga; landscapes that separate the moderate and high potential areas would have low potential. Cornerstone B predicts a higher potential for spread than Cornerstone A (and E), but lower than the status quo scenario. The highest potential would occur on the western border of the Central section. Also, the areas with low potential that separated moderate-potential areas in Cornerstone A (and E) would also have moderate potential, so that the area of moderate potential would extend from Raleigh to Birmingham. Cornerstone C predicts the lowest potential for spread—most of the Piedmont would have a low potential for spread, high potential areas would be extremely limited, and moderate potential areas would occur around Washington and Atlanta as well as the major metropolitan areas in Virginia (Richmond), North Carolina (Raleigh-Durham, Winston-Salem, and Charlotte), and Tennessee (Chattanooga). Cornerstone D (and F) predicts the highest potential for spread. With the exception of the Central section, where the potential would be mostly moderate in its northern half, most of the Piedmont would have a high potential for spread, with only a few scattered areas having a moderate potential.

Japanese Climbing Fern

Under the status quo scenario, the potential for spread of Japanese climbing fern would be low across the Piedmont (fig. 37). Cornerstones A (and E), B, and D (and F) predict outcomes that would be very similar to the status quo scenario, although the amount of forested areas would have been decreased by urban sprawl around major metropolitan areas. Under Cornerstone C, however, the potential for spread would be high around Greenville, SC and Montgomery, AL; the potential would be moderate along the southern edge of the Central section, along the northwestern edge (upstate South Carolina) and in the southwestern corner of the Southern section, and in most of the Ridge and Valley section.

Nepalese Browntop

Under the status quo scenario, the potential of Nepalese browntop to spread would vary by Piedmont section. The potential for spread would be high for most of the Central and Ridge and Valley sections (fig. 38), moderate-to-low in the southeastern tip of the Central section, and mostly moderate with some low-potential areas in the southern edge of the Ridge and Valley section. About two-thirds of the Southern section (bordering the Coastal Plain) would have low potential for spread, but upstate South Carolina and the Atlanta area would have high potential mixed with some areas of moderate potential.

Cornerstone A (and E) predicts considerably lower potential for spread of Nepalese browntop than the status quo scenario. Although most of the Piedmont would have low potential for spread, one hot spot just south of Washington would have high potential and the northern part of Central section would mostly have moderate potential with scattered areas of moderate potential around cities in the other Piedmont sections. Cornerstone B predicts higher potential for spread than Cornerstone A but still lower than the status quo scenario—areas of high potential include Washington and other cities in Virginia (Charlottesville), North Carolina (Boone and Hickory), South Carolina (Greenville-Spartanburg), the area between Atlanta and Chattanooga, and the Alabama area around Anniston and the Talladega National Forest. Cornerstone C predicts the lowest potential for spread of Nepalese browntop, low potential for most of the Piedmont with moderate potential around Atlanta and Birmingham and around the cities in Virginia (Richmond), North Carolina (Raleigh-Durham and Charlotte), and South Carolina (near Greenville). Cornerstone D (and F) predicts the highest potential for spread, high potential for most of the Piedmont, with scattered areas of moderate potential throughout; this would obviously provide the most conducive conditions to increase potential for spread—at the opposite end of the spectrum, Cornerstone C would provide the least conducive conditions for spread.

RESEARCH GAPS

The need for research and action to address many aspects of invasive plants in the southern forests and elsewhere is critical (Miller and others 2013). Specific research gaps include the absence of data on the degree that invasive plants impact tree and stand growth and forest structure for all forest management types. Essentially no data exist about relationships among invasive plants, hydrology, and changes in water quality and quantity in the South. The need is also critical for new approaches to help managers avoid marked and permanent alterations of forested, agricultural, and conservation lands and waters as invasive plants spread outward from urban, suburban, and exurban lands and the rights-of-way that connect them (Miller and others 2013).

Invasive plants thus represent a complex and perplexing societal dilemma, threatening to bequeath degraded ecosystems and ecosystem services to future generations in the absence of more comprehensive awareness, management strategies, coordinated programs, and updated laws. A concerted, holistic effort that integrates science with management in new ways will be required for predicting, managing, and mitigating the spread of invasive species, as will the involvement of a broad segment of southern society in new approaches (Miller and others 2013).

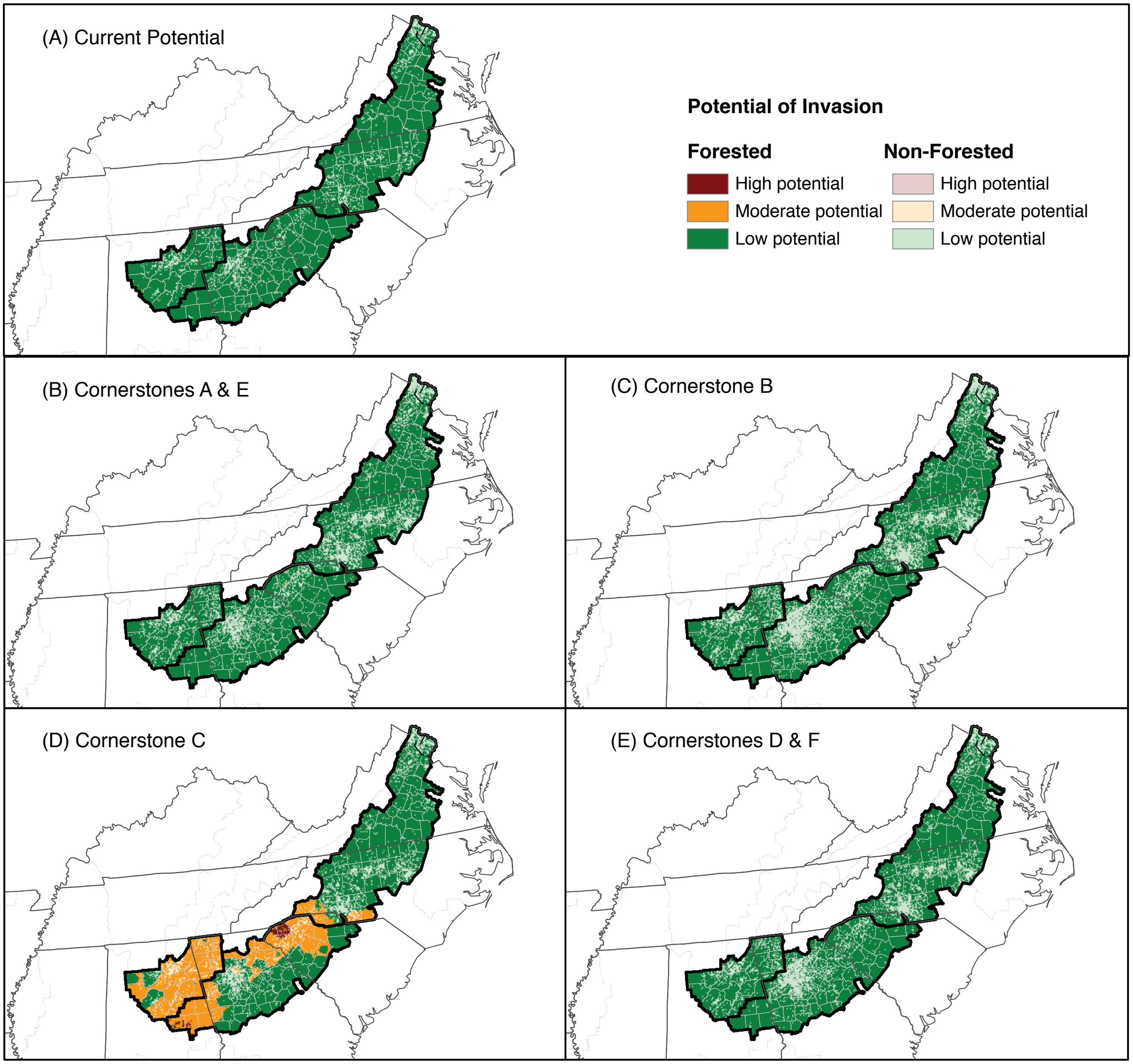


Figure 37—Potential for Japanese climbing fern occupation into 2060 assuming (A) continuation of current climate conditions, (B) maximal warming and drying predicted under Cornerstones A and E, (C) moderate warming and minimal drying predicted under Cornerstone B, (D) minimal warming with increased rainfall predicted under Cornerstone C, and (E) minimal warming and drying predicted under Cornerstones D and F; each Cornerstone 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 and E are MIROC3.2 + A1B, B is CSIROMK3.5 + A1B, C is CSIROMK2 + B2, and D and F are HadCM3 + B2 (Source: McNulty and others 2013).

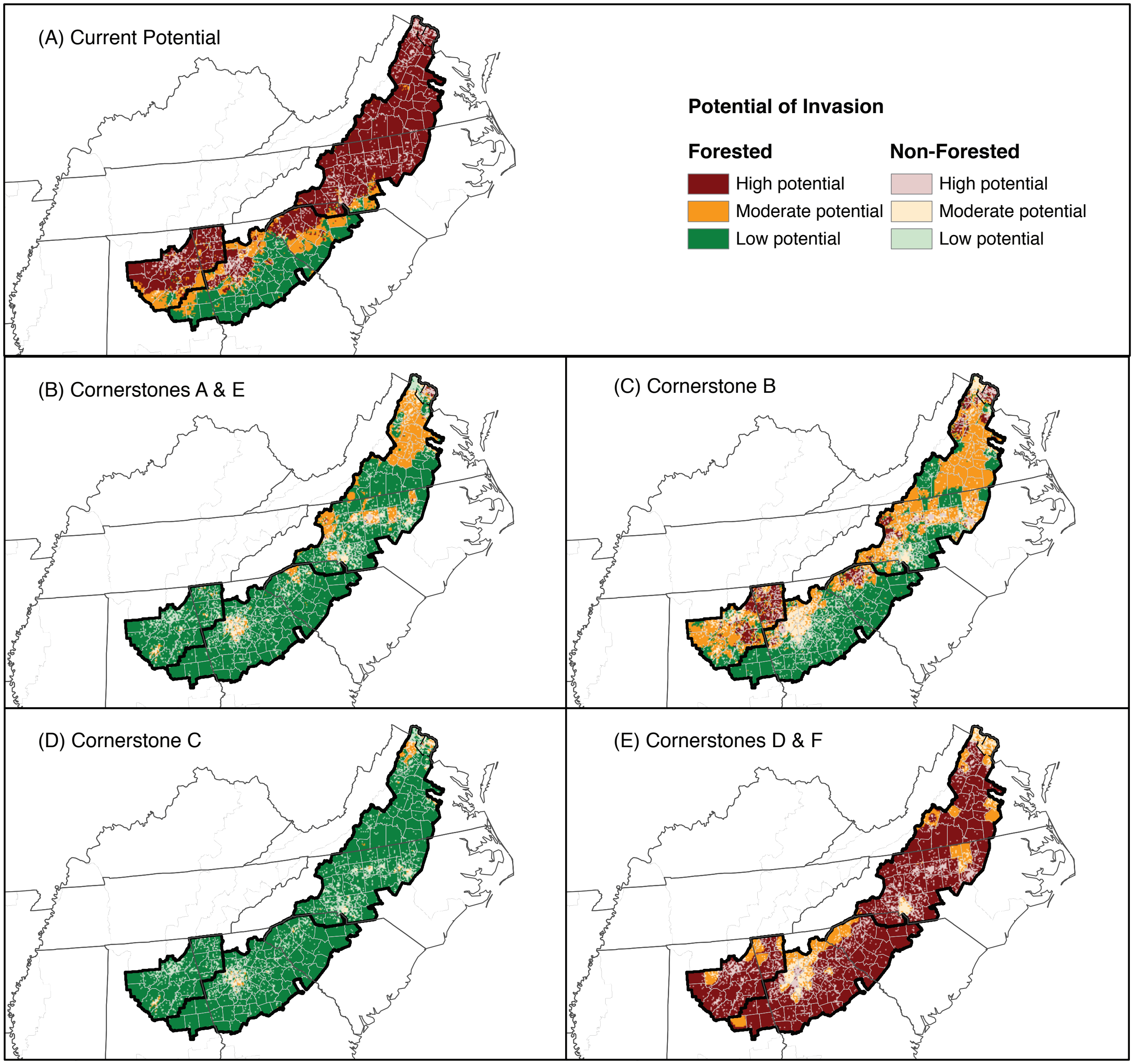


Figure 38—Potential for Nepalese browntop occupation into 2060 assuming (A) continuation of current climate conditions, (B) maximal warming and drying predicted under Cornerstones A and E, (C) moderate warming and minimal drying predicted under Cornerstone B, (D) minimal warming with increased rainfall predicted under Cornerstone C, and (E) minimal warming and drying predicted under Cornerstones D and F; each Cornerstone 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 and E are MIROC3.2 + A1B, B is CSIROMK3.5 + A1B, C is CSIROMK2 + B2, and D and F are HadCM3 + B2 (Source: McNulty and others 2013).

CHAPTER 7.
Insect and Disease Outbreaks

Duerr and Mistretta (2013) described the prevalent insects and diseases of high threat in the South, how they were introduced into the United States, their impacts on the forests, and how best to control them. The purpose of this report is to focus on the insects and diseases that are already affecting, or could affect, forests in the Piedmont (table 11).

SPECIES WITH WIDESPREAD DISTRIBUTION

Southern Pine Beetle

Southern pine beetle (*Dendroctonus frontalis*) is the most destructive insect pest of pine forests in the Piedmont. Southern pine beetle attacks all species of pines, and impacts over the next 50 years are expected to be significant, especially if pine acreage increases in the Piedmont. A warmer, drier climate is likely to increase activity and impacts of southern pine beetles. In addition to the effects that forest composition, temperature, and moisture will have on the outlook for southern pine beetles, forest management is expected to play a defining role. Planting the proper species for a given site and at lower densities and thinning pine stands can increase stand vigor and resiliency and possibly reduce damage from southern pine beetles.

Other Bark Beetles

Bark beetles—the six-spined engraver (*Ips calligraphus*), the southern pine engraver (*Ips grandicollis*), the small southern pine engraver (*Ips avulsus*), and the black turpentine beetle (*Dendructonus terebrans*)—are currently found throughout the Piedmont where pines (particularly loblolly, shortleaf, longleaf, and slash pines) occur. These beetles are usually considered secondary pests because they normally infest only stressed, weakened, damaged, or downed pines. They also colonize pines that have been attacked by southern pine beetles or another bark beetle species. Increased temperature and decreased precipitation would stress pines and could therefore increase the impacts of these bark beetles, but they are unlikely to become primary pests that kill large areas of trees.

Hardwood Borer

Hardwood borers—carpenterworm (*Prionoxystus robiniae*), red oak borer (*Enaphalodes rufulus*), white oak borer (*Goes tigrinus*), redheaded ash borer (*Neoclytus acuminatus*), poplar borer (*Saperda calcarata*), oak timberworm (*Arrhenodes minutus*), Columbian timber beetle (*Corthylus columbianus*), and ambrosia beetle (*Xyleborus celsus*)—are important pests of hardwood trees throughout the Piedmont. Borers that are endemic to an area do not normally cause dieback and mortality, but in abnormally large numbers they contribute to tree decline and stand degradation. Temperature change by itself would be unlikely to have much effect on hardwood borer populations. As secondary insect pests, they are expected to have increased impacts as populations of hardwood age and decline, especially during periods of drought stress. Hardwood borer activity and damage is likely to increase throughout the Piedmont over the next 50 years if current predictions of future climate change prove accurate.

Nantucket Pine Tip Moth

The Nantucket pine tip moth (*Rhyacionia frustrana*) is a common forest insect in the Piedmont. Although most commercial southern pine species are susceptible to attack, they vary considerably in relative susceptibility. Longleaf nursery seedlings and all ages of shortleaf, loblolly, and Virginia pines are highly susceptible, while slash and older longleaf pines are highly resistant. Based on the warmer and possibly drier climate that is expected over the next 50 years, the activity and damage levels of Nantucket pine tip moth are likely to increase in the Piedmont.

Pine Reproduction Weevils

Pine reproduction weevils—pales weevil (*Hylobius pales*), pitch-eating weevil (*Pachylobius picivorus*), and eastern pine weevil (*Pissodes nemorensis*)—are damaging to pine seedlings throughout the Piedmont. Pales and pitch-eating weevils prefer loblolly, shortleaf, pitch, and eastern white pines (*Pinus strobus*). They almost never attack longleaf and slash pines, but on rare occasions have been observed feeding on hardwoods. Although the eastern pine weevil

Table 11—Important insect and disease pests of forests in the Southern United States

Pest	Description	Origin	Host(s)
Annosus root disease (*Heterobasidion annosum*)	Fungus	Native	Pines in the loblolly-shortleaf and longleaf-slash pine forests
Asian longhorned beetle (*Anoplophora glabripennis*)	Insect	China	Most hardwoods
Bark beetles, other than southern pine beetle[a]	Insect	Native	Pines in the loblolly-shortleaf and longleaf-slash pine forests
Beech bark disease (*Nectria coccinea* var. *faginata*)	Fungus vectored by beech scale (*Cryptococcus fagisuga*)	Unknown	American beeches in oak-hickory forests
Brown spot needle disease (*Scirrhia acicola*)	Fungus	Native	Longleaf pines in longleaf-slash forests
Butternut canker (*Sirococcus clavigignenti-juglandacearam*)	Fungus	Unknown	Butternuts in oak-hickory forests
Chestnut blight (*Cryphonectria parasitica*)	Fungus	Asia	American chestnuts, chinquapins, and several oak species in oak-hickory forests
Dogwood anthracnose (*Discula destructiva*)	Fungus	Unknown	Dogwoods in oak-hickory forests
Dutch elm disease (*Ophiostoma ulmi* or *Ophiostoma novo-ulmi*)	Fungus vectored by two bark beetles	Europe	All elm species
Emerald ash borer (*Agrilus planipennis*)	Insect	Asia	All ash species
Forest tent caterpillar (*Malacosoma disstria*)	Insect	Native	Hardwoods in oak-gum-cypress forests
Fusiform rust (*Cronartium fusiforme* f. sp. *fusiforme*)	Fungus	Native	Loblolly and slash pines in loblolly-shortleaf and longleaf-slash forests
Gypsy moth (*Lymantria dispar*)	Insect	Europe and Asia	Hardwoods (all types)
Hardwood borers	Various insects	Native	All species of hardwoods
Hemlock woolly adelgid (*Adelges tsugae*)	Insect	Asia	Hemlocks
Laurel wilt (*Raffaelea lauricola*)	Fungus vectored by ambrosia beetle (*Xyleborus glabratus*)	Unknown	Redbays
Littleleaf disease (*Phytophthora cinnamomi*)	Complex of fungus and site factors	Southeast Asia (likely)	Shortleaf and loblolly pines in loblolly-shortleaf forests
Loblolly pine decline (*Lophodermium* spp.)	Complex of fungi and bark beetles (*Hylastes* spp.)	Unknown	Pines
Nantucket pine tip moth (*Rhyacionia frustrana*)	Insect	Native	Pines
Oak decline	Complex of fungi, insects, and site conditions	Mixed	Oaks
Oak wilt (*Ceratocystis fagacearum*)	Fungus	Native	Oaks in oak-hickory forests
Pine reproduction weevils (*Hylobius pales, Pachylobius picivorus*)	Insect	Native	Pines
Sirex woodwasp (*Sirex noctilio*)	Complex of an insect and fungus (*Amylostereum areolatu*)	Widespread[b]	Pines
Southern pine beetle (*Dendroctonus frontalis*)	Insect	Native	Pines
Sudden oak death (*Phytophthora ramorum*)	Fungus	Unknown	Oaks
Thousand cankers disease (*Geosmithia morbida*)	Fungus vectored by walnut twig beetle (*Pityophthorus juglandis*)	Unknown	Black walnuts

[a] *Ips avulsus, I. calligraphus, I. grandicolli,* and *Dendructonus terebrans.*

[b] Europe, Asia, and northern Africa.

prefers cedar (*Juniperus virginiana*), it also attacks most southern yellow pines, such as loblolly, slash, and shortleaf. The future outlook for the activity and damage levels of reproduction weevils is similar to the recent past. Warmer winter months might allow them to increase in numbers or to prolong activity (or both) and to produce more generations per year. Decreased precipitation could reduce their activity.

Fusiform Rust

Fusiform rust, caused by a fungus (*Cronartium fusiforme* f. sp. *fusiforme*) occurs primarily on slash and loblolly pines. Although its range extends throughout its available host range in the Piedmont, losses from fusiform rust are most serious on Coastal Plain sites from Louisiana to southeastern South Carolina. Several variables including weather, amount of inoculum, abundance of oaks (the alternate host), and susceptibility of the individual host species govern incidence of this disease. Over the next 50 years given the general availability of oak alternate hosts for the fungus and the only slight predicted migration of pine from coastal areas upward into the Appalachian Mountains, the pathogen will likely fully colonize the extended range of its hosts.

Annosus Root Disease

Annosus root disease, caused by a fungus (*Heterobasidion annosum*) occurs throughout the Piedmont. Slash and loblolly pines are very susceptible to this disease. Increased temperatures, reduced rainfall, and increased host growth (from more carbon dioxide in the atmosphere) would all produce some increases in disease activity resulting from increased host susceptibility, but would not significantly increase fungus virulence.

Littleleaf Disease

Littleleaf disease is caused by a complex of factors including a nonnative fungus (*Phytophthora cinnamomi*), low soil nitrogen, eroded soils, poor internal soil drainage, and a plow pan, which is a compacted layer of soil that has become less porous than the soil above or below, generally the result of tilling or other farming operations (Duerr and Mistretta 2013). The littleleaf fungus is distributed throughout (and well beyond) the range currently occupied by shortleaf and loblolly pine in the Piedmont. The disease has its greatest impact in Alabama, Georgia, and South Carolina (Duerr and Mistretta 2013), with additional scattered pockets occurring in eastern Tennessee and southeastern Kentucky. Losses to this disease are expected to continue at the same rate on affected sites. However, its range should contract if higher temperatures cause its hosts to migrate northward, and its impact should lessen over time as sites are rehabilitated.

Oak Decline

Decline of oaks in upland hardwood and mixed oak-pine forests is a complex involving environmental stressors (often drought), root diseases, insect pests of opportunity such as the two-lined chestnut borer (*Agrilus bilineatus*), introduced pests such as the Japanese beetle (*Popillia japonica*) and Asiatic oak weevil (*Cyrtepistomus castaneus*), and the physiological maturity of the trees (Duerr and Mistretta 2013). Bottomland oak forests are also subject to oak decline but at a lower incidence. Stress agents of bottomland hardwoods also include seasonal (and sometimes prolonged) flooding. Significant oak decline episodes continue to occur in the South (primarily in Arkansas and Virginia) where predisposing conditions, inciting events, and contributing factors are coincident (Duerr and Mistretta 2013). With higher temperatures and potentially less rainfall being predicted, oak decline is expected to increase, possibly significantly.

Forest tent Caterpillar

Forest tent caterpillar (*Malacosoma disstria*) heavily defoliates sweetgum (*Liquidambar styraciflua*), blackgum (*Nyssa sylvatica*), and various oak species. The most persistent and extreme outbreaks in the Piedmont occur on host trees in bottomlands, forested wetlands, and riparian areas. Outbreaks occur in several States, where thousands of acres can be defoliated in a single season. However, outbreaks do not cause significant amounts of tree mortality unless there is repeated, heavy defoliation.

SPECIES WITH SCATTERED DISTRIBUTION

Emerald Ash Borer

Although emerald ash borer (*Agrilus planipennis*) generally has infested areas outside the Piedmont, it was recently detected in southern Virginia (Central section). The emerald ash borer will likely infest most of the ash trees in the South over the next 50 years. Generally, ash is not a dominant component of southern forests, but it is almost always common in some areas, and green ash is a small but significant component of most riparian forests in the South. The range of ash trees in the South is expected to shrink as the climate warms; between climate stress and emerald ash borer infestations, the Piedmont is likely to lose millions of ash trees in the next 50 years.

Gypsy Moth

Gypsy moth (*Lymantria dispar*) was detected in the Southern section of the Piedmont (in South Carolina) in the 1990s, where it was treated. This moth defoliates hardwoods, particularly oaks, where it weakens trees to such an extent that they could be attacked and killed by secondary organisms. Extended drought intensifies the death rate. Because the gypsy moth is still spreading southward, impacts will likely increase over the next 50 years. The severity and extent of the impacts, however, depend on many factors including the continuation of active programs to slow the spread, suppression and eradication activities, the amount and health of hardwood forests the moth will encounter, and potential unknown temperature and moisture effects on the moth, its hosts, and its natural enemies.

Hemlock Woolly Adelgid

Hemlock woolly adelgid (*Adelges tsugae*) is currently found in the Piedmont wherever hemlocks occur (fig. 39). Within the next 50 years, hemlock woolly adelgid will likely kill most of the hemlocks that are alive today. Climate change is unlikely to reverse the spread of hemlock woolly adelgid; in fact, a warming trend would presumably only exacerbate the situation.

Brown Spot Needle Disease

Brown spot needle disease, caused by a fungus (*Scirrhia acicula*) is considered the most damaging disease of longleaf pine. Although it occurs primarily on the Coastal Plain throughout the range of longleaf, it has also infected upland longleaf stands in the Piedmont. Over the next 50 years, the emphasis on longleaf pine restoration is likely to have a greater impact on this disease than climate warming. Higher temperatures might slightly favor increase in growth of longleaf; reductions in rainfall, dew, and fog would likely favor the longleaf pine over the fungus.

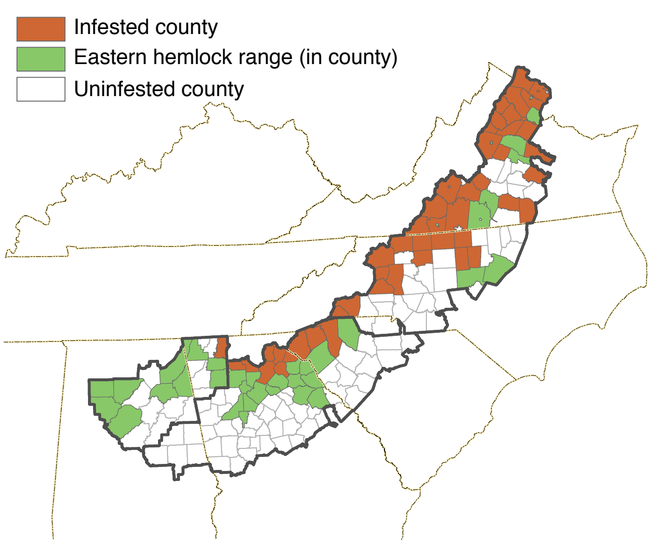


Figure 39—County-level distribution of established hemlock woolly adelgid populations in the Southern U.S. Piedmont, as reported by State forest health officials in 2009; note that populations are not distributed evenly in infested counties and that this map is undergoing rapid change because of the ongoing expansion of the range of this insect (Source: USDA Forest Service 2010).

Butternut Canker

A fungus (*Sirococcus clavigignenti-juglandacearum*) causes multiple cankers on the main stem and branches of butternut (*Juglans cinerea*) trees. Butternut canker has been found in 55 counties in the South extending north from northern Alabama along the Appalachian Mountains into North Carolina, Tennessee, Virginia, and Kentucky, with scattered occurrences throughout Kentucky and Tennessee (Duerr and Mistretta 2013). Butternut is not a common tree in the Piedmont, but it does have a spotty and scattered distribution. Data from forest surveys show a dramatic decrease in the number of live butternut trees in the United States (77 percent loss in North Carolina and Virginia) (Duerr and Mistretta 2013). Although the higher temperatures and predicted increases in atmospheric carbon dioxide could increase the butternut growth, drier conditions resulting from reduced precipitation would offset this increase. Overall, more cankering and mortality occurring on fewer butternut trees would be expected.

Chestnut Blight

The chestnut blight fungus (*Cryphonectria parasitica*) has affected American chestnuts (*Castanea dentata*) throughout its range, including its limited range in the Piedmont where it occurs on the western side by the Appalachian-Cumberland highlands. Research is underway to develop disease-resistant hybrids. However, large areas of forest land will not be restored to chestnut in the next 50 years because of an insufficient supply of seedlings. Further, if climate change is considered, the impacts on chestnut deployed in the restoration effort would probably be similar to those predicted for oaks suffering from oak decline.

Dogwood Anthracnose

Dogwood anthracnose is caused by an introduced fungus (*Discula destructiva*). The range of this disease stretches southward into South Carolina (Southern section) and Alabama (Ridge and Valley section) and westward into central Tennessee and scattered western Kentucky counties (Duerr and Mistretta 2013) with activity concentrated in the Appalachian Mountains. The southernmost limit of the dogwood anthracnose range relative to available host trees suggests that this disease is temperature limited; in some areas of the South, dogwoods have been all but eliminated from the forest ecosystem >3,000 feet (Duerr and Mistretta 2013). Increased temperature and aridity encroaching at higher-than-current elevations will likely diminish the importance of this disease in the Piedmont.

Dutch Elm Disease

The Dutch elm disease pathogen is vectored by one of two bark beetles and can be caused by either of two closely related species of fungi (*Ophiostoma ulmi* or *Ophiostoma novo-ulmi*). All native elms are susceptible to the disease, although their susceptibility varies. Despite the presence of several elm species in the Piedmont—American elm, winged elm (*Ulmus alata*), and slippery elm (*Ulmus rubra*)—very little Dutch elm disease can be found in areas below northern North Carolina (Central section). This suggests that either the beetles or the fungi involved in transmitting/causing the disease are temperature limited. Barring significant changes in its pathogen/vector combination, increasing temperature and migration of the host slightly to the north is expected to diminish the disease's overall impact in the Piedmont.

Loblolly Pine Decline

Any number of fungi (*Leptographium serpens, Leptographium terebrantis,* or *Leptographium lundbergii*) in the roots of affected trees (Duerr and Mistretta 2013) may be the primary pathogens or may simply be taking advantage of already significantly weakened trees. Also, a bark beetle (*Hylastes* spp.) has been found in the root systems of many declining pines and is suspected of vectoring the fungus from infected to uninfected trees (Duerr and Mistretta 2013). Information is lacking as to whether they select weakened trees to attack or are indiscriminate in their attacks (which would suggest that healthy trees are able to overcome successful inoculation). Little is known about the potential range and severity beyond data collected from field surveys in central northern Alabama and Fort Benning, GA (Duerr and Mistretta 2013), both of which border the Piedmont. Tree decline is likely to increase in a warmer and drier climate, regardless of inputs from disease and insect vectors.

Oak Wilt

Oak wilt is caused by a fungus (*Ceratocystis fagacearum*). All species of oak are susceptible but to varying degrees. As of 2005, oak wilt has been identified in one South Carolina county in the Southern section (USDA Forest Service 2013), although it is more prevalent in the Appalachian-Cumberland highlands. Given the apparent adaptation of the fungus to warmer temperatures and relatively dry conditions, significant oak loss is highly probable in previously unaffected areas along the Gulf of Mexico and in Georgia within 50 years. However, if the apparent adaptation to warmer and drier conditions proves inadequate for continued disease spread, an overall slight lessening of the impact of oak wilt would be likely in the South.

SPECIES NOT YET DETECTED

Asian Longhorned Beetle

Although Asian longhorned beetle (*Anoplophora glabripennis*) has not been detected yet in the Piedmont, a wide variety of southern hardwood trees (especially maples) is at risk, which means that this beetle will likely spread to the Piedmont in the future. However, vast areas of hardwoods are unlikely to be killed within the next 50 years because the beetle is a slow disperser and takes several years to kill host trees.

Sirex Woodwasp

Sirex woodwasp (*Sirex noctilio*) has not been reported in the Piedmont. However, within the next 50 years, natural or human-aided spread will very likely introduce this pest to Piedmont forests. Many of the Piedmont's most important pine species are susceptible to Sirex, and many trees will succumb if attacks are as aggressive as they have been in South America and Australia. Although this scenario could result in catastrophic ecological and economic losses, the complexity of southern forests (mixed stands, high biodiversity, and many possible competitors, predators, and parasitoids) contrasts with the monoculture pine plantations in other countries where the pest has been most damaging. Studies are underway to assess the potential level of danger to southern forests.

Beech Bark Disease

Beech bark disease is caused by a complex of two or more agents working in concert. The beech scale (*Cryptococcus fagisuga*) attacks the bark of American beech (*Fagus grandifolia*), creating infection courts that are subsequently colonized by a fungus (*Nectria coccinea* var. *faginata*). This fungus causes cankers that grow together and girdle host trees. Although beech bark disease has not been detected in the Piedmont, American beech occurs in the Piedmont. It is a matter of time before beech bark disease affects trees in the Piedmont.

Laurel Wilt

Laurel wilt is caused by an introduced fungus (*Raffaelea lauricola*), which is vectored from host to host by an ambrosia beetle (*Xyleborus glabratus*). It is currently decimating the redbay (*Persea borbonia*) population of the southern Coastal Plain. Several additional hosts have been identified for this vectored disease including swamp bay (*Persea palustris*), sassafras (*Sassafras albidum*), avocado

(*Persea americana*), camphor (*Cinnamomum camphorate*), pondberry (*Lindera melissifolia*), and pondspice (*Litsea aestivalis*). Although laurel wilt has not been detected in the Piedmont, sassafras trees are common.

Figure 40 shows the ranges of red bay and sassafras and the projected progression of laurel wilt through the Piedmont (Duerr and Mistretta 2013); note that according to the projection laurel wilt should have reached the Piedmont before 2010. However, the combination of redbay's natural range and climatic barriers that affect the vector and fungus will likely stall further progress of the disease.

Sudden Oak Death

Sudden oak death is caused by a fungus (*Phytophthora ramorum*), which causes several nonspecific symptoms depending on the host and host part affected. It has not yet been detected in the Eastern United States, but the list of hosts currently reported for this pest is extensive. As of 2010 the list includes 45 proven regulated hosts plus another 82 associated hosts regulated in the nursery trade (Duerr and Mistretta 2013). Northern red oak (*Q. rubra*) and pin oak (*Q. palustirs*) are susceptible to infection. Sudden oak death appears to have the potential to devastate the entire eastern oak population, even absent climate change considerations (Duerr and Mistretta 2013). Increased temperatures and atmospheric carbon dioxide could be expected to increase growth of both the pathogen and its host, at least in the short term. That effect would be somewhat counteracted by reductions in precipitation and increased ozone in conjunction with warmer temperatures. Nevertheless, once acclimated to the eastern forest, the disease would probably spread even faster than it has in California.

Figure 41 represents the relative risk of sudden oak death across the Piedmont. The western third of the Central section, more than half of the Southern section, and a small area of the northern Ridge and Valley section are at high risk, while most of the rest of the Central section and Ridge and Valley section, and all of the remaining Southern section are at moderate risk.

Thousand Cankers Disease

Thousand cankers disease is caused by a fungus (*Geosmithia morbida*) and vectored from infected to healthy trees by the walnut twig beetle (*Pityophthorus juglandis*). The fungus infects and subsequently kills black walnut (*Juglans nigra*), a species that is highly valued for furniture, paneling, and walnuts. Although it has not been reported in the Piedmont, thousand cankers disease was recently discovered and confirmed in urban/suburban settings in four Tennessee counties (with suspect trees occurring in similar settings in an additional 10 counties). Although the Tennessee infections were the first reported east of the Great Plains, they may have been occurring since the 1990s. The full extent of this infection is yet to be determined. Finding no barriers to spread, thousand cankers disease could occupy the entire range of black walnut within 50 years, similar to the projected spread of laurel wilt.

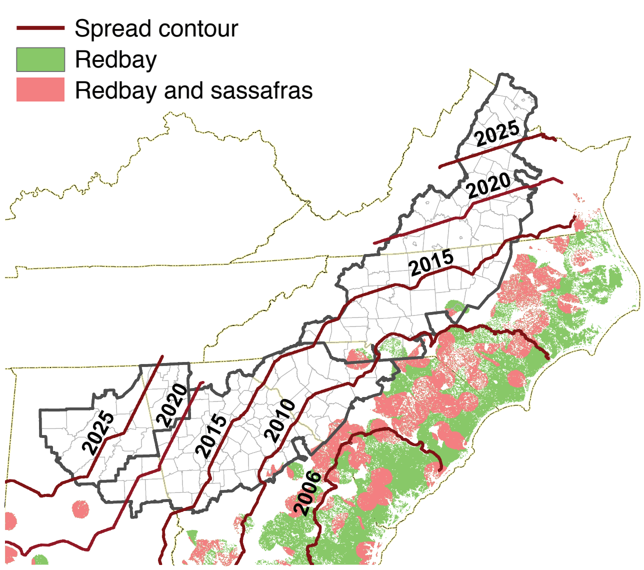


Figure 40—Probable spread of laurel wilt disease in the Southern United States from 2006 to 2025, based on the current rate of spread and known distribution of the redbay host (Adapted from Koch and Smith 2008b).

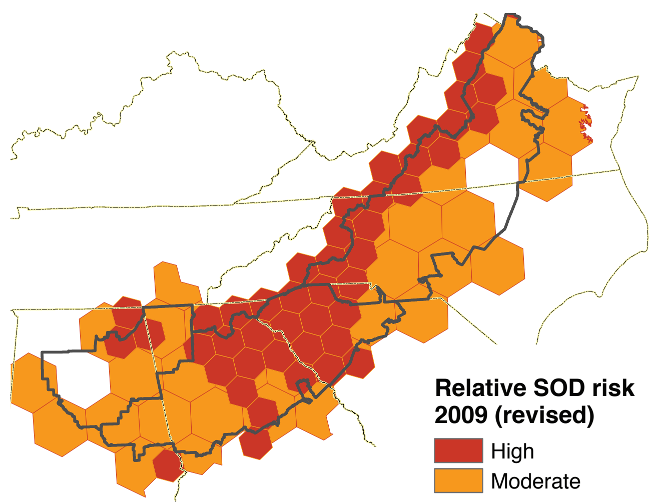


Figure 41—Potential range for sudden oak death (SOD) in the Southern U.S. Piedmont, 2009, based on the distribution of known or likely hosts, climate conditions adequate for the survival and propagation of the pathogen, and probable pathways of introduction outside the current range of the pathogen (Revised from Koch and Smith 2008a by Frank H. Koch).

CHAPTER 8.
Wildfire and Prescribed Burning

Stanturf and Goodrick (2013) described how wildland fire conditions could evolve over the next 50 years, and how these changing conditions would impact prescribed fire in the South. The purpose of this report is to apply their predictions to the forests of the Piedmont.

Most prescribed burning in the South is carried out in the Coastal Plain and Piedmont. However, fire is also an integral part of the landscape in the Piedmont, where it is an important tool used to manage hazardous fuels—thereby decreasing the risk of catastrophic wildfires—and to provide other ecological and economic benefits (Stanturf and Goodrick 2013). Most acreage is burned to reduce hazardous fuel, improve forest health, and manage habitat for various wildlife species. However, an increasing number of acres are burned for ecosystem restoration; this use of prescribed burning is becoming increasingly important, in particular for longleaf pine and prairie restoration.

Continued population growth in the Piedmont increases the potential threat that wildfires pose to life and property. In addition, forestry and forestry-related industry represent a significant portion of the region's economy, making each wildfire a potential loss to a local economy.

Climate Impacts on Wildfire Potential

Annual Fire Potential

Wildfire reports compiled as part of the Southern Wildfire Risk Assessment reveal that the primary areas of wildfire activity from 1997 to 2002 were in the Ridge and Valley section and the lower portion of the Southern section (fig. 42) (Stanturf and Goodrick 2013). Other areas may be important locally but are limited in geographic extent, such as throughout the Central section and in the upper portion of the Southern section.

Fire potential is expressed by the potential drought index: positive where evapotranspiration exceeds precipitation, negative where precipitation exceeds evapotranspiration, and near zero where the moisture budget is balanced. All four Cornerstone Futures provided a view of annual fire potential in 2010 that was consistent with data collected for baseline years of 1997 to 2002 (fig. 43). Because of higher precipitation and lower summer temperatures, areas farthest west were dominated by negative drought index values, with the wettest areas occurring on the western edge of the Southern section. Areas farther east were dominated by lower precipitation, leading to more balanced drought index values.

All Cornerstone Futures depict drier conditions for the next 50 years (fig. 44). Cornerstone A predicts the most severe conditions with an eastward expansion of dry areas and an intensification of dryness in the 2010 primary fire areas (fig. 42); fire potential would be especially severe in all Southern section areas except those on its western edge, which would have a negative drought index value. Cornerstones B through D are very consistent in their depiction of drier

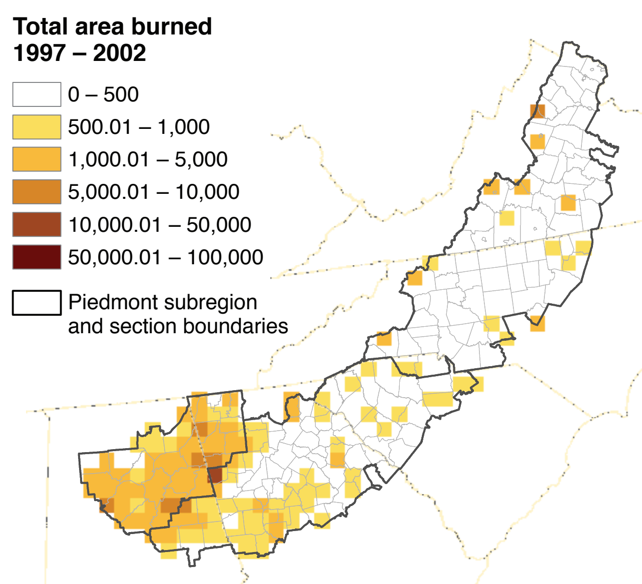


Figure 42—Annual area burned by wildfires, 1997 to 2002, in the Southern U.S. Piedmont [Source: Southern Wildfire Risk Assessment: http://www.southernwildfirerisk.com/ (Date accessed: March 23, 2013)].

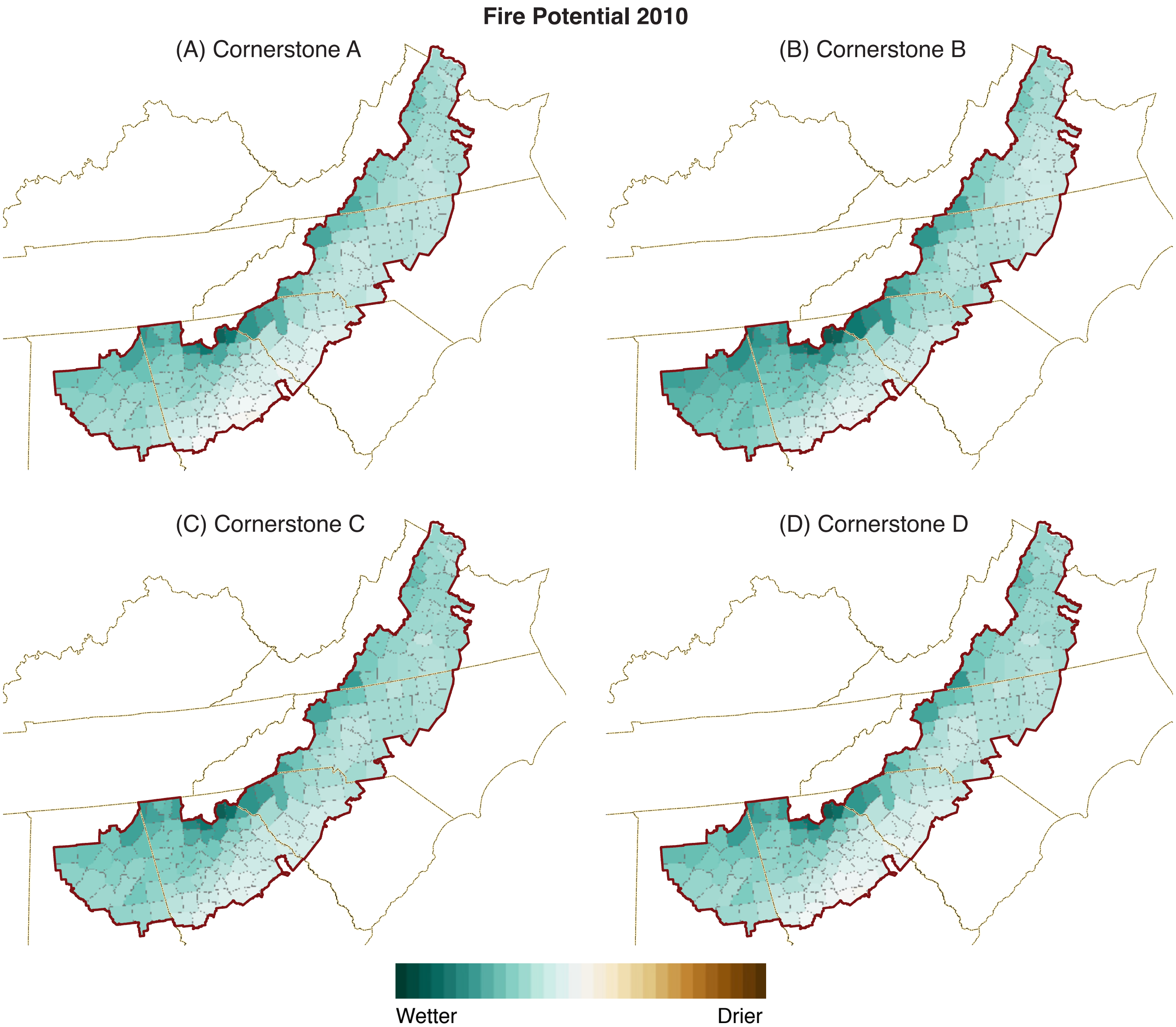


Figure 43—Simulation of annual fire potential, 2010, for the Southern U.S. Piedmont as forecasted by (A) Cornerstone A, (B) Cornerstone B, (C) Cornerstone C, (D) Cornerstone D; each Cornerstone represents a general circulation model (MIROC3.2, CSIROMK3.5, CSIROMK2, or HadCM3) paired with one of two emission scenarios (A1B representing low-population/high-economic growth, high energy use; B2 representing moderate growth and use): A is MIROC3.2 + A1B, B is CSIROMK3.5 + A1B, C is CSIROMK2 + B2, and D is HadCM3 + B2 (Source: McNulty and others 2013).

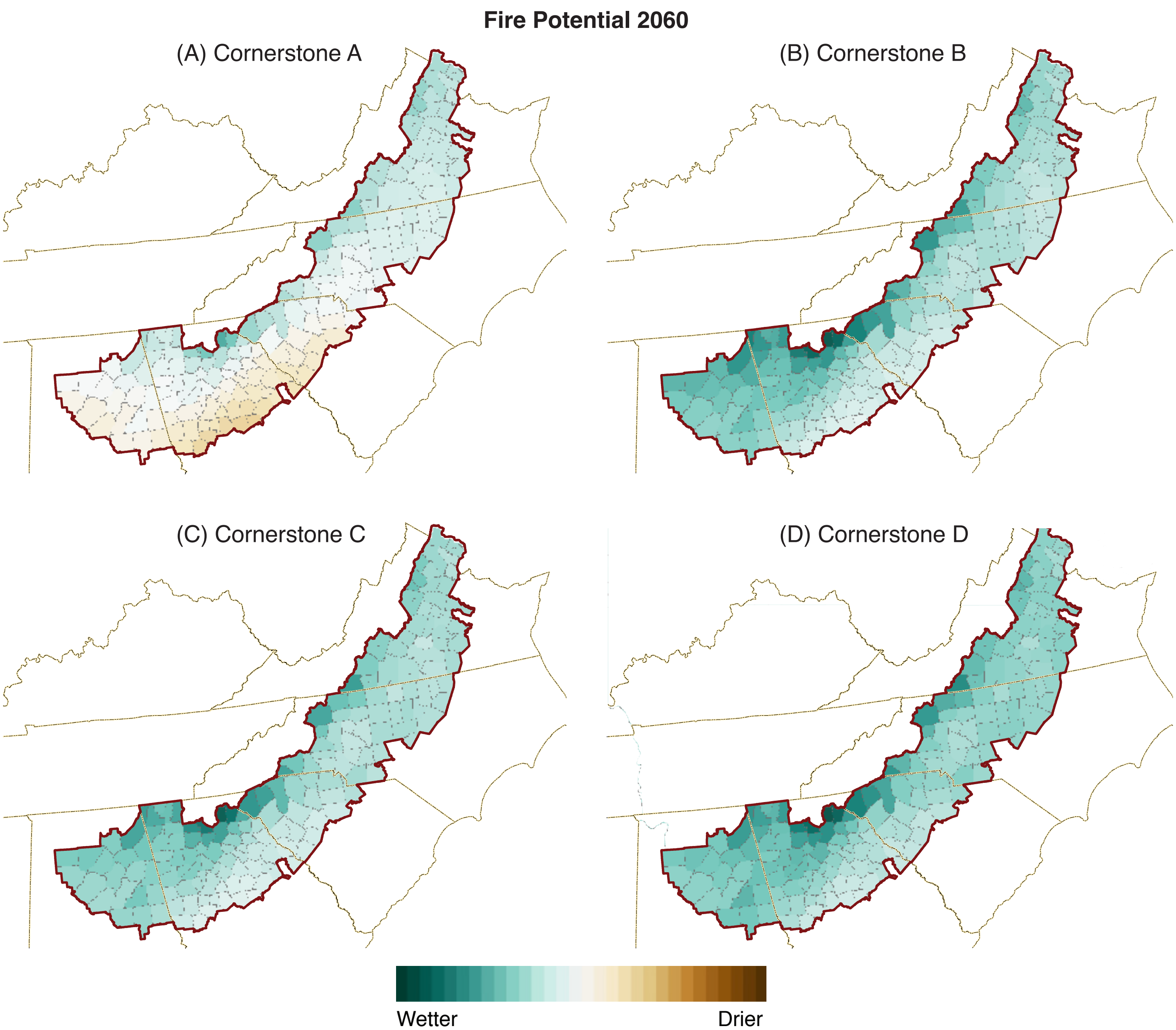


Figure 44—Predicted annual fire potential, 2060, for the Southern U.S. Piedmont as forecasted by (A) Cornerstone A, (B) Cornerstone B, (C) Cornerstone C, (D) Cornerstone D; each Cornerstone represents a general circulation model (MIROC3.2, CSIROMK3.5, CSIROMK2, or HadCM3) paired with one of two emission scenarios (A1B representing low-population/high-economic growth, high energy use; B2 representing moderate growth and use): A is MIROC3.2 + A1B, B is CSIROMK3.5 + A1B, C is CSIROMK2 + B2, and D is HadCM3 + B2 (Source: McNulty and others 2013).

conditions, which are more similar to conditions in 2010 than Cornerstone A.

Seasonal Variation in Wildfire Potential

Although annual numbers provide a glimpse of future wildland fire conditions, examination of drought index changes at the seasonal scale provides more information and insight.

For the 1997 to 2002 baseline, the acreage burned during the winter months (December, January and February) was highest in the eastern Ridge and Valley section and northern Central section, although wildfire activity was present at lower levels across much of the Piedmont (fig. 45A). Spring (March, April, and May) brought more wildfire activity, particularly to the Ridge and Valley section and Southern section (fig. 45B) but little-to-no activity in the northern half of the Central section. By summer (June, July, and August), wildfire activity decreased throughout the Piedmont, with a low level of activity persisting in the southern half of the Central section (fig. 45C). Autumn (September, October, and November) brought a return of wildfire activity to the Ridge and Valley section and a substantial reduction in the southern Central section (fig. 45D).

Although wildfires are possible in any season, the areas discussed above have distinct wildfire seasons. For the Ridge and Valley section, wildfire activity is lowest in the summer and highest in the other three seasons. For the Central section, activity is lowest in the summer and highest in the winter, with spring providing a secondary peak in wildfire activity in southern areas and autumn providing a secondary peak in wildfire activity in northern areas. Wildfire activity in the Southern section is considerably higher during the spring and is lowest in the summer extending into the autumn.

For the simulated 2010 conditions under Cornerstone A, winter is the primary rainy season, with the wettest area being the western portion of the Southern section and the northwestern portion of the Ridge and Valley section (fig. 46); summer is dominated by pronounced drying. Over the course of 50 years, winter would be uniformly wet across the Piedmont, with negative drought index values continuing into the spring and highest in the northern portion of the Central section (fig. 46). Summer and autumn would be considerably drier, practically eliminating negative drought index values across the Piedmont.

Cornerstone B offers a better representation of the simulated 2010 conditions than Cornerstone A (fig. 47). The area of moist conditions shifts eastward during spring as dry conditions expand across the Piedmont. Summer brings wetter conditions to the Piedmont, especially the southern half of the Central section and the northern portion of Southern section. During autumn, drier conditions return, where the eastern side of the Piedmont has more balanced moisture, except for the southeastern Southern section, which is drier. Winter is the wettest season, with the Ridge and Valley section and the western portion of the Southern section being the wettest areas. The predicted changes in wildfire potential in 50 years would be less extreme from one season to the next than under Cornerstone A (fig. 47). The Central section would remain wetter during winter. In the Ridge and Valley section, drier winter conditions would continue into spring. Wintertime drying could adversely affect prescribed burning by favoring conditions that promote escaped prescribed fires, especially in the Southern section and Ridge and Valley section. Drier conditions would also promote increased fuel consumption on prescribed burns, increasing the likelihood of air quality problems.

Cornerstones C and D resemble Cornerstone B in spatial patterns but the degree of change after 50 years would be smaller.

Monthly Variation in Wildfire Potential

An examination of monthly changes in wet and dry acreage in each State provided additional information and perspective. What constitutes wet versus dry conditions for each Cornerstone Future was determined by adding all drought index values for the 2010 simulation and dividing the result into thirds. The third with the highest drought index values represented dry conditions and the lowest third represented wet conditions.

For the 2010 simulated conditions, Cornerstone A places all Piedmont sections predominantly in the wettest category from November through March (table 12); the Southern and Ridge and Valley sections are in the driest category mostly in June through August, with the Central section being driest mostly in June. Cornerstone B (table 13) places all sections predominantly in the wettest category from December through March, with a shorter transition period in late autumn and also a gradual transition in spring; the driest category is in August for all sections, with the southern portion of the Southern section and the Ridge and Valley section extending drying into September. Cornerstone C (table 14) also places all sections predominantly in the wettest category from December through March, but with a shorter transition period in late autumn; the driest category is in June for the southern portion of the Southern section and the Ridge and Valley section and also in August for the Southern and Ridge and Valley sections, but is nonexistent for the Central section. Cornerstone D (table 15) is very similar to Cornerstone C. The transition periods in spring and autumn described above are typical of the southern wildfire season, and they largely depend on the annual

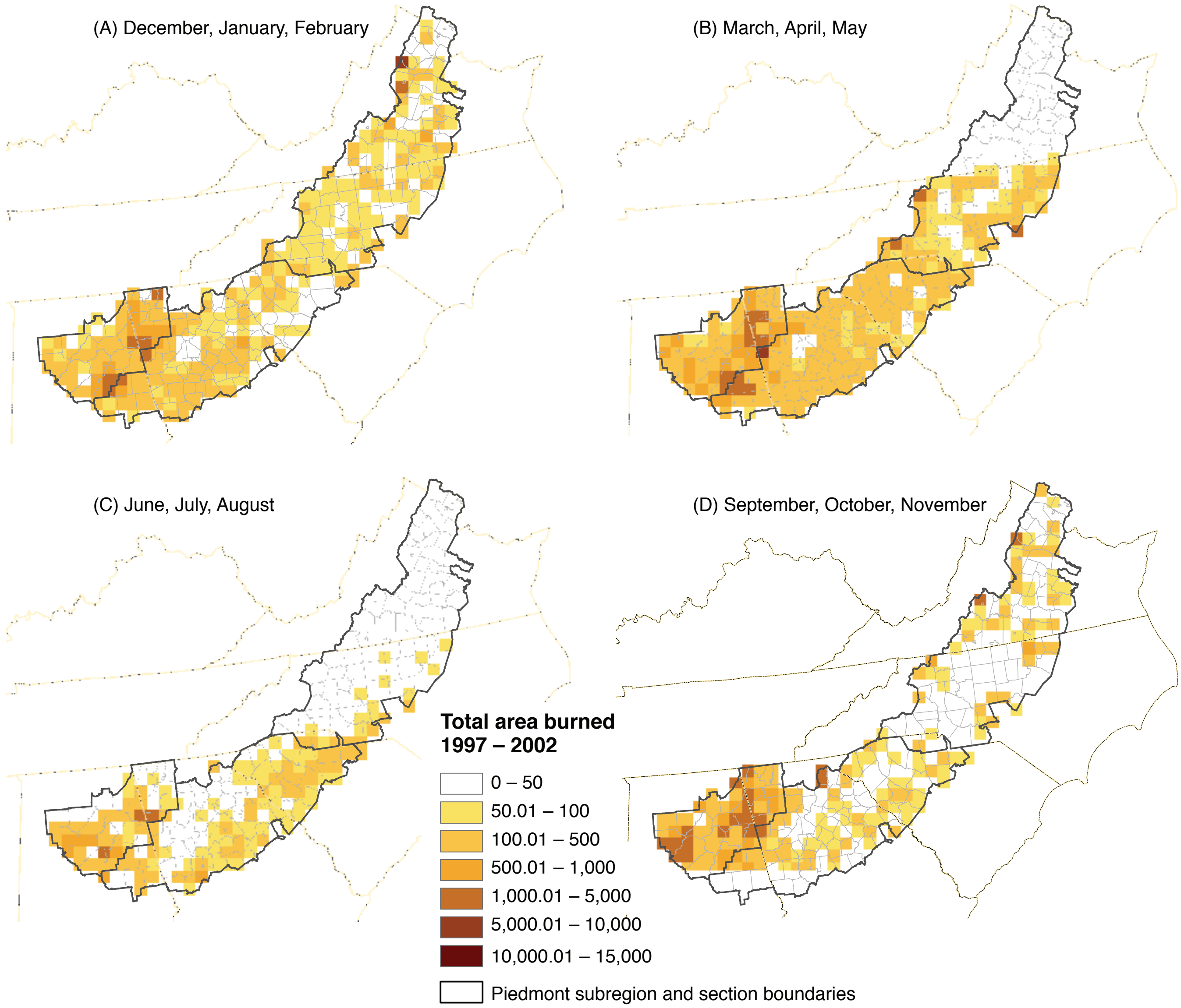


Figure 45—Area burned in the Southern U.S. Piedmont, 1997 to 2002, during (A) winter months of December through February, (B) spring months of March through May, (C) summer months of June through August, and (D) autumn months of September through November [Source: Southern Wildfire Risk Assessment: http://www.southernwildfirerisk.com/ (Date accessed: March 23, 2013)].

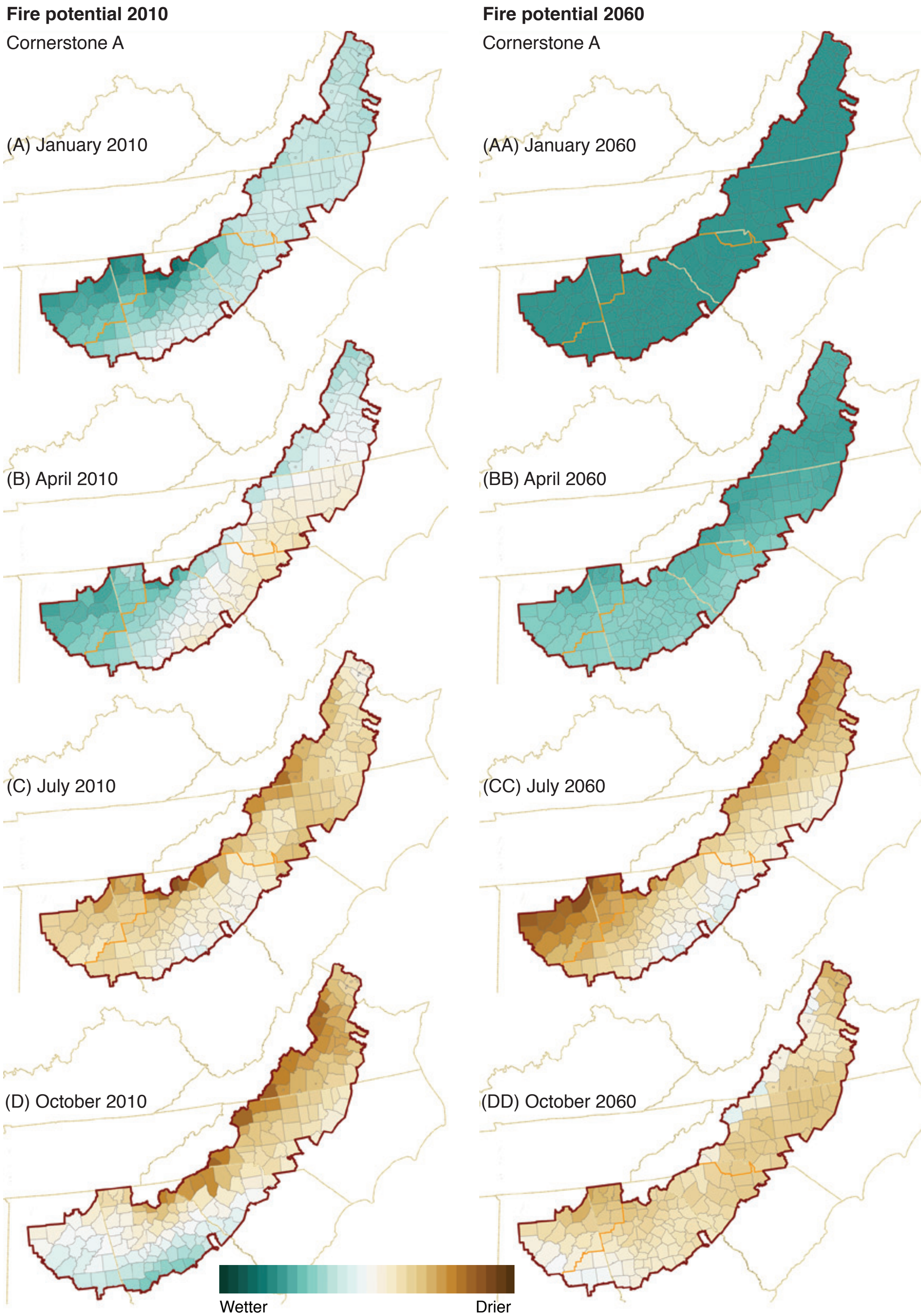


Figure 46—Fire potential in the Southern U.S. Piedmont as forecasted under Cornerstone A for (A) January 2010, (B) April 2010, (C) July 2010, (D) October 2010, (AA) January 2060, (BB) April 2060, (CC) July 2060, and (DD) October 2060; each of the four Cornerstone Futures represents a general circulation 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 is MIROC3.2 + A1B (Source: McNulty and others 2013).

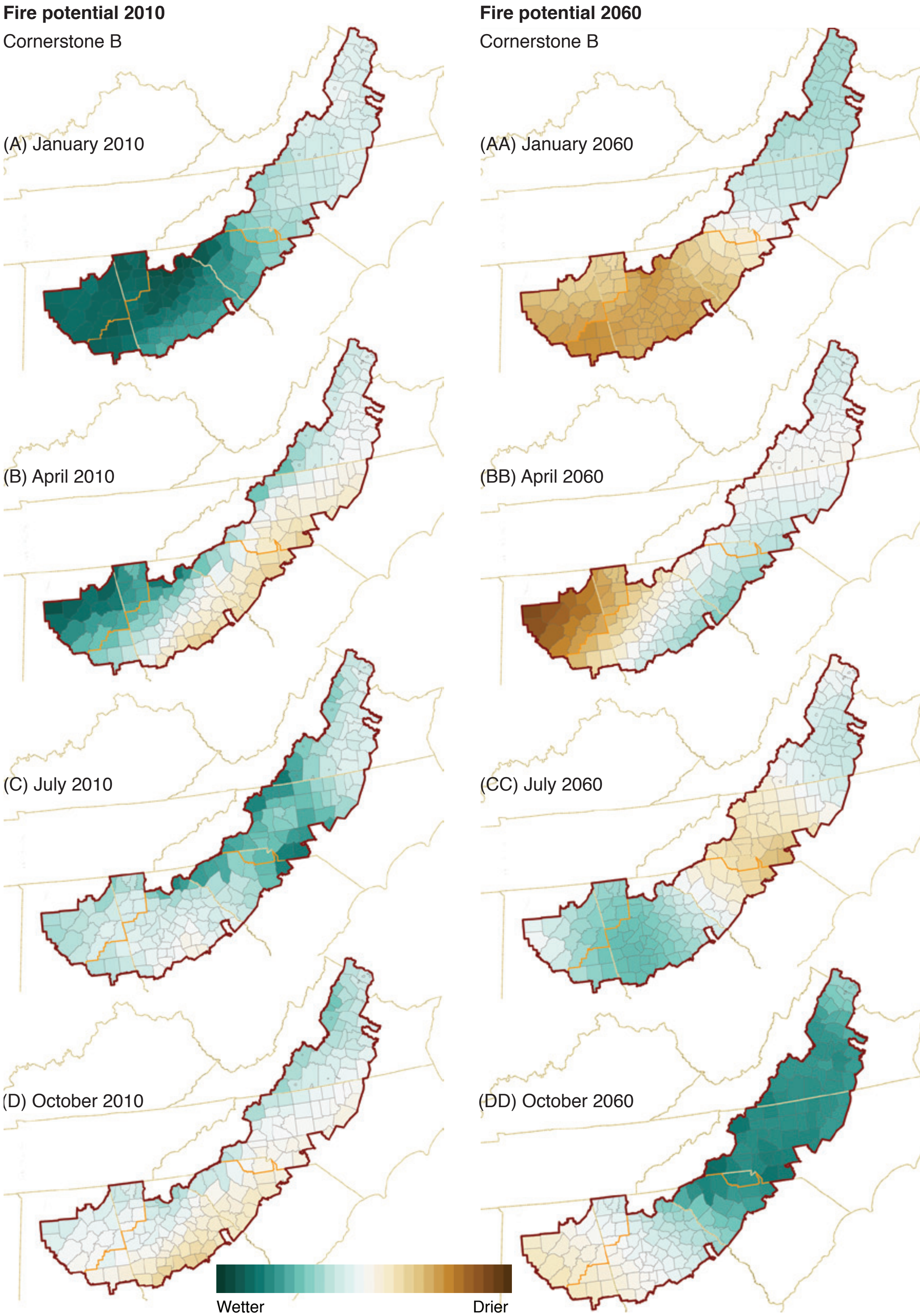


Figure 47—Fire potential in the Southern U.S. Piedmont as forecasted under Cornerstone B for (A) January 2010, (B) April 2010, (C) July 2010, (D) October 2010, (AA) January 2060, (BB) April 2060, (CC) July 2060, and (DD) October 2060; each of the four Cornerstone Futures represents a general circulation 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): B is CSIROMK3.5 + A1B (Source: McNulty and others 2013).

Table 12—Month-by-month percent of area in dry and wet classes for the baseline year of 2010 and predicted for 2060 in the Southern U.S. Piedmont under Cornerstone A[a]

			Percent of area in driest and wettest classes											
State	Class[b]	Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Alabama[c]	Driest	2010	0	0	0	0	0	100	32	85	0	0	0	0
		2060	0	0	0	0	46	100	100	100	100	0	0	0
	Wettest	2010	100	100	100	9	0	0	0	0	0	0	99	100
		2060	100	100	8	0	0	0	0	0	0	0	0	98
Georgia[d]	Driest	2010	0	0	0	0	0	97	73	56	1	1	0	0
		2060	0	0	0	44	80	100	100	100	98	52	0	0
	Wettest	2010	84	100	82	4	1	0	0	0	0	1	31	84
		2060	74	58	15	0	0	0	0	0	0	0	2	32
South Carolina[e]	Driest	2010	0	0	0	0	0	100	28	12	0	0	0	0
		2060	0	0	0	10	83	100	100	100	100	0	0	0
	Wettest	2010	98	100	100	5	0	0	0	0	0	0	100	100
		2060	89	84	6	0	0	0	0	0	0	0	0	26
North Carolina[f]	Driest	2010	0	0	0	0	0	63	0	2	0	0	0	0
		2060	0	0	0	0	8	98	93	95	88	0	0	0
	Wettest	2010	100	100	100	4	3	0	0	0	2	11	45	100
		2060	100	100	16	0	0	0	0	0	0	1	7	86
Virginia[g]	Driest	2010	0	0	0	0	0	63	6	10	0	0	0	0
		2060	0	0	0	0	0	100	100	97	98	0	0	0
	Wettest	2010	100	100	100	0	0	0	0	0	0	12	97	100
		2060	100	100	8	0	0	0	0	0	0	0	0	100

[a] Each of the four Cornerstone Futures represents a general circulation model (MIROC3.2, CSIROMK3.5, CSIROMK2, and 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 is MIROC3.2 + A1B.

[b] Driest class is ≥700 and wettest class is ≤99 on the Keetch-Byram Drought Index.

[c] Counties: Randolph, Clay, Chambers, Tallapoosa, Coosa, Marshall, De Kalb, Cherokee, Cleburne, Calhoun, Etowah, Winston, Cullman, Walker, Blount, Jefferson, Shelby, St. Clair, and Talladega.

[d] Counties: White, Habersham, Stephens, Franklin, Hart, Banks, Madison, Elbert, Wilkes, Lincoln, Columbia, Warren, Taliaferro, Hancock, Greene, Oglethorpe, Clarke, Jackson, Hall, Forsyth, Dawson, Pickens, Cherokee, Cobb, Paulding, Haralson, Carroll, Douglas, Fulton, De Kalb, Gwinnett, Barrow, Oconee, Walton, Morgan, Putnam, Baldwin, Jones, Jasper, Newton, Rockdale, Clayton, Henry, Butts, Monroe, Lamar, Upson, Pike, Talbot, Harris, Troup, Meriwether, Spalding, Fayette, Coweta, Heard, Dade, Catoosa, Whitfield, Murray, Walker, Chattooga, Gordon, Floyd, Bartow, and Polk.

[e] Counties: Cherokee, York, Oconee, Pickens, Greenville, Spartanburg, Union, Chester, Lancaster, Fairfield, Newberry, Laurens, Anderson, Abbeville, Greenwood, Saluda, McCormick, and Edgefield.

[f] Counties: Warren, Vance, Granville, Person, Caswell, Rockingham, Stokes, Surry, Wilkes, Yadkin, Forsyth, Guilford, Alamance, Orange, Durham, Wake, Franklin, Lee, Chatham, Randolph, Davidson, Davie, Rowan, Iredell, Alexander, Catawba, Polk, Rutherford, Cleveland, Lincoln, Gaston, Mecklenburg, Cabarrus, Stanly, Union, Anson, and Montgomery.

[g] Counties: Loudoun, Arlington, Fairfax, Fauquier, Prince William, Rappahannock, Culpeper, Stafford, Madison, Spotsylvania, Orange, Greene, Albemarle, Louisa, Fluvanna, Hanover, Goochland, Powhatan, Chesterfield, Amelia, Cumberland, Buckingham, Appomattox, Prince Edward, Nottoway, Dinwiddie, Brunswick, Lunenburg, Charlotte, Campbell, Bedford, Franklin, Pittsylvania, Halifax, Mecklenburg, Henry, and Patrick.

Source: McNulty and others (2013).

Table 13—Month-by-month percent of area in dry and wet classes for the baseline year of 2010 and predicted for 2060 in the Southern U.S. Piedmont under Cornerstone B[a]

			Percent of area in driest and wettest classes											
State	Class[b]	Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Alabama[c]	Driest	2010	0	0	0	0	0	0	0	94	17	0	0	0
		2060	0	0	0	0	0	0	93	100	21	0	0	0
	Wettest	2010	100	100	66	61	39	0	0	0	0	0	26	100
		2060	100	94	45	0	6	0	0	0	0	0	0	100
Georgia[d]	Driest	2010	0	0	0	0	0	0	7	71	20	0	0	0
		2060	0	0	0	0	0	30	83	65	77	1	0	0
	Wettest	2010	100	100	32	21	16	0	0	0	1	0	11	55
		2060	71	42	19	4	4	0	0	0	0	0	2	100
South Carolina[e]	Driest	2010	0	0	0	0	0	0	0	47	0	0	0	0
		2060	0	0	0	0	0	18	68	45	58	0	0	0
	Wettest	2010	100	100	26	6	17	0	0	0	0	0	6	53
		2060	76	32	13	0	0	0	0	0	0	0	0	100
North Carolina[f]	Driest	2010	0	0	0	0	0	0	0	19	0	0	0	0
		2060	0	0	0	0	8	0	64	41	8	0	0	0
	Wettest	2010	100	100	87	22	86	2	1	0	15	0	16	96
		2060	100	71	59	10	7	0	0	0	0	3	6	100
Virginia[g]	Driest	2010	0	0	0	0	0	0	0	4	0	0	0	0
		2060	0	0	0	0	0	3	76	32	0	0	0	0
	Wettest	2010	100	100	100	45	51	0	0	0	0	0	35	100
		2060	100	100	66	6	0	0	0	0	0	0	2	100

[a] Each of the four Cornerstone Futures represents a general circulation model (MIROC3.2, CSIROMK3.5, CSIROMK2, and HadCM3) paired with one of two emission scenarios (A1B representing low-population/high-economic growth, high energy use; B2 representing moderate growth and use): B is CS1ROMK3.5 + A1B.

[b] Driest class is ≥700 and wettest class is ≤99 on the Keetch-Byram Drought Index.

[c] Counties: Randolph, Clay, Chambers, Tallapoosa, Coosa, Marshall, De Kalb, Cherokee, Cleburne, Calhoun, Etowah, Winston, Cullman, Walker, Blount, Jefferson, Shelby, St. Clair, and Talladega.

[d] Counties: White, Habersham, Stephens, Franklin, Hart, Banks, Madison, Elbert, Wilkes, Lincoln, Columbia, Warren, Taliaferro, Hancock, Greene, Oglethorpe, Clarke, Jackson, Hall, Forsyth, Dawson, Pickens, Cherokee, Cobb, Paulding, Haralson, Carroll, Douglas, Fulton, De Kalb, Gwinnett, Barrow, Oconee, Walton, Morgan, Putnam, Baldwin, Jones, Jasper, Newton, Rockdale, Clayton, Henry, Butts, Monroe, Lamar, Upson, Pike, Talbot, Harris, Troup, Meriwether, Spalding, Fayette, Coweta, Heard, Dade, Catoosa, Whitfield, Murray, Walker, Chattooga, Gordon, Floyd, Bartow, and Polk.

[e] Counties: Cherokee, York, Oconee, Pickens, Greenville, Spartanburg, Union, Chester, Lancaster, Fairfield, Newberry, Laurens, Anderson, Abbeville, Greenwood, Saluda, McCormick, and Edgefield.

[f] Counties: Warren, Vance, Granville, Person, Caswell, Rockingham, Stokes, Surry, Wilkes, Yadkin, Forsyth, Guilford, Alamance, Orange, Durham, Wake, Franklin, Lee, Chatham, Randolph, Davidson, Davie, Rowan, Iredell, Alexander, Catawba, Polk, Rutherford, Cleveland, Lincoln, Gaston, Mecklenburg, Cabarrus, Stanly, Union, Anson, and Montgomery.

[g] Counties: Loudoun, Arlington, Fairfax, Fauquier, Prince William, Rappahannock, Culpeper, Stafford, Madison, Spotsylvania, Orange, Greene, Albemarle, Louisa, Fluvanna, Hanover, Goochland, Powhatan, Chesterfield, Amelia, Cumberland, Buckingham, Appomattox, Prince Edward, Nottoway, Dinwiddie, Brunswick, Lunenburg, Charlotte, Campbell, Bedford, Franklin, Pittsylvania, Halifax, Mecklenburg, Henry, and Patrick.

Source: McNulty and others (2013).

Table 14—Month-by-month percent of area in dry and wet classes for the baseline year of 2010 and predicted for 2060 in the U.S. Southern Piedmont under Cornerstone C[a]

			Percent of area in driest and wettest classes											
State	Class[b]	Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Alabama[c]	Driest	2010	0	0	0	0	0	64	0	92	0	0	0	0
		2060	0	0	0	0	65	75	17	89	9	0	0	0
	Wettest	2010	100	100	100	1	0	0	0	0	0	0	26	100
		2060	100	100	100	15	0	0	0	0	0	0	15	100
Georgia[d]	Driest	2010	0	0	0	0	0	23	0	64	25	0	0	0
		2060	0	0	0	0	73	52	28	60	41	0	0	0
	Wettest	2010	99	99	62	5	0	0	0	0	0	0	15	67
		2060	97	46	60	6	0	0	0	0	0	0	8	88
South Carolina[e]	Driest	2010	0	0	0	0	0	0	0	21	0	0	0	0
		2060	0	0	0	0	19	13	27	32	0	0	0	0
	Wettest	2010	100	100	81	0	0	0	0	0	0	0	6	43
		2060	100	29	68	0	0	0	0	0	0	0	4	96
North Carolina[f]	Driest	2010	0	0	0	0	0	0	0	8	0	0	0	0
		2060	0	0	0	0	0	1	31	30	0	0	0	0
	Wettest	2010	100	100	100	9	3	0	0	0	1	4	28	76
		2060	100	79	99	9	0	0	0	0	3	4	13	100
Virginia[g]	Driest	2010	0	0	0	0	0	0	10	0	0	0	0	0
		2060	0	0	0	0	0	9	64	76	0	0	0	0
	Wettest	2010	100	100	100	0	0	0	0	0	0	2	92	99
		2060	100	100	60	0	0	0	0	0	0	0	3	100

[a] Each of the four Cornerstone Futures represents a general circulation model (MIROC3.2, CSIROMK3.5, CSIROMK2, and HadCM3) paired with one of two emission scenarios (A1B representing low-population/high-economic growth, high energy use; B2 representing moderate growth and use): C is CS1ROMK2 + B2.

[b] Driest class is ≥700 and wettest class is ≤99 on the Keetch-Byram Drought Index.

[c] Counties: Randolph, Clay, Chambers, Tallapoosa, Coosa, Marshall, De Kalb, Cherokee, Cleburne, Calhoun, Etowah, Winston, Cullman, Walker, Blount, Jefferson, Shelby, St. Clair, and Talladega.

[d] Counties: White, Habersham, Stephens, Franklin, Hart, Banks, Madison, Elbert, Wilkes, Lincoln, Columbia, Warren, Taliaferro, Hancock, Greene, Oglethorpe, Clarke, Jackson, Hall, Forsyth, Dawson, Pickens, Cherokee, Cobb, Paulding, Haralson, Carroll, Douglas, Fulton, De Kalb, Gwinnett, Barrow, Oconee, Walton, Morgan, Putnam, Baldwin, Jones, Jasper, Newton, Rockdale, Clayton, Henry, Butts, Monroe, Lamar, Upson, Pike, Talbot, Harris, Troup, Meriwether, Spalding, Fayette, Coweta, Heard, Dade, Catoosa, Whitfield, Murray, Walker, Chattooga, Gordon, Floyd, Bartow, and Polk.

[e] Counties: Cherokee, York, Oconee, Pickens, Greenville, Spartanburg, Union, Chester, Lancaster, Fairfield, Newberry, Laurens, Anderson, Abbeville, Greenwood, Saluda, McCormick, and Edgefield.

[f] Counties: Warren, Vance, Granville, Person, Caswell, Rockingham, Stokes, Surry, Wilkes, Yadkin, Forsyth, Guilford, Alamance, Orange, Durham, Wake, Franklin, Lee, Chatham, Randolph, Davidson, Davie, Rowan, Iredell, Alexander, Catawba, Polk, Rutherford, Cleveland, Lincoln, Gaston, Mecklenburg, Cabarrus, Stanly, Union, Anson, and Montgomery.

[g] Counties: Loudoun, Arlington, Fairfax, Fauquier, Prince William, Rappahannock, Culpeper, Stafford, Madison, Spotsylvania, Orange, Greene, Albemarle, Louisa, Fluvanna, Hanover, Goochland, Powhatan, Chesterfield, Amelia, Cumberland, Buckingham, Appomattox, Prince Edward, Nottoway, Dinwiddie, Brunswick, Lunenburg, Charlotte, Campbell, Bedford, Franklin, Pittsylvania, Halifax, Mecklenburg, Henry, and Patrick.

Source: McNulty and others (2013).

Table 15—Month-by-month percent of area in dry and wet classes for the baseline year of 2010 and predicted for 2060 in the U.S. Southern Piedmont under Cornerstone D[a]

			Percent of area in driest and wettest classes											
State	**Class[b]**	**Year**	**Jan.**	**Feb.**	**March**	**April**	**May**	**June**	**July**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**
Alabama[c]	Driest	2010	0	0	0	0	0	96	0	79	7	0	0	0
		2060	0	0	0	0	0	91	83	94	3	0	0	0
	Wettest	2010	100	100	95	0	0	0	0	0	0	0	56	100
		2060	100	100	100	0	0	0	0	0	0	0	22	100
Georgia[d]	Driest	2010	0	0	0	0	5	72	0	47	19	0	0	0
		2060	0	0	0	0	6	63	56	61	2	0	0	0
	Wettest	2010	100	100	36	1	0	0	0	0	0	0	21	74
		2060	91	100	89	1	1	0	0	0	0	0	11	74
South Carolina[e]	Driest	2010	0	0	0	0	0	6	0	15	0	0	0	0
		2060	0	0	0	0	0	37	33	29	0	0	0	0
	Wettest	2010	100	100	32	0	0	0	0	0	0	0	6	82
		2060	100	100	100	0	0	0	0	0	0	0	6	57
North Carolina[f]	Driest	2010	0	0	0	0	0	0	0	2	0	0	0	0
		2060	0	0	0	0	0	53	15	14	0	0	0	0
	Wettest	2010	100	100	97	5	3	0	11	0	0	0	21	100
		2060	100	100	100	8	3	0	0	0	0	1	13	100
Virginia[g]	Driest	2010	0	0	0	0	0	0	0	7	0	0	0	0
		2060	0	0	0	0	0	77	44	47	0	0	0	0
	Wettest	2010	100	100	98	0	0	0	0	0	0	2	42	100
		2060	100	100	100	2	0	0	0	0	0	0	2	100

[a] Each of the four Cornerstone Futures represents a general circulation model (MIROC3.2, CSIROMK3.5, CSIROMK2, and HadCM3) paired with one of two emission scenarios (A1B representing low-population/high-economic growth, high energy use; B2 representing moderate growth and use): D is HadCM3 + B2.

[b] Driest class is ≥700 and wettest class is ≤99 on the Keetch-Byram Drought Index.

[c] Counties: Randolph, Clay, Chambers, Tallapoosa, Coosa, Marshall, De Kalb, Cherokee, Cleburne, Calhoun, Etowah, Winston, Cullman, Walker, Blount, Jefferson, Shelby, St. Clair, and Talladega.

[d] Counties: White, Habersham, Stephens, Franklin, Hart, Banks, Madison, Elbert, Wilkes, Lincoln, Columbia, Warren, Taliaferro, Hancock, Greene, Oglethorpe, Clarke, Jackson, Hall, Forsyth, Dawson, Pickens, Cherokee, Cobb, Paulding, Haralson, Carroll, Douglas, Fulton, De Kalb, Gwinnett, Barrow, Oconee, Walton, Morgan, Putnam, Baldwin, Jones, Jasper, Newton, Rockdale, Clayton, Henry, Butts, Monroe, Lamar, Upson, Pike, Talbot, Harris, Troup, Meriwether, Spalding, Fayette, Coweta, Heard, Dade, Catoosa, Whitfield, Murray, Walker, Chattooga, Gordon, Floyd, Bartow, and Polk.

[e] Counties: Cherokee, York, Oconee, Pickens, Greenville, Spartanburg, Union, Chester, Lancaster, Fairfield, Newberry, Laurens, Anderson, Abbeville, Greenwood, Saluda, McCormick, and Edgefield.

[f] Counties: Warren, Vance, Granville, Person, Caswell, Rockingham, Stokes, Surry, Wilkes, Yadkin, Forsyth, Guilford, Alamance, Orange, Durham, Wake, Franklin, Lee, Chatham, Randolph, Davidson, Davie, Rowan, Iredell, Alexander, Catawba, Polk, Rutherford, Cleveland, Lincoln, Gaston, Mecklenburg, Cabarrus, Stanly, Union, Anson, and Montgomery.

[g] Counties: Loudoun, Arlington, Fairfax, Fauquier, Prince William, Rappahannock, Culpeper, Stafford, Madison, Spotsylvania, Orange, Greene, Albemarle, Louisa, Fluvanna, Hanover, Goochland, Powhatan, Chesterfield, Amelia, Cumberland, Buckingham, Appomattox, Prince Edward, Nottoway, Dinwiddie, Brunswick, Lunenburg, Charlotte, Campbell, Bedford, Franklin, Pittsylvania, Halifax, Mecklenburg, Henry, and Patrick.

Source: McNulty and others (2013).

evolution of live fuel moisture conditions. In spring, live fuel moisture values are low until the start of green up. Periods of drought in spring create periods of high fire danger. When live fuel moisture peaks, the moisture content acts as a heat sink, reducing the fire danger. In the autumn, live fuel moistures begin to decrease in many species; this, along with drying from high summer temperatures, brings about the autumn wildfire season. The onset of winter rains typically signals the end of the autumn wildfire season.

In 50 years, Cornerstones A through D all predict that all three sections of the Piedmont would be predominantly in the wettest category from December to March. Under Cornerstone A, almost every acre of the Piedmont would be in the driest category from June through September (table 13), and that the dry season also extends into late spring (May) for the Southern and Ridge and Valley sections. Under Cornerstone B, all sections would be in the driest category in July and August, with the Southern section having a longer dry period extended into June and September and the Ridge and Valley section extended into September (table 13). Under Cornerstone C, the Southern and Ridge and Valley sections would have an extended dry period of May through August, but the Central section's driest period would be in July and August (table 14). Cornerstone D predicts that the dry season for all three sections would be June through August (table 15).

Other Influences on Wildfire Predictions

Results from the four Cornerstone Futures indicate that wildfire potential is likely to increase over the next 50 years. All four predict longer, drier summers and either shorter or similar wetter winters. These drier conditions are likely to result in a prolonged spring wildfire season and an earlier autumn wildfire season. These changes in wildfire potential in the Piedmont would lead to longer fire seasons, especially in the Southern section.

However, for the elevated fire potential to translate to an increase in acres burned requires ignitions. Because the vast majority of southern wildfires are human caused, changes in ignitions are more likely to be closely tied to social issues than to climate. As the population in the Piedmont continues to increase and the wildland-urban interface continues to expand, ignitions caused by human carelessness are likely to increase, creating wildfire conditions that quickly exceed local suppression capabilities.

Outlook for Prescribed Fire

Prescribed fire is an important tool used in the Piedmont to manage hazardous fuels. The potential for an extended wildfire season will magnify the importance of effective fuels management. However, the same drying that is extending the wildfire season could also limit the ability to use prescribed fire because the drier conditions would likely increase both the potential for escaped fires and the potential for fires to harm resources. Dry conditions promote increased fuel consumption, which increases emission levels. If air quality standards continue to tighten, efforts to protect the health of growing populations could include further constraints on prescribed fire. Air quality issues could result in restricted burning over large areas, not just in the wildland-urban interface.

One of the key indicators of air quality is whether monitoring shows compliance with the national air quality standards established by the Environmental Protection Agency (EPA). Although the EPA does not directly regulate the use of prescribed fire, it is responsible for enforcing the sections of the Clean Air Act that govern attainment and maintenance of the national ambient air quality standards. Although nitrogen oxides from prescribed burning are not of concern on a local level, they combine with other emissions and contribute to ozone formation that may be a concern—with a consistent overlap between urban areas and areas of nonattainment. Ozone and particulate levels are generally at their lowest ambient levels during the prescribed burning season (winter and early spring) in the Piedmont (Stanturf and Goodrick 2013). But occasionally growing season (summer) burns are recommended for ecological reasons, a practice that would be limited in areas—such as Charlotte, NC and the Atlanta metropolitan area—that are designated as nonattainment for ozone and particulates.

Because of their size, wood smoke particulates scatter light and reduce visibility. Standards for particulate matter have been trending toward increasing stringency since 1971 (Stanturf and Goodrick 2013), with current thresholds of 35 $\mu g/m^3$ averaged for any 24-hour period and 15 $\mu g/m^3$ averaged over a full year. Recent annual and 24-hour ambient $PM_{2.5}$ levels for the States east of the Mississippi River and south of Virginia are displayed in figures 48 and 49. Although current ambient levels for most of the Piedmont are below national standards, one monitoring site near Birmingham has exceeded the annual threshold $PM_{2.5}$ level, and several sites near Birmingham and Atlanta have come close to reaching 24-hour threshold $PM_{2.5}$ levels.

The Piedmont exemplifies the problems of mixing urbanized land uses with fire-adapted natural vegetation. With increasing urban development, fragmentation of the landscape occurs and expands the wildland-urban interface, thus causing challenges to conducting prescribed burns. Urbanization constrains traditional forest management and concerns for transportation safety constrain the use of prescribed burning even at the wildland end of the wildland-urban gradient. In areas closer to the urban end of the gradient, these concerns greatly increase often resulting in abandonment of fuel management and increased risk of

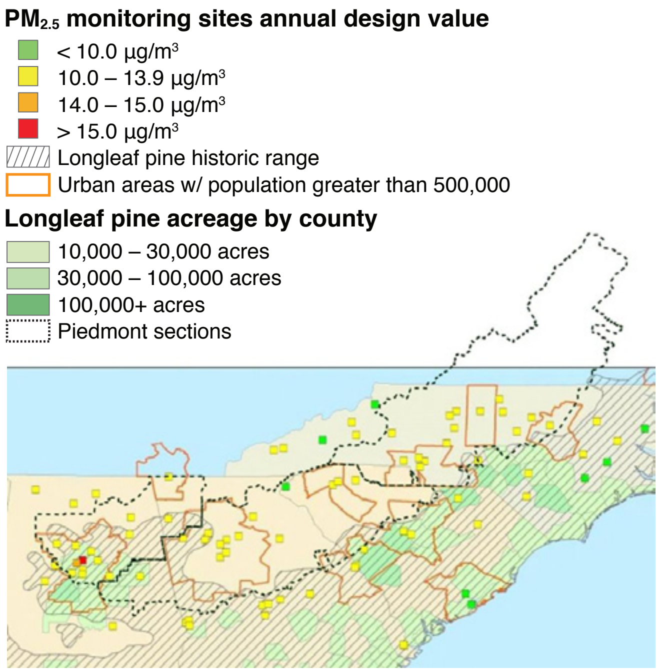


Figure 48—Annual average ambient air concentrations at particulate-matter ($PM_{2.5}$) monitoring sites, 2007 to 2009, for States participating in the Southeast Regional Partnership for Planning and Sustainability; concentrations calculated according to the Clean Air Act regulations for comparison to the National Ambient Air Quality Standards (Source: Southeast Regional Partnership for Planning and Sustainability 2010; map created by Darren Palmer).

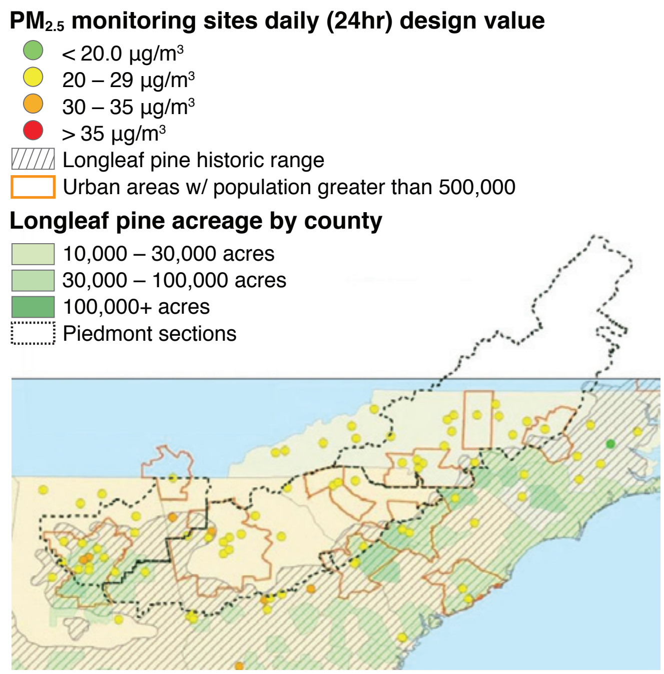


Figure 49—Twenty-four-hour average ambient air concentrations at particulate-matter ($PM_{2.5}$) monitoring sites, 2007 to 2009, for States participating in the Southeast Regional Partnership for Planning and Sustainability; concentrations calculated according to the Clean Air Act regulations for comparison to the National Ambient Air Quality Standards (Source: Southeast Regional Partnership for Planning and Sustainability 2010; map created by Darren Palmer).

occurrence and severity of inevitable wildfires. Because of its extensive road system, the whole Piedmont could be regarded as a wildland-urban interface, at least in terms of managing smoke from prescribed burning. This transportation system presents a challenge, even though most burns are carried out without incident. The relatively few burns that have caused smoke and smoke/fog visibility obstructions resulted in numerous accidents with loss of life and personal injuries, especially at night when smoke can drift or inversions entrap smoke near the ground.

Even when continued forest management is feasible, further constraints on prescribed burning will be likely in the wildland-urban interface because of the health risks from smoke. The biggest health threat from wood smoke appears to come from fine particles, which can impact outdoor workers, firefighters, and emergency-response workers as well as vulnerable populations (the very young, pregnant women, the elderly, and individuals with pre-existing respiratory and cardiac conditions) at considerable distance from a prescribed burn.

CHAPTER 9. Societal Benefits from Forests

WATER

Water (supply and quality) is a critical issue for the Piedmont. The headwaters of most of the major river basins on the southern Atlantic seaboard rise in the Piedmont. Major river basins that drain from the Piedmont include: Black Warrior, Coosa, Tallapoosa, Chattahoochee, Altamaha, Savannah, Catawba, Santee, Pee Dee, Neuse, Roanoke, James, and Rappahannock.

The 2005 U.S. Geological Survey Water Use Survey (Kenney and others 2009) estimated that Piedmont counties withdrew 24 billion gallons per day, with only 2 percent coming from groundwater sources. In contrast to the rest of the South, most of the water withdrawn in the Piedmont (88 percent) was used in thermoelectric power generation. The second largest category (9.5 percent) was public and domestic water supplies. Agriculture and industry combined accounted for about 2.4 percent of total water withdrawals. Although irrigation was the largest consumptive use southwide, it was negligible in the Piedmont (Lockaby and others 2013).

The Cornerstone projections of increasing population, urban land use, and decreasing forest cover suggest several general trends. Overall demand for water will likely increase with rising population. Increasing urban area and decreasing forest cover would increase water yield (reduced evapotranspiration loss) but could also alter hydroperiods, thereby reducing overall water availability for consumption. Finally water quality issues will likely become more critical with increased urban runoff that is likely to elevate levels of physiochemical, microbiological, and pharmaceutical pollutants in some streams. The effects would have significant impacts in the Piedmont but would also be manifest in the lower reaches of primary Coastal Plain watersheds. In addition to drinking water quality, these pollutants carry negative implications for recreational use of waters, biotic integrity of streams, and human health. Such impairment of water quality in the Piedmont would be primarily from urban land use, not forestry.

Weidner and Todd (2011) developed U.S. indices of the importance of surface drinking water by 12-digit Hydrologic Unit Codes (HUCs), and of the importance of forest cover to surface drinking water (FIMP). The FIMP index combines a measure of dependence on drinking water with the proportion of forest cover in the HUC watershed using a scale of 0 to 100. High index values indicate critical dependence as a water source combined with significant forest cover. The most important areas of the Piedmont where forest cover is associated with surface drinking water supply tend to be close to the fall line separating the Piedmont from the Coastal Plain (fig. 50). Other critical areas are in Virginia (north of Richmond) and Georgia (west of Atlanta). Weidner and Todd (2011) also projected housing density through 2030 and combined it with the data on forest cover and importance of forests to drinking water supply. The result was an index of the development threats to forest cover that have impacts on drinking water (fig. 51). These projections highlight pressures west and north of Atlanta, in metropolitan Birmingham, east of Richmond in Virginia, and in metropolitan Raleigh in North Carolina.

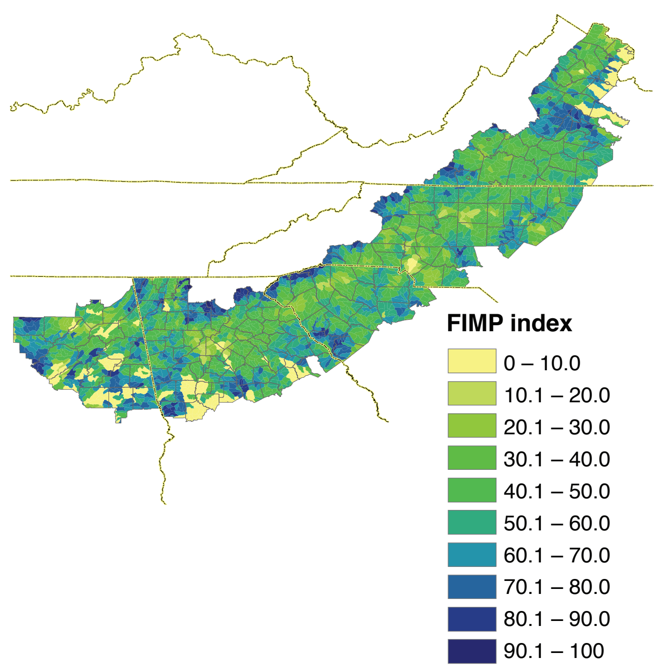


Figure 50—Estimated index of forest importance to surface drinking water supply (FIMP) in the Southern U.S. Piedmont; the scale of the index is 0 to 100, with high index values indicating more critical dependence (Source: Weidner and Todd 2011).

Relatively little forest land in the Piedmont is considered protected from development—merging the Protected Areas Database (Conservation Biology Institute 2010) with the National Land Cover Dataset from 2006 (Fry and others 2011) resulted in an estimate of 2,623,756 acres of protected forests (about 8.5 percent of total forest cover). National forests in the Piedmont are the largest single category and cover 1,193,236 acres (USDA Forest Service 2011). This leads to the conclusion that private forest ownership and management are critical to maintaining quality drinking water supplies.

Lockaby and others (2013) described projections of a water supply stress index (WaSSI) in the South. WaSSI is the ratio of total water demand to total supply in a watershed and considers all water use, not just drinking water, compared against estimated supply. For example, in the Pamunkey watershed (HUC 02080106) in Virginia, use is currently estimated to be 82.2 percent of available water supply. Figure 52 shows WaSSI values projected to 2050 using Cornerstone projections of changes in forest cover, population, and climate. Areas with high WaSSI values remain a concern into the future, especially in areas surrounding Atlanta.

Concerns about water quality and the regulatory authorities provided by legislation such as the Clean Water Act have prompted a number of active responses including water quality monitoring and reporting, zoning, permitting for water withdrawals and discharges, and regional and watershed planning. Forest protection, as a strategy to address water issues, has been relatively limited. Although most of the protected lands in the Piedmont are in national forests, other types of protection are underway. Falling Waters LLC, for example, has over 7,000 acres under easement in the Virginia Piedmont as a mitigation bank. Mitigation banking is an open market system that trades ecological functional value as an offset to development impacts on water and wildlife. Mitigation bank project areas are scattered throughout the Piedmont. Conceivably, increasing demand for development will provide a market incentive to set aside more forested areas in protected status.

Although the primary concern addressed in Lockaby and others (2013) is conversion of forest land to other uses, water quality can also be affected by forest management activities. Currently, water quality impacts are managed by application of forestry best management practices, which are voluntary in all the Piedmont States. Each State uses a standard protocol for compliance monitoring and reporting. The average implementation rate for the South was 87 percent (Southern Group of State Foresters 2008) in the most recent reporting period. A detailed analysis of implementation in North Carolina (North Carolina Division of Forest Resources 2011) measured compliance rates across subregions and found that compliance in the Piedmont was higher than in the Appalachian Mountains. Aust and others (1996) found that in Virginia the per-acre cost of implementation

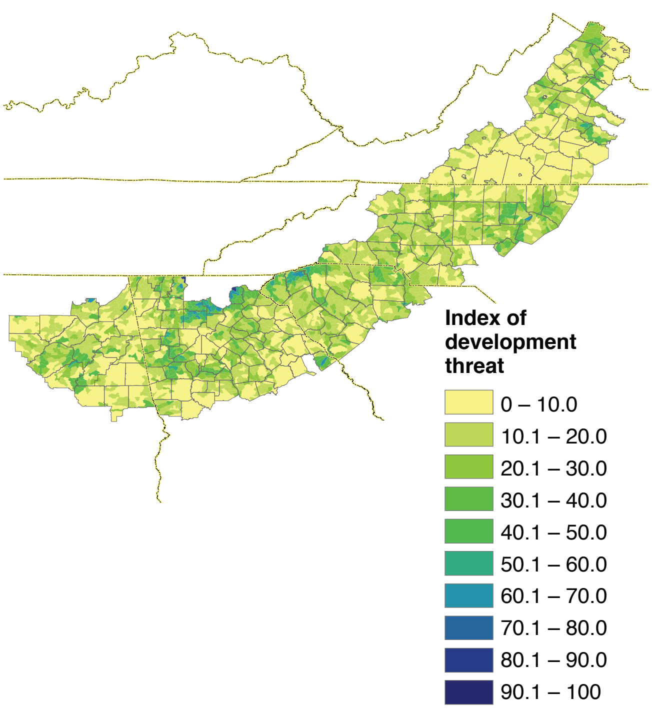


Figure 51—Index of development pressure on forests and drinking water supply, 2030, in the Southern U.S. Piedmont; the scale of the index is 0 to 90, with high index values indicating higher pressure (Source: Weidner and Todd 2011).

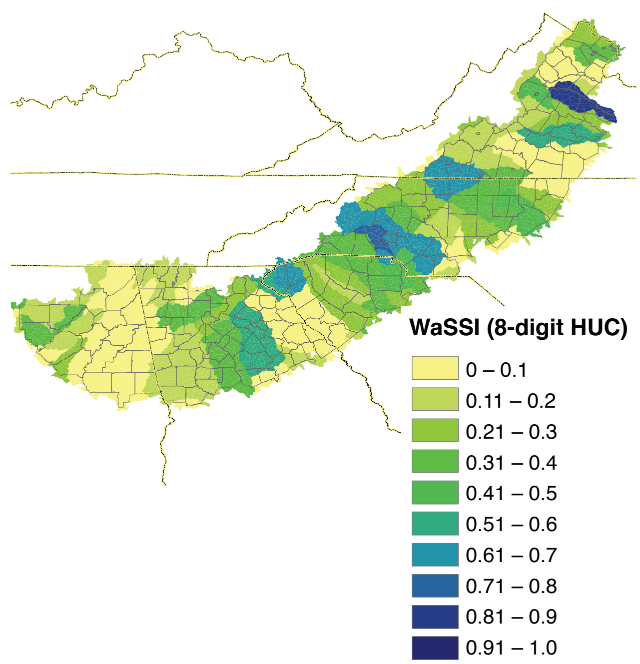


Figure 52—Projected water supply stress index (WaSSI) values, in 2050, for the watersheds (defined by 8-digit Hydrologic Unit Codes) of the Southern U.S. Piedmont; the WaSSI scale is 0 to 1, with high index values indicating high stress.

was higher—but the benefit-to-cost ratio was nearly 2-to-1—in the Piedmont compared to the Coastal Plain or the Appalachian Mountains. This shows the importance of compliance in the mitigation of water quality impacts during forest operations and treatments.

FOREST PRODUCTS MARKETS

Changes in forest products markets were examined by considering two contrasting alternatives (Wear and others 2013b): a "low gross domestic product" scenario of weak growth (Cornerstones C, D, and F), or a "high gross domestic product" scenario of strong economic and population growth (Cornerstones A, B, and E). Wear and others (2013b) examined potential changes in southern forest products markets under these conditions.

Historically, the South has provided a major component of national forest products output. However from 1998 to 2009 the forest industry experienced an adjustment phase of reduced demand and increased timber supply. Overall pulpwood production capacity is level-to-declining. Lumber and panel output has been soft because of a sustained housing crisis. Although long-term demand for housing is expected to eventually support growth in the solid products sector, a prolonged delay in economic recovery could result in a structural change (loss of capacity) in the forest products industry.

Analysis of the Cornerstone Futures shows that timber harvesting is projected to expand through 2025. Under constant-demand assumptions, timber removals would level off beyond 2025; under expanding-demand assumptions and enhanced productivity, timber removals would continue to grow through 2055. Softwood pulpwood pricing is forecast to be weak-to-declining under all Cornerstones, but sawtimber and hardwood product values would experience significant increases. These general projected trends reflect a decrease in hardwood supply in the Piedmont (the result of urbanization-driven forest losses) coupled with increased softwood supply from plantation expansion, mostly in the Coastal Plain but also some in the Piedmont as several million acres of pines are planted after timber harvesting operations.

To display the spatial distribution of forest-loss—supply-contraction, a removal intensity index was developed by dividing Forest Inventory and Analysis growing stock removal values for 2005 by forest area (100 cubic feet per acre). Assuming level demand into the future, we calculated removal intensity for all Piedmont counties in 2050 under a scenario of high growth and high timber prices. We then used a ratio of current-to-future intensity to identify the counties where forest removal intensity would have to increase to maintain current levels of output (fig. 53). This increase could result from increased management intensity on existing acres or expansion of timber removal to a larger percentage of the total forest area. Forest products companies that draw supply from high-ratio counties will likely face challenges from increasing competition and rising prices. This scenario is a simplistic approach to identify areas of potential challenge for the existing forest products industry.

Most of the high index counties (those with a removal intensity of >75 percent increase) are located in Georgia (44 counties), North Carolina (17 counties), and Virginia (10 counties). In 2005 the harvest removals from these counties represented 31 percent of the total Piedmont harvest. In the Central section (Virginia and North Carolina) the impact would mostly affect hardwood production, supporting the finding by Wear and others (2013b) that urbanization pressures would impact hardwood sawtimber utilization more than softwood. In the Southern and Ridge and Valley sections, however, the impact would be greater on softwood supply.

Another key question that will shape the forest products industry is the nature of future demand. Growing population is expected to drive demand for building products but questions remain about the type of housing and the potential substitution of concrete, steel, and other materials for wood. Paper products are less susceptible to substitution, but the per capita demand for paper products can change with innovations in technology and packaging. Wear and others (2013b) concluded that the "future of timber markets will largely be determined by demand growth that would emerge

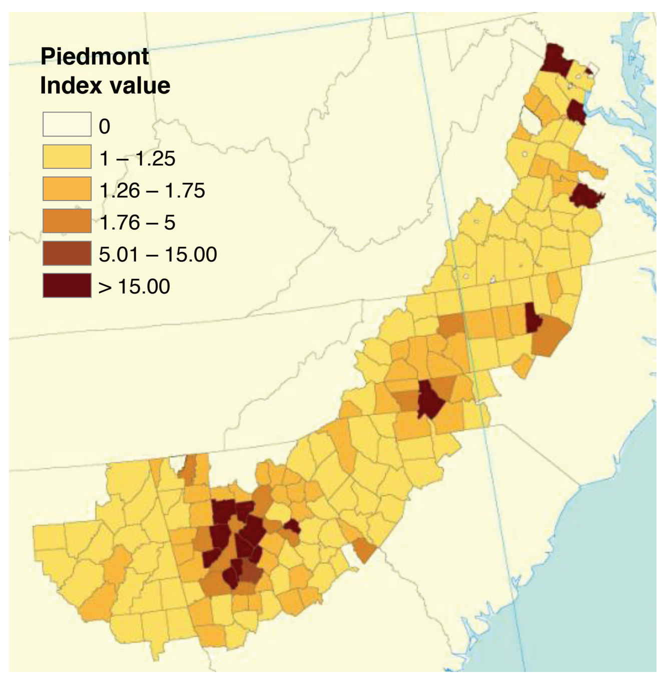


Figure 53— Projected timber removal intensity for 2050 under a scenario of high growth and high timber prices—highlighting counties where forest loss will increase competition assuming constant demand; the index scale is 0 to 20.00, with high index values indicating the highest removal level.

primarily from the requirements of forest fiber inputs to supply biobased energy."

BIOENERGY

A growing bioenergy industry in the South would be congruent with the Cornerstone Futures that include increasing timber prices (Cornerstones A and C) and by Cornerstone E, which also includes higher planting rates in response to market demands.

The Piedmont is a large energy consumer, both for electricity and transportation fuels. Based on per capita consumption rates (U.S. Energy Information Administration 2011) and population data, the Piedmont used 8.8 billion gallons of transportation fuel and about 205 billion kilowatts per hour of electricity. Power plants generated about 340 billion kilowatts per hour in 2005, suggesting the Piedmont is currently a net exporter of electric power. About 75 percent of Piedmont electric generation came from coal or natural gas.

Alavalapati and others (2013) pointed out that future electricity production could be partially sourced from renewable materials including woody biomass. Two States in the Piedmont currently have renewable portfolio standards with very different provisions. In Virginia, the voluntary goal is that 15 percent of electricity consumption will be sourced from renewables by 2025. Interestingly, the Virginia legislation caps the amount of woody biomass that can be used at 1.5 million green tons per year. North Carolina requires that 12.5 percent of consumption be from in-State based renewable generation and efficiency measures after 2021. Woody biomass would only be one of many biomass feedstocks that could be used to comply with these standards.

In a baseline reference case, the U.S. Energy Information Administration (2011) estimated that woody biomass could account for about 7 percent of total electricity generation by 2035. This level of use would be consistent with State goals for renewable portfolio standards. With projected electricity demand, Piedmont electricity consumers would need about 76 million green tons per year of woody biomass for power production—about half of the total southern woody biomass demand described by Alavalapati and others (2013) under the "low-consumption" scenario. The U.S. Energy Information Administration estimates that most of the woody biomass electrical generation will be at end-user locations (forest products facilities) rather than in dedicated biomass power plants. Some of the feedstock demand could be sourced from Piedmont forests to supply regional generation plants. However, by 2050 this level of woody biomass demand would exceed current harvest removals from all Piedmont forests.

Industrial pellet production is also expanding in the South (Alavalapati and others 2013). However, because most of the current pellet production is for export, pellet facilities tend to be located in the Coastal Plain where transport links to port facilities are available. For example, in southern Virginia and northeastern North Carolina three new export pellet plants produce about 1.5 million tons of pellets per year requiring about 3.5 million tons of wood. These facilities are situated just below the fall line and are expected to draw some of their wood supply from boundary counties in the Piedmont. Pellet production capacity is expected to significantly increase as the European Union moves towards its target of 20 percent renewable energy by 2020.

Renewable energy in the form of liquid fuels is also expected to be a part of the future for southern forestry. The Renewable Fuel Standard included in the Energy Independence and Security Act of 2007 requires 21 billion gallons of cellulosic or advanced biofuel production by 2022. The Billion Ton Update (U.S. Department of Energy 2011) estimated that by 2022, the requirement could be met by a combination of agricultural (36 percent), forest (17 percent), and energy crop (47 percent) feedstocks. If the forest-based feedstocks were sourced in a similar distribution as current forest products, the Piedmont might be producing 10 million dry tons per year of woody feedstock for liquid fuel production. Liquid fuel production technologies are uncertain; however production facilities are likely to be sited near feedstock supplies and with access to water and product distribution networks. These constraints would suggest that liquid fuel feedstock demands would more likely occur near the fall line.

Bioenergy demand for woody feedstock offers both benefits and challenges for Piedmont forests. The additional resource values that could develop with a bioenergy market could help mitigate forest loss in the face of urbanization pressures. Increasing wood bioenergy use might help reduce the environmental impacts of expanding population by offsetting fossil carbon emissions and reducing air quality problems associated with coal-based electrical generation. Conversely, increasing demand for woody biomass to meet energy needs could increase competition for fiber in the forest products industry, resulting in price increases, particularly for lower valued products such as pulpwood. Alavalapati and others (2013) noted that bioenergy markets are generally beneficial for sawtimber producers because they provide additional value in byproducts without directly competing for the standing timber.

TAXES AND POLICY

Tax policy alters the relative return from alternative land uses, thereby influencing their financial viability and ultimately changing the mix of land use. Federal income tax provisions recognize the unique nature of forest management and provide special allowances for operational expenses and long-term capital gain treatment of timber income. In addition, current use valuation for State property tax assessments explicitly discourages land-use changes that are driven by potential property values, as noted by Greene and others (2013). These examples show that tax policy has not been blind to the economic impact of taxes on forest management and ownership.

Greene and others (2013) noted that taxes rank with timber-harvesting returns and rotation length in determining the viability of forest management investments. Taxes have the effect of reducing the financial returns from forest land, thus reducing its economic value. The Federal income tax alone reduces land values by about 20 percent; in the South, State and local taxes reduce it, on average, by an additional 15 percent (Greene and others 2013). Of the Piedmont States, North Carolina and Georgia have the highest estimated total tax burden, exceeding 40 percent of land expectation value. Both of these States also have higher-than-average income and property taxes. Alabama, with a low overall tax structure, has the lowest total tax burden at about 29 percent of land expectation value.

Further, tax policy was a key driver of the dramatic shifts in forest industry ownership of forest land described by Butler and Wear (2013). Investment groups have different tax structures than corporate or individual owners of forest land. Investment groups also have certain constraints that affect how they manage forest assets to maximize returns to investors. This ownership shift presents challenges to sustainable management that include increased forest fragmentation and parcelization, forest land conversion and development, and increased liquidity of forest assets resulting in more frequent turnover and harvesting and loss of stability in forest products markets. The Federal tax legislation that defines the rules for investment groups date back to the 1960s and was not drafted with an intent to impact forest management. However, an evolving tax code and changes in the financial and portfolio management of the forest products industry led to large-scale divestiture of industry lands with the associated impacts.

Future Federal income tax policy is unlikely to be driven by any regional concerns such as Piedmont forest loss. Recent political proposals have included options as varied as shifting to a value-added tax, simplification of the Federal tax code, flat taxes, reduced corporate tax rates, increased personal tax rates, and changes in capital gains treatment. Any of these changes could have dramatic impacts on forest ownership and management in the Piedmont.

State tax policies are more likely than Federal policies to respond to regional issues including loss of forest land. State support for current use valuation treatment of forest land is clearly a response to local concern about land-use change. If Piedmont forests decrease at the rates predicted by Wear (2013)—1 in 5 forest acres under the high-loss scenario—how would States respond? One possibility would be to increase public land acquisition or conservation, either through direct purchase or policy support (such as tax credits) for nonprofit organizations. Alabama's Forever Wild program and South Carolina's Heritage Trust program are examples of existing State programs that have increased conservation acreage in the Piedmont through direct purchase. However, given increasing competition for State budget resources, land acquisition programs are unlikely to expand significantly. States would be more likely to seek collaborative solutions to achieve conservation objectives. Virginia's Land Conservation Fund, for example, uses a grant program to leverage State funds with external funds.

Although future direction in tax policy through the period covered by this report is impossible to estimate, taxes will undoubtedly be both a challenge and a potential solution to the forces of change as tax policy evolves to address social and political issues. These changes could clearly exacerbate forest-land loss. However tax policy, primarily State tax codes, can also be used to mitigate pressure on forest land and encourage conservation.

SOCIAL/ECONOMIC CONDITIONS

Population and Urbanization

From 1990 to 2000 the population of the Piedmont increased from 13.8 to 16.7 million (21 percent), with large urban areas growing the fastest. For example, from 2000 to 2010 Atlanta's population increased 24 percent, and Raleigh-Durham area in North Carolina increased 33 percent (the highest rate of any U.S. metropolitan area from 2000 to 2010). Population density ranged from 10 to >6,500 people per square mile in the most populated counties (fig. 54). The number of counties with density >150 people per square mile increased while the number of counties with density <150 people decreased. Lang and Dhavale (2005) found that only 67 percent of megapolitan populations reside in urbanized Piedmont areas compared to a national average of 86 percent, suggesting that urbanization in the Piedmont is somewhat unique in the United States and that the existing megapolitan space could have room for additional urban "build-out."

The Cornerstone Futures are based on two primary population trends from the Intergovernmental Panel on Climate Change (2007)—an A1B storyline of high population growth and economic development and a B2 storyline of moderate economic and population growth. All the Cornerstone Futures predict a significant increase in the population of the South with the Piedmont experiencing the largest increases in population density. Piedmont population is projected to increase from 20.5 million to 27.3 million with moderate growth and to 30.1 million under high growth. The expanding population will likely be concentrated in and around existing urban centers with increases both in the density of existing

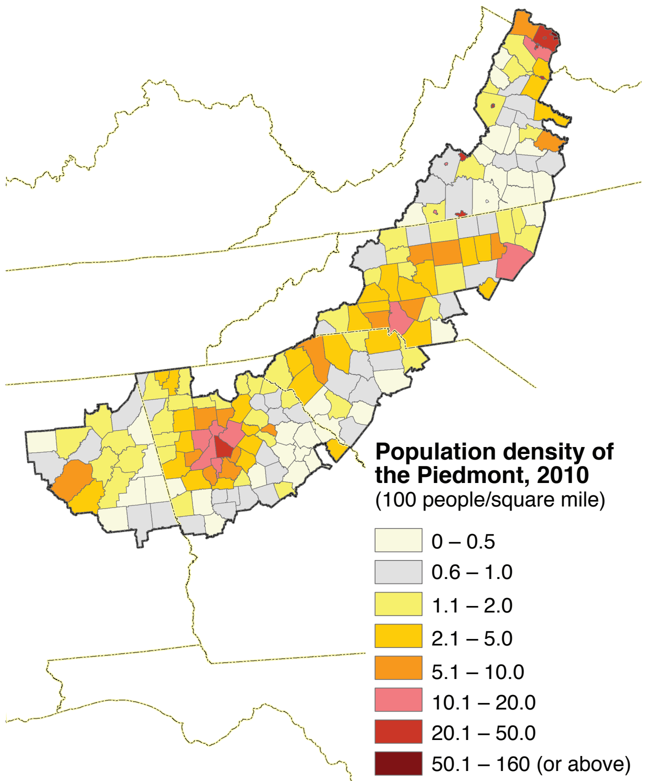


Figure 54—Population density in the Southern U.S. Piedmont, 2010.

urban areas and in the area of urban development (fig. 55). Under the high growth storyline, 13 Piedmont counties would more than double in population compared to only four counties under the moderate growth storyline.

Urban growth is driven in part by economic opportunity. Urban population grows because people find employment and amenities in the cities that they do not have in rural areas. This prompts questions about interactions between an increasingly urban and affluent population and Piedmont forest land.

Jobs and Economic Activity

In 2009 average per capita income in the Piedmont was $32,000 (U.S. Department of Commerce Bureau of Economic Analysis 2011), primarily derived from a diverse economy. The Atlanta metropolitan area, for example, had a gross domestic product of about $272 billion, with almost half in business and financial services. The metropolitan areas that include the Piedmont acreage had a total gross domestic product of about $1.3 trillion in 2010 (about 10 percent of the total national output).

Forest-related economic activity includes logging and forestry work, wood products manufacturing, pulp and paper

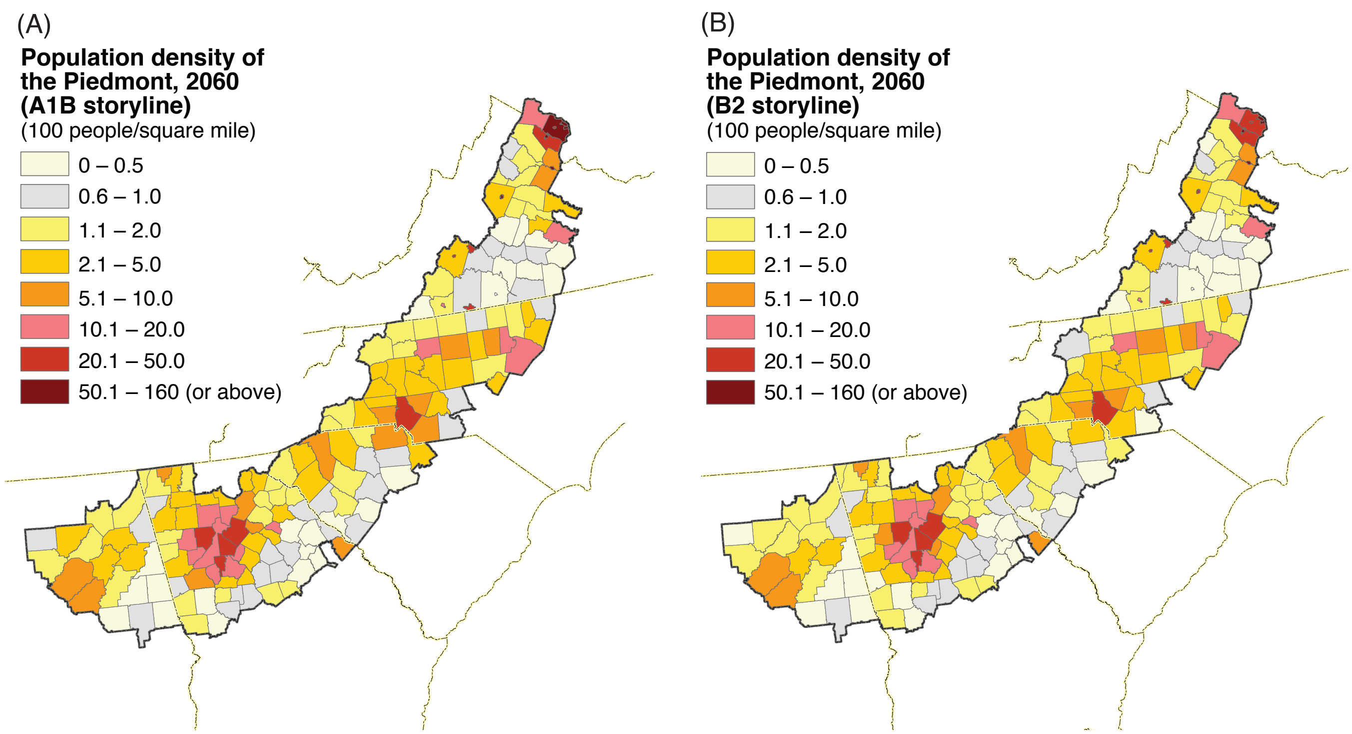


Figure 55—Population density in the Southern U.S. Piedmont, 2060 assuming one of two emissions storylines (A) the high economic growth and high population growth of storyline A1B and (B) the moderate economic and population growth of storyline B2 (Source: Intergovernmental Panel on Climate Change 2007).

manufacturing, and forest-based recreation. Although Abt (2013) found that wood-related manufacturing comprised <1 percent of southern jobs and income in 2008, forest products manufacturing companies often offer higher wages than other regional occupations. The national average hourly wage was about $24 per hour for paper manufacturing (NAICS 322) and about $17 per hour for wood products manufacturing (U.S. Bureau of Labor Statistics 2012). Average logging wages (NAICS 311) ranged from $13 to $18 with supervisory jobs as high as $24 per hour. Direct economic contribution of wood-related manufacturing and logging totaled about $117 billion in 2009 for the entire South. Based on the Piedmont's relative contribution to total U.S. wood production, wood-related manufacturing in the Piedmont could amount to about $23 billion in direct economic benefits.

Piedmont forests currently provide a wide range of social and economic values including timber, wildlife, recreation, esthetics, and clean water. Even as the total acres of forest land have slightly decreased, the growing stock inventory has increased (table 16). In 2005 Piedmont forests supported removal of 1.6 billion cubic feet of timber (59 percent softwood, 41 percent hardwood). This is about 10 percent of total U.S. timber production and mirrors the southwide production allocation between hardwood and softwood. The Piedmont has 379 sawmills (fig. 56) that are well distributed, with every county of the Piedmont within 50 miles of at least five facilities. It has nine pulpmills (fig. 56) located in the western Ridge and Valley section and at the North Carolina-Virginia border in the Central section. All Piedmont counties are within 100 miles of a pulpmill.

Forest-based recreation is an additional economic generator derived from southern forest resources, offering a range of outdoor opportunities (Bowker and others 2013, Cordell and others 2013) and income opportunities that include lodging and guest receipts, recreational equipment sales, transportation and vehicle expenditures, and recreational fees. Almost 80 percent of southern adults engage in some form of outdoor recreation. From National Recreation Survey data, Bowker and others (2013) estimate that southern adults had 672 million days of participation in developed site use in 2008. The resulting employment and economic impact however is difficult to estimate because many of the services are not tied to a single recreational pursuit.

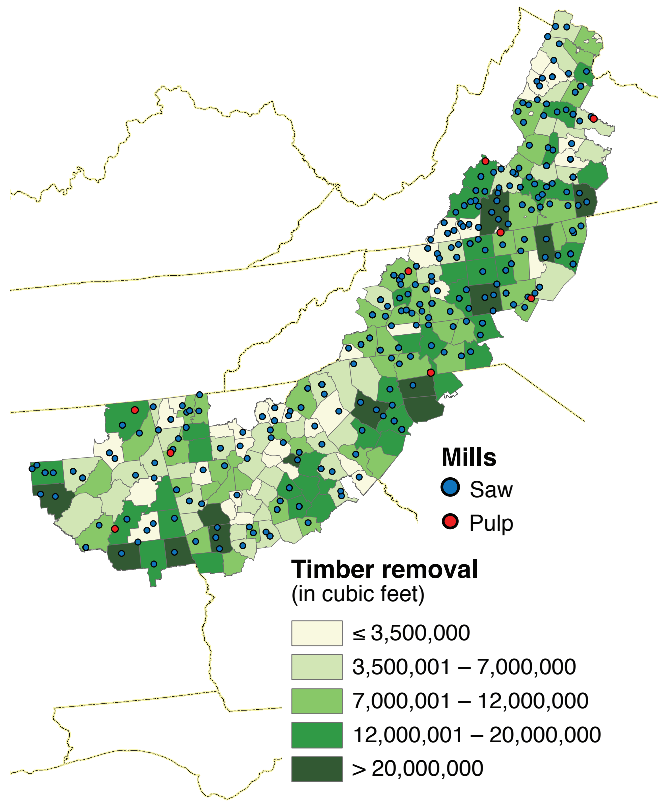


Figure 56—Timber removals and location of pulp and saw mills in the Southern U.S. Piedmont, 2005.

Table 16—Growing stock inventory from the early 1980s to 2007 in the forests of the Southern U.S. Piedmont and its sections—Central Appalachian Piedmont, Southern Appalachian Piedmont, and Piedmont Ridge, Valley, and Plateau

Geographic area	Growing stock			Change 1980s to 2007	Average annual change
	Early 1980s	Early 1990s	2007		
	---------- billion cubic feet ----------			---------- percent ----------	
Central	19.5	22.8	23.2	19.4	0.7
Southern	16.7	18.0	20.4	22.0	0.8
Ridge and Valley	5.5	5.8	7.1	29.8	1.1
All Piedmont	41.6	46.6	50.7	21.8	0.8
All South	222.1	239.1	292.3	31.6	1.2

Piedmont forests will undoubtedly continue to provide direct employment in managing, harvesting, and processing forest products. Abt (2013) suggested that logging employment could increase out to 2018 but that total wood-related manufacturing employment would likely decrease. Coupled with population growth, this would cause the economic impact of forestry employment to continue decreasing as a percent of the total Piedmont economy. To the extent that forest recreation-based jobs are a function of total population and per capita recreational demand, total expenditures for forest-based recreation would increase. Although Bowker and others (2013) noted that ≥75 percent of southern adults participate in outdoor recreation of one sort or another, Abt (2013) concluded that growth of outdoor recreation will likely be at a slower rate than population growth because of changes in the types of outdoor recreational activities available and technical advances in the way recreation is produced.

Piedmont forests will likely provide the highest value for society through the critical ecosystem services of clean water and air, wildlife habitat, and landscape esthetics. For a growing percentage of the population, Piedmont forests are not likely to provide direct employment. However, to the extent that a connection is made, everyone arguably benefits from general ecosystem services. Heal (1999) pointed out that assigning a value for forest ecosystem services is difficult. The public is accustomed to getting those benefits for free. Will the projected loss of Piedmont forest land (4 to 6 million acres) reduce the supply of ecosystem services to a point where a market price develops? More likely, would the loss of forest land create enough public demand that a transfer payment (such as a subsidy or tax benefit) to forest owners would be established to promote retention of forests? For this to occur, the issue of identifying and communicating the value of forests to society at large will be critical.

CONCLUSIONS

Piedmont forests will likely decline over time in response to growing population and urbanization. The society that evolves in the Piedmont will be faced with the effects of forest loss. This report highlights water quality and water supply from forests, recreational opportunities, wildlife habitat changes, and increasing competition for traditional forest products industries. None of these changes appear to be consequential enough to tip the balance in favor of forest area conservation over higher valued urban development.

Two possible approaches could counter the forest losses posited in this report. The first would be to maintain or enhance the economic value of forest land. Clearly forest losses are associated with the relative value of forest products. Cornerstone C, with moderate urbanization and increasing timber prices, would result in a 13-percent forest loss compared to the 20-percent loss that would result from weak timber prices. This is not to say that forest value must come from commercial timber production. Any land-use or policy structure that enhances economic return to ownership and management would have a similar effect. Potential bioenergy markets could provide new economic returns from forests. The limitation of this strategy is that most forests at the fringe of urban areas are often fragmented and seldom in productive forest management. They will likely continue to be divided and converted because of the difficulties in finding economically viable options for keeping them forested. One exception may be forest areas that have high recreational value because of their proximity to urban centers. Such forest areas may also attract advocacy groups that bring value beyond simple economic return (i.e., user fees).

A second approach that could have more impact in the urban fringe is conservation through policy and regulation. For example, one policy tool—current use tax valuation—directly addresses the issue of land-use changes that are driven by potential property values. Other policy tools like zoning or greenspace requirements could also be employed. However all of these approaches require a political consensus for action. Will an urbanizing Piedmont population be sufficiently concerned about forest values to support regulation that restricts private property rights or that provides for transfer payments to forest landowners? The types of changes forecast in this report suggest that developing such a consensus could be difficult.

Climate change forecasts need to consider changes in precipitation and air temperature together. For the Piedmont, precipitation is predicted to decrease and air temperature is predicted to increase over the next 50 years. As air temperature rises, water use also increases. With a decrease in precipitation and an increase in air temperature, water shortages would be more frequent and droughts would occur (or continue), thus reducing streamflow. This would stress trees, making them more susceptible to insects and disease. Species composition—not only trees but also other flora and fauna—could change as a result, and those species that are more tolerant of warmer and drier conditions would prevail. Also, water supplies for the growing populations in the Piedmont would be limited, possibly leading to more water restrictions.

Forecasts of human population growth and urban expansion (Wear 2013) raise the possibility of a substantial impact on forest species and the communities that support them. Continued growth in the Piedmont would increase the number of threats associated with infrastructure development, water development, land conversion, and other effects of an urbanizing population. The number of species negatively affected by the loss of forest is expected to increase. The geographic pattern of richness and imperilment results in a clustering of many species into identifiable areas of unique richness. Under the Cornerstone B projections of urban growth and associated forest loss, the overlap of these areas with hot spots of imperiled species could become the focus of conflicts between advocates of development and species conservation and management.

Substantial urban growth in the Piedmont could reduce the richness of amphibians and mammals. Management of species on public lands could be hindered by the pressures of expanding human populations in surrounding counties, while the smaller (and shrinking) tracts typical of private ownership would offer few opportunities for sustainable forest management. Plants in transitional communities, such as the escarpments and foothills of northern South Carolina or the southern extensions of the Piedmont in northern Alabama and adjacent Georgia, also are at-risk from habitat loss and climate change.

The Piedmont has an exceptionally high diversity of salamanders—amphibians whose ecology is strongly influenced by temperature and precipitation. Significant losses are projected for the high elevation habitats of these and other species existing at their thermal maxima (Griep and Collins 2013). Forest amphibians associated with cool, moist conditions could be subject to microclimates beyond their tolerance. Ephemeral streams and ponds could be especially vulnerable to drying with variable precipitation patterns, thus affecting habitat limitations of several taxonomic groups.

Forest communities in the Piedmont would also be influenced by changes in fire frequency. Although some species of fire-maintained ecosystems might benefit from more frequent fires, urban growth around major cities would probably override climate change effects in many of these ecosystems.

The problem of invasive plants is an issue that is not diminishing. In the next 50 years the area of invasives is projected to increase from the current 19 million acres to 27 million acres. This conservative estimate does not take fully into account the growing effects of land disturbances, fragmentation, parcelization, and urbanization on the spread of invasive plants, or effects of potential climate changes. Of the five species evaluated with the general circulation models, none were close to their potential full extent.

With few exceptions, diseases and harmful insects associated with southern host species are expected to migrate with their hosts. The exceptions are those pests that already occur throughout the South and extend into northern areas of the United States. Longer and warmer summertime temperatures are expected to increase pathogen and insect activity. Insect populations might increase with increases in the availability of the host materials on which they browse, or might be able to produce an additional generation each year.

The potential for an extended wildfire season magnifies the importance of effective fuels management. Because natural wildfires have been limited both by an aggressive fire suppression effort and by forest fragmentation, prescribed burning plays a critical ecological role in promoting wildlife habitat and restoring and maintaining the integrity of fire-dependent forest and grassland communities in the Piedmont. However, the same drying that is extending the wildfire season could also limit the use of prescribed fire because of a likely increase in the potential for escaped fires and harm to resources. But the biggest threat to the continued use of prescribed burning comes from the effects of smoke on public health, transportation safety, and air quality. Dry conditions promote increased fuel consumption and consequently increased emissions. If air quality standards continue to tighten, these added emissions could prompt further constraints on use of prescribed fire to protect the health of the growing population.

The future of prescribed burning in the Piedmont is problematic. Changing land use and demographics have increased the numbers of people and the value of structures in close proximity to “wildlands,” thus increasing the extent of the wildland-urban interface.

A final note, Piedmont forests are a clear reminder of resiliency. The current forests that are so clearly valued in the Piedmont are the legacy of resource exploitation, severe environmental damage from past agricultural practices, and ultimately human intervention. Land-use practices in the early 1900s prompted the development of science-based forest management. Successful development of sustainable forest industries supported local economies, enhanced forest values to society, and provided a reason to keep forests on the landscape. This set of conditions is changing as forests contribute less to the regional economy, fewer jobs depend on forest products, and traditional forest industries face global competition. The management of the Piedmont’s forest resources should be considered if the subregion is to continue to benefit from the ecological and economic services and make forests relevant to its citizens and their future generations.

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The Piedmont, a complex physiographic subregion of the U.S. South, encompasses parts of Virginia, North Carolina, South Carolina, Georgia, and Alabama. Anticipating the future and analyzing what the interaction of future changes might mean for the forests of the Piedmont and the services they provide can improve decisions by resource managers and policymakers that have long-term consequences. The authors extracted and analyzed detailed results from the Southern Forest Futures Project to provide a set of key findings and implications for the Piedmont. The general conclusion of this analysis is that Piedmont forests will likely decline over time in response to growing populations and urbanization. Over the next several decades the Piedmont will be faced with the effects of forest loss, including changes in water quality and water supply from forests, recreational opportunities, wildlife habitat, and increasing competition for traditional forest products industries.

Keywords: Climate, forest conservation, futuring, integrated assessment, Piedmont, Southern Forest Futures Project, sustainability, urbanization.

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