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Outlook for Mississippi Alluvial Valley Forests:

A SUBREGIONAL REPORT from the Southern Forest Futures Project

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Cover photos

MAIN IMAGE: Flower of trumpet honeysuckle (*Lonicera sempervirens*), a native honeysuckle of bottomland hardwood forests (Shelley Griffin). TOP ROW LEFT TO RIGHT: Crossvine (*Bignonia capreolata*) in flower (Shelley Griffin); fruit of Alabama supplejack (*Berchemia scandens*), a common vine in bottomland hardwood forests (Shelley Griffin); flooded black willow (*Salix nigra*) forest on the Mississippi River (Rebecka McCarthy); pondberry (*Lindera melissifolia*), the only Federally endangered plant native to the Mississippi Alluvial Valley (Emile Gardiner); and American alligator (James Henderson, Golden Delight Honey, Bugwood.org).

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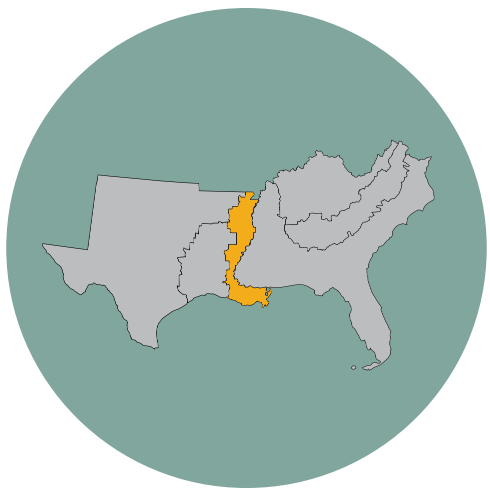

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PROLOGUE

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This report describes a set of likely forest futures and the management implications associated with each for the Mississippi Alluvial Valley, one of five subregions of the U.S. South. Its findings are based on the findings of the Southern Forest Futures Project, a multi-agency effort to anticipate the future and to analyze what the interaction of future changes might mean for forests and the benefits they provide in the 13 Southern States. The Futures Project investigators examined a labyrinth of driving factors, forest outcomes, and human implications to describe how the landscape of the South might change. Their findings, which are detailed in a 17 chapter technical report (Wear and Greis 2013) and synthesized in a compact summary report (Wear and Greis 2012), consist of analyses of specific forecasts and natural resource issues. Because of the great variations across southern forest ecosystems, the Futures Project also draws out findings and management implications for each of five subregions (fig. P1) including the one addressed in this report.

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

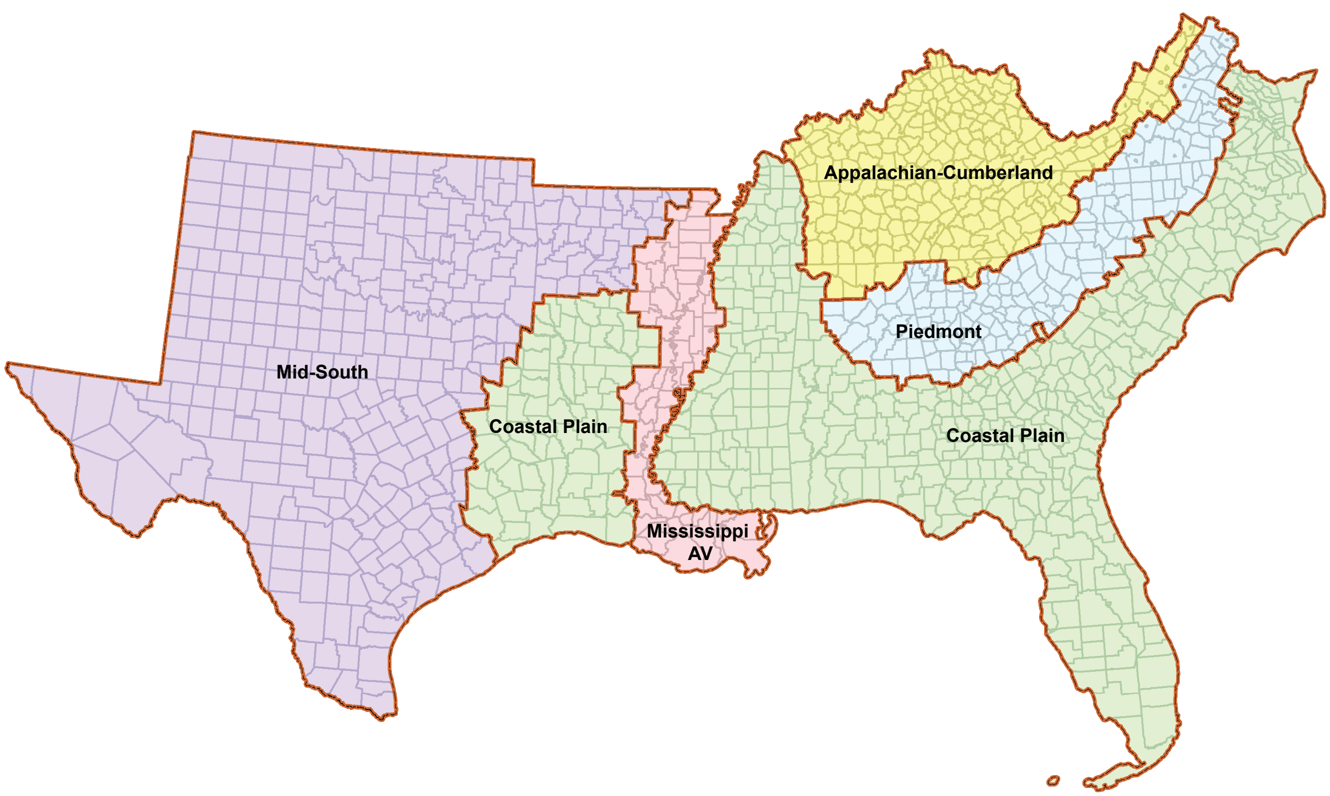

Figure P1—The five subregions of the U.S. South.

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

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

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

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

Designing the Futures Project

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

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

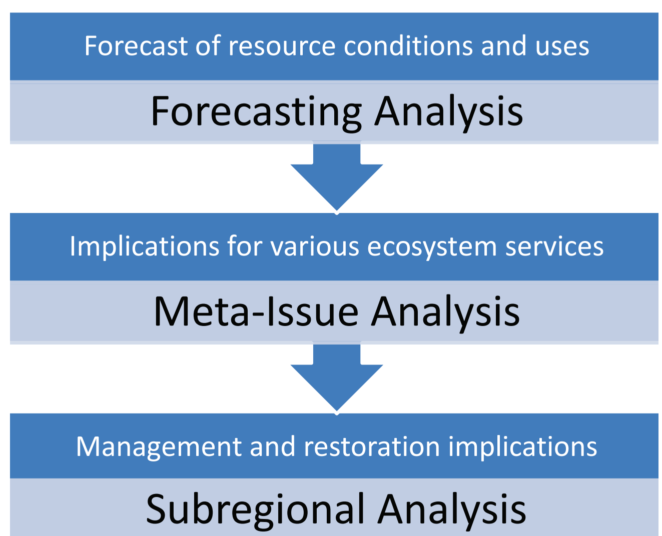

Figure P2—The three phases of the Southern Forest Futures Project.

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

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

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

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

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

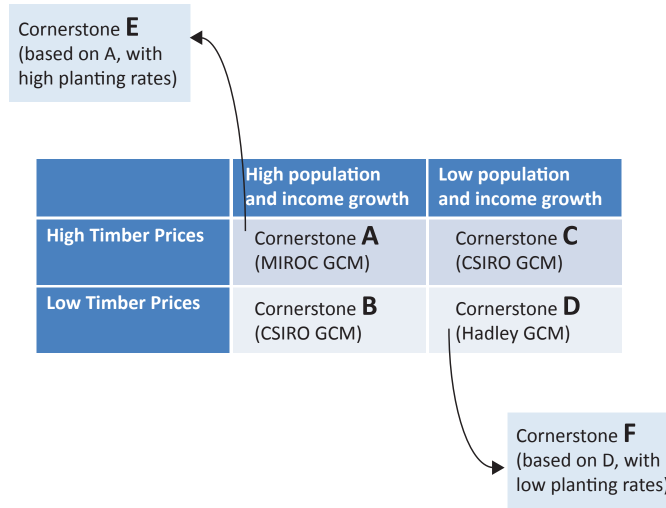

Figure P3—Six Cornerstone Futures, each of which represents a general circulation model (MIROC3.2, CSIROMK3.5, CSIROMK2, or HadCM3) paired with one of two emission scenarios (A1B representing high-population/high-economic growth, high energy use, and B2 representing low growth and use) and two timber price futures; and then extended by evaluating forest planting rates above and below current levels. Sources: Intergovernmental Panel on Climate Change (2007), U.S. Department of Agriculture Forest Service (2012).

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

This report draws together the findings from the 17 chapters of the Southern Forest Futures Project technical report (Wear and Greis 2013) to isolate the findings of most critical consequences for management and policy decisionmaking within the Mississippi Alluvial Valley. 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 Mississippi Alluvial Valley.

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.

LITERATURE CITED

Intergovernmental Panel on Climate Change. 2007. IPCC fourth assessment report: climate change 2007 (AR4). http://www.ipcc.ch/publications_and_data/publications_and_data_reports.htm. [Date accessed: March 3, 2013].

U.S. Department of Agriculture (USDA) Forest Service. 2012. Future of America's forest and rangelands: Forest Service 2010 Resources Planning Act Assessment. Gen. Tech. Rep. WO-87. Washington, DC. 198 p.

Wear, D.N.; Greis, J.G., eds. 2002a. The Southern Forest Resource Assessment: technical report. Gen. Tech. Rep. SRS-53. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 635 p.

Wear, D.N.; Greis, J.G. 2002b. The Southern Forest Resource Assessment: summary report. Gen. Tech. Rep. SRS-54. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 103 p.

Wear, D.N.; Greis, J.G.; Walters, N. 2009. The Southern Forest Futures Project: using public input to define the issues. Gen. Tech. Rep. SRS-115. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 17 p.

Wear, D.N.; Greis, J.G., eds. 2012. The Southern Forest Futures Project: summary report. Gen. Tech. Rep. SRS-168. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 54 p.

Wear, D.N.; Gries, J.G., eds. 2013. The Southern Forest Futures Project: technical report. Gen. Tech. Rep. SRS-178. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 542 p.

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ABSTRACT

The Mississippi Alluvial Valley, which can be broadly subdivided into the Holocene Deposits section and the Deltaic Plain section, is a 24.9-million-acre area generally approximating the alluvial floodplain and delta of the lower Mississippi River. Its robust agricultural economy is maintained by a largely rural population, and recreational resources draw high visitation from nearby urban centers. The Mississippi Alluvial Valley forms a key corridor for migratory animals, and the Mississippi River has been developed as a vital conduit of commerce for much of North America. Although forest land use currently makes up only 28 percent of the Mississippi Alluvial Valley, bottomland hardwood forests and coastal swamps remain invaluable for producing forest products, sustaining biodiversity, providing recreational opportunities, and performing essential ecosystem services. Forecasts generated by the Southern Forest Futures Project provide science-based projections of how alternative futures of economic growth, population growth, climatic patterns, and a range of forest threats could drive potential trajectories of land use, forest conditions, water resources, recreational resources, and wildlife habitats across the Southern Region. This report identifies findings from the Southern Forest Futures Project that are relevant to the Mississippi Alluvial Valley, expands on the relevant findings through additional science synthesis and analysis, and outlines noteworthy implications of the alternative futures to forest-based resources and ecosystem services of the Mississippi Alluvial Valley.

Keywords: Bottomland hardwood forests, coastal swamps, forest threats, land use, Lower Mississippi Alluvial Valley, LMAV, Mississippi Alluvial Plain, Mississippi Delta, Southern Forest Futures Project.

KEY FINDINGS

Climate

- Average annual temperatures are projected to rise by 1.2 to 2.9 °C within the Mississippi Alluvial Valley through 2060.

- The largest increases in average annual temperature for the Mississippi Alluvial Valley are likely to occur in the Holocene Deposits section where a 1.3 to 3.2 °C rise could be realized by 2060.

- Average annual precipitation for the Mississippi Alluvial Valley is forecasted to decrease by 1 to 24 percent through 2060.

- The largest decreases in average annual precipitation for the Mississippi Alluvial Valley are projected for the Holocene Deposits section where a 2 to 24 percent decrease could be realized by 2060.

- Average annual precipitation forecasts for the Deltaic Plain section range from an 11 percent increase to a 25 percent decrease.

Wildfire

- Compared to other areas of the U.S. South, the Mississippi Alluvial Valley experiences a low incidence of wildfire; from 1997 to 2002, fire impacted about 0.5 percent of forests in the Holocene Deposits section and 0.03 percent in the Deltaic Plain section.

- Forty percent of wildfires reported in the Mississippi Alluvial Valley occurred during the autumn months of September, October, and November; the remaining 60 percent were equally distributed across the winter, spring, and summer.

- Forecasted shifts towards a hotter and dryer climate through 2060 are likely to raise the potential for wildfire over much of the Holocene Deposits section, particularly in Arkansas.

- The Deltaic Plain section of the Mississippi Alluvial Valley is not expected to experience a substantial rise in wildfire risk.

Land Use

- The most substantial change in the distribution of acreage among land use categories in the Mississippi Alluvial Valley would likely occur under a future of high population and economic growth along with increasing timber prices.

- Deforestation is likely to persist in the Mississippi Alluvial Valley, but future clearing would be driven by urbanization not agricultural development.

KEY FINDINGS *(continued)*

- Although agriculture will likely continue to be the primary land use in the Mississippi Alluvial Valley, the acreage used for this purpose is expected to decrease through 2060.

- Increased urbanization is expected to drive the largest shift in land use within the Mississippi Alluvial Valley over the next 50 years.

- For the Holocene Deposits section, decreases in forest acreage would be highest under a future of high population and economic growth coupled with weak timber prices.

- Futures of increasing timber prices could mitigate deforestation in the Holocene Deposits section by deflecting urbanization demands to agricultural land; however, the same relationship would not hold for the Deltaic Plain section where agricultural land occupies a smaller proportion of the landscape.

- Urbanization is expected to claim substantial forest acreage in the Deltaic Plain section; all forecasts predict that the proportion of forest land in this section will decrease below 50 percent of the total land base within the next decade.

Invasive Plants

- Twenty-one high priority nonnative plant taxa currently cover >3.1 percent (206,782 acres) of all forests in the Mississippi Alluvial Valley.

- Currently occupying an estimated 112,000 acres, Japanese honeysuckle is the most pervasive nonnative plant in the forests of the Mississippi Alluvial Valley.

- Currently occupying 37,000 acres, tallowtree is the most widespread and abundant nonnative tree in the Mississippi Alluvial Valley and the most prevalent nonnative plant in the Deltaic Plain section.

- The invasiveness of nonnative plants in the Mississippi Alluvial Valley will depend on taxa-specific potentials to respond to changing temperature and precipitation patterns, shifting land use patterns, human population growth, and other key factors.

- Range expansion of tallowtree into more northerly forests of the Mississippi Alluvial Valley would be most likely under relatively high air-temperature increases coupled with decreased average annual precipitation.

- The potential invasiveness of Japanese climbing fern, nonnative roses, and Nepalese browntop could decline in the Mississippi Alluvial Valley under relatively high air-temperature increases coupled with decreased average annual precipitation.

- Suitable habitats remain available for increased forest occupation by previously naturalized nonnative plants, imparting continuing ecological degradation and economic loss in the Mississippi Alluvial Valley.

KEY FINDINGS *(continued)*

Insect and Disease Pests

- Activities of particular insect and disease pests indigenous to the Mississippi Alluvial Valley are not expected to increase simply in response to the changing climate conditions that are projected for the next 50 years.

- Lowland forests of the Mississippi Alluvial Valley are aging and have been degraded through alteration of natural hydrologic regimes; these factors increase biotic and abiotic stresses that predispose forests to increased occurrence of complex decline and dieback syndromes.

- Nonnative insect and disease pathogens established elsewhere in the United States are likely to create forest health issues in the Mississippi Alluvial Valley within the next 50 years.

- Once established in the Mississippi Alluvial Valley, emerald ash borer and other specialized nonnative pests could bring dire consequences to forest health and sustainability through acute damage that results in widespread elimination of their hosts.

- The gypsy moth and other host generalists would inflict chronic damage to forest health and sustainability of the Mississippi Alluvial Valley through recurring attacks that reduce vigor and render host susceptible to secondary abiotic or biotic stresses.

Forest Conditions

- Forecasts for the Mississippi Alluvial Valley project that the change in forest acreage could range from a 5.8-percent loss to a 2.1-percent gain, depending on trajectories of population and economic growth, timber prices, and investment in plantation establishment.

- Area managed for planted pine is forecasted to increase by 103,650 to 500,475 acres through 2060; decreases are expected for other management types.

- Total growing stock volumes of softwood are expected to increase in the Mississippi Alluvial Valley, but total volume is expected to decrease because hardwoods constitute a much larger proportion of total growing stock.

- Net expansion in forest acreage in the Mississippi Alluvial Valley would likely be limited to the Holocene Deposits section.

- Volume of hardwood growing stock in the Holocene Deposits section is forecasted to decrease by 4.5 to 16 percent by 2060.

- In contrast to the Holocene Deposits section where a strong economy and increasing timber prices would spur an increase in forest acreage, the Deltaic Plain section is projected to lose 4 to 22 percent of its forested acreage through 2060.

- As the Deltaic Plain section experiences losses of forest acreage, the inventory of hardwood growing stock volume could decrease as much as 28 percent by 2060.

KEY FINDINGS *(continued)*

Wildlife and Forest Communities

- Pressure from urbanization, coupled with decreasing timber prices, could drive additional deforestation of the remnant 130,000 acres of species-rich, higher elevation alluvial sites in the Holocene Deposits section; they are highly productive for agriculture and desirable for urbanization, and therefore poor candidates for substantial forest restoration.

- Coastal baldcypress-water tupelo swamps of the Deltaic Plain section are vulnerable for nearly complete degradation and loss from urbanization as well as altered hydrologic and sediment regimes, land subsidence, and sea-level rise.

- The engineered stability of the lower Mississippi River will minimize channel migration and sediment accretion along channel margins but could also jeopardize the sustainability of the surviving 255,500 acres of eastern cottonwood and black willow forests in the Mississippi Alluvial Valley.

- Harmful logging practices and urban development are likely to degrade and shrink a substantial amount of the surviving 2,372,700 acres of oak-dominated lowland forests in the Mississippi Alluvial Valley.

Water Resources

- Water supply stress in the Mississippi Alluvial Valley is currently low to moderate (< 0.6 on the WaSSI).

- Change in the water supply stress index in the Mississippi Alluvial Valley through 2050 will more likely be driven by shifting climate factors than by shifts in land use or future population dynamics.

- A 2.1 °C rise in average annual temperature and 183 mm decrease in precipitation would increase water supply stress over the entire Mississippi Alluvial Valley, with localized surges approaching 200 percent by 2050.

- A 1.2 °C rise in average annual temperature and an 83 mm decrease in precipitation would have relatively minor impact on the water supply stress over most of the Mississippi Alluvial Valley, and could reduce water supply stress in the Deltaic Plain section and over localized areas in the southern Holocene Deposits section by 2050.

- Regardless of climate change forecast, portions of the Mississippi Alluvial Valley currently experiencing the highest water supply stress are generally not expected to experience the largest increases in future water supply stress.

- Although urban land use is expected to grow by 72 to 112 percent by 2050, water supply stress is forecasted to be minimally affected by this factor for the Mississippi Alluvial Valley and its associated sections.

- Impacts to water supply stress resulting from population growth will likely range from 10 to 100 percent in localized areas of the Deltaic Plain section of the Mississippi Alluvial Valley, and generally be more severe than in the Holocene Deposits section.

KEY FINDINGS *(continued)*

Energy from Forest Biomass

- Five industrial facilities generate electricity and two facilities manufacture fuel pellets from hardwood processing waste produced in the Mississippi Alluvial Valley; one company markets verifiable carbon offsets derived from hardwood plantations.

- Development of a bioenergy market is not anticipated to substantially impact future hardwood sawtimber prices, inventories, or removals through 2050.

- Prices for pulpwood and other (nonsawtimber) hardwoods are projected to rise with increased consumption by bioenergy markets; prices could exceed 2007 values by 200 percent if bioenergy consumption reaches moderate-to-high levels.

- Inventories of pulpwood and other (nonsawtimber) hardwoods are expected to remain relatively stable, but removals could increase through 2050 if bioenergy consumption reaches high levels.

- The Mississippi Alluvial Valley appears ideal for forging a bioenergy industry based on biomass feedstocks produced in short rotation woody crop systems, but progress has been stalled by the combination of low economic returns and few government incentives.

Outdoor Recreation

- Forecasted population growth in the Mississippi Alluvial Valley would increase demand for outdoor recreation through 2060, more markedly in the Deltaic Plain section (versus the Holocene Deposits section) where the current population density is higher and future growth could approach 750 persons per square mile.

- The biggest loss of forest-based recreational resources will likely occur in the Deltaic Plain section where deforestation driven by urbanization could claim 11 to 25 percent of current forested acreage.

- Although privately held forest acreage is projected to decrease, provisions are in place to increase the amount of publicly held forest acreage in the Mississippi Alluvial Valley.

- Adult participation in most outdoor activities common in the Mississippi Alluvial Valley is expected to increase through 2060, but the course of per capita participation in many of these activities will depend on population growth, economic development, demographical changes, and land use changes.

CHAPTER 1.
The People and Forests of the Mississippi Alluvial Valley

The lower Mississippi Valley is an expansive physiographic feature centrally located in the southernmost portion of the United States. It begins at the confluence of the upper Mississippi and Ohio Rivers, and flanks the Mississippi River southward to its mouth at the Gulf of Mexico. Along this expanse, the lower Mississippi Valley extends between 29° and 37° north latitude and from 89° to 92° west longitude encompassing parts of Illinois, Missouri, Kentucky, Tennessee, Arkansas, Mississippi, and Louisiana.

For the purpose of this report, sampling and inference were drawn on a 24.9-million-acre area of the lower Mississippi Valley in Tennessee, Arkansas, Mississippi, and Louisiana (fig. 1). This assessment area, designated as the Mississippi Alluvial Valley, is one of five subregions in the Southern United States—along with the Coastal Plain, Mid-South, Piedmont, and Appalachian-Cumberland highlands—and includes 1 Tennessee county, 22 Arkansas counties, 11 Mississippi counties, and 30 Louisiana parishes (table 1). Counties and parishes of the lower Mississippi Valley are defined as part of the subregion if ≥50 percent of their land base occurs in its physiographic area. As a result of this classification procedure, some counties having substantial acreage in the lower Mississippi Valley were not included in the subregional analyses of the Mississippi Alluvial Valley; likewise, some counties having substantial acreage in other physiographic areas were included.

LANDFORMS AND SOILS

The lower Mississippi Valley is confined within the Atlantic Plain Physiographic Region, bounded on the east by the East Gulf Coastal Plain and on the west by the West Gulf Coastal Plain and the Interior Highlands (Fenneman and Johnson 1946). Gradually sloped with elevation decreasing only about 350 feet over its length (Brown and others 1973), it consists of two broad units (table 1, fig. 2) that are defined by origin and age of surface features (Saucier 1994). The Mississippi Alluvial Plain is predominated by braided-stream terraces of the late Pleistocene Epoch (Early and Late Wisconsin age, about 12,000 to 75,000 years ago) and alluvial sediments of the Holocene Epoch (<12,000 years ago) (Saucier 1974, 1994). The Deltaic Plain is built on sediments discharged from the Mississippi River and its distributaries primarily during the Holocene Epoch (Saucier 1974, 1994).

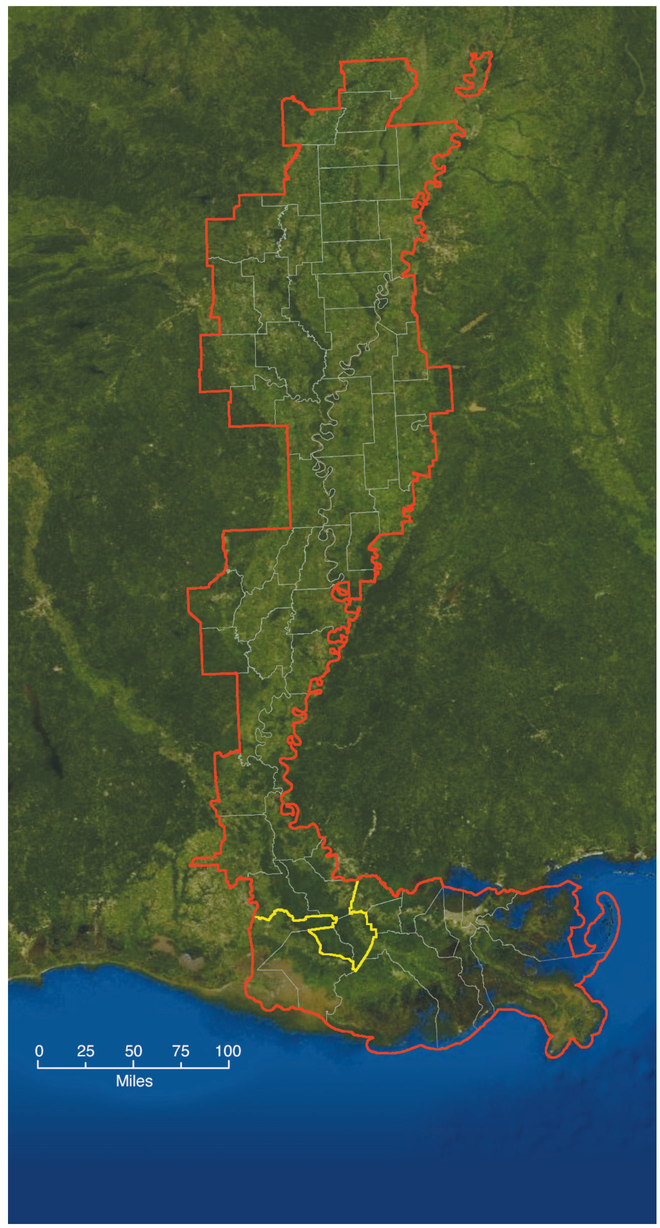

Figure 1—Range and extent of the U.S. Mississippi Alluvial Valley (red outline) and the counties that it encompasses (white outlines). Yellow line separates the Holocene Deposits section from the Deltaic Plain section.

Table 1—Counties and land area of counties forming the U.S. Mississippi Alluvial Valley, and its associated sections, Holocene Deposits and Deltaic Plain

	Holocene Deposits section		Deltaic Plain section	
State (acres)	**County name**	**Acres**	**County name**	**Acres**
LOUISIANA (10,940,397)	Assumption	216,756	Ascension	186,578
	Avoyelles	532,758	Iberia	368,082
	Caldwell	338,825	Jefferson	196,170
	Catahoula	450,333	Lafourche	694,192
	Concordia	445,381	Orleans	115,556
	East Carroll	269,721	Plaquemines	540,516
	Franklin	399,109	St. Bernard	297,624
	Iberville	395,929	St. Charles	181,529
	Madison	399,414	St. James	157,524
	Morehouse	508,317	St. John the Baptist	140,092
	Ouachita	390,737	St. Mary	392,187
	Pointe Coupee	356,698	Terrebonne	803,152
	Richland	357,409		
	St. Landry	594,334		
	St. Martin	473,504		
	Tensas	385,588		
	West Baton Rouge	122,369		
	West Carroll	230,014		
Total acres for section		**6,867,194**		**4,073,203**
ARKANSAS (9,881,923)	Arkansas	632,631		
	Chicot	412,176		
	Clay	409,149		
	Craighead	454,935		
	Crittenden	390,505		
	Cross	394,140		
	Desha	489,591		
	Greene	369,604		
	Jackson	405,454		
	Jefferson	566,279		
	Lawrence	375,402		
	Lee	385,063		
	Lincoln	359,168		
	Lonoke	490,213		
	Mississippi	574,877		
	Monroe	388,252		
	Phillips	443,308		
	Poinsett	484,951		
	Prairie	413,396		
	St. Francis	405,654		
	White	661,776		
	Woodruff	375,399		
Total acres for section		**9,881,923**		**0**
MISSISSIPPI (3,969,630)	Bolivar	560,819		
	Coahoma	354,656		
	Humphreys	267,576		
	Issaquena	264,359		
	Leflore	378,832		
	Quitman	259,096		
	Sharkey	273,734		
	Sunflower	444,024		
	Tallahatchie	412,108		
	Tunica	291,076		
	Washington	463,349		
Total acres for section		**3,969,630**		**0**
TENNESSEE (104,587)	Lake	104,587		
Total acres for section		**104,587**		**0**

Source: Forest Inventory and Analysis, Southern Research Station, U.S. Forest Service.

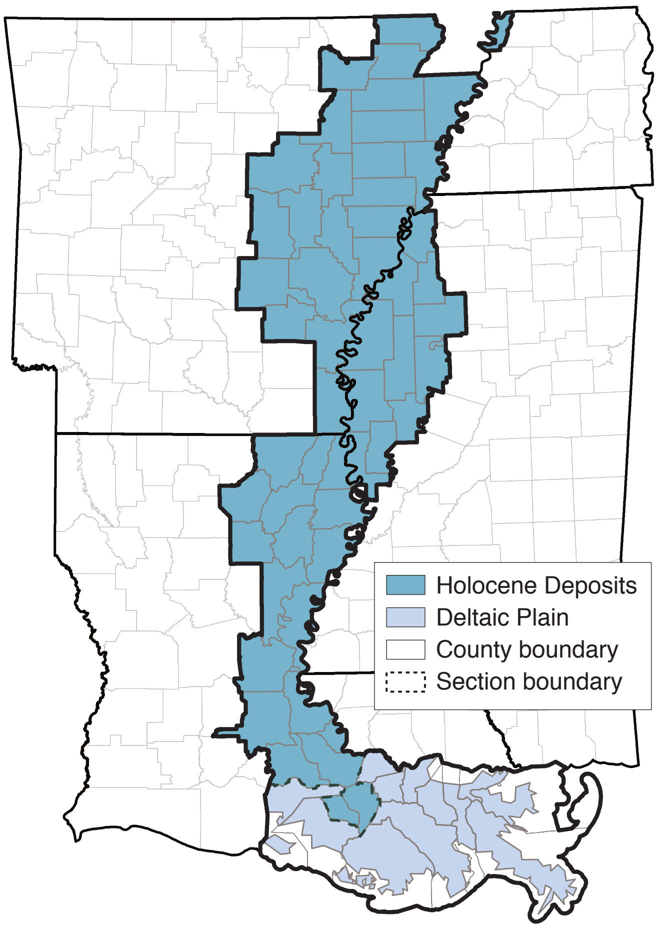

Figure 2—Range and extent of the Holocene Deposits section and the Deltaic Plain section of the U.S. Mississippi Alluvial Valley.

The Mississippi Alluvial Plain encompasses six major drainage basins—the Western Lowlands, the St. Francis Basin, the Arkansas Lowland, the Yazoo Basin, the Boeuf Basin, and the Tensas Basin—that are separated by the Mississippi River and remnant uplands and terraces including Crowley's Ridge, the Grand Prairie, and Maçon Ridge (Saucier 1994). Crowley's Ridge—a Tertiary Period (>1.6 million years ago) upland capped with younger fluvial and loess deposits—is the oldest feature in the Mississippi Alluvial Plain, and may have divided the Ohio and Mississippi River valleys (Saucier 1994). The Grand Prairie is a broad, flat terrace created by the Arkansas River during the Pleistocene Epoch; Maçon Ridge is an upland feature consistent with glacial outwash during the Early Wisconsin Age (Saucier 1994). The Deltaic Plain consists of the Atchafalaya Basin, Pontchartrain Basin, Barataria Basin, and the Terrebonne Marsh; these are broad interdistributary lowlands separated primarily by distributary ridges (Saucier 1994). For this project, the Mississippi Alluvial Plain is represented by a 20.8-million-acre area designated the Holocene Deposits section, and the Deltaic Plain is represented by a 4.1-million-acre area designated the Deltaic Plain Section. Although the Atchafalaya Basin is a component of the Deltaic Plain, it was included in the Holocene Deposits section for the purposes of this report because of similarities in soils and forest types.

Surface features in the major river and interdistributary basins result from fluvial processes that occur during channel migration (Hodges 1997). Natural levees (fronts, ridges, swales, flats, sloughs, and oxbow lakes) are characteristic of a meandering river channel. Soils that develop on these topographic features reflect depositional environments, drainage characteristics, and inundation regimes (Hodges 1997, Stanturf and Schoenholtz 1998). Entisols, Inceptisols, and Alfisols are characteristic of the fronts and ridges in the Mississippi Alluvial Plain, where sands and silts precipitate out of relatively high-energy stream environments (Aslan and Autin 1998). Vertisols form at slackwater and depressional sites—including flats, swales, and sloughs—where clays precipitate from relatively low-energy environments (Aslan and Autin 1998). These same soil orders are predominant in the Deltaic Plain, but Histosols also develop in marsh and swamp environments of southern Louisiana. Older upland and terrace features in the Mississippi Alluvial Plain, such as Crowley's Ridge, Maçon Ridge and the Grand Prairie, show development of Alfisols and Ultisols.

MAJOR FOREST TYPES AND VEGETATIVE COMMUNITIES

The Forest Inventory and Analysis Program of the U.S. Forest Service assigns a forest type to all inventory plots that have a stocking level of ≥10 percent. Type is assigned with a computer algorithm that combines individual tree data measured in sample plots. Forest type definitions are based on descriptions by Eyre (1980). This procedure does not account for the many distinct plant communities and species associations commonly observed in bottomland hardwood and swamp forests of the lower Mississippi Valley. Consequently, the forest types assigned by the computer algorithm do not always provide an accurate representation of species prevalence on a site. An example is sweetbay-swamp tupelo-red maple (*Magnolia virginiana* L.-*Nyssa biflora* Walter-*Acer rubrum* L.), which is noted in this report as a significant type of the Deltaic Plain section. Although sweetbay and swamp tupelo rarely occur in the section, the computer algorithm assigns this type to plots when red maple accounts for the majority of stocking. Similar inaccuracies occur with sugarberry-hackberry-elm-green ash (*Celtis laevigata* Willd.-*Celtis occidentalis* L.-*Ulmus* spp.-*Fraxinus pennsylvanica* Marsh.): hackberry does not range southward into the Deltaic Plain section.

The natural vegetative cover of the lower Mississippi Valley is predominantly deciduous, alluvial broadleaf forests (McNab and others 2005), also known as bottomland hardwood forests, that support >100 native tree species (Little 1971, 1977); sweetgum (*Liquidambar styraciflua* L.), green ash, sugarberry, American sycamore (*Platanus occidentalis* L.), eastern cottonwood (*Populus deltoides* Bartr. ex Marsh.), black willow (*Salix nigra* Marsh.), baldcypress [*Taxodium distichum* (L.) L.C. Rich.], maples, water tupelo (*Nyssa aquatica* L.), elm, hickory (*Carya* spp.), and oak (*Quercus* spp.) are among the most prevalent species (Gardiner and Oliver 2005). Species distributions are closely tied to the soils and hydrologic regimes associated with the various surface features described above (Gardiner and Oliver 2005, Hodges 1997). Forests are generally skewed to older age classes, with 75 percent of all stands >30 years, and 48 percent >50 years (fig. 3). Lowland hardwoods are particularly skewed to older age classes, with 82 percent >30 years, and 54 percent >50 years (fig. 3).

Two recognized forest types, sugarberry-hackberry-elm-green ash and sweetgum-Nuttall oak-willow oak (*Liquidambar styraciflua* L.-*Q. texana* Buckley-*Q. phellos* L.), combine to occupy nearly 36 percent of the forested acreage in the Holocene Deposits section (table 2). Other forest types occupying substantial acreage include overcup oak-water hickory [*Q. lyrata* Walter-*Carya aquatica* (Michx. f.) Nutt.], loblolly pine (*Pinus taeda* L.), and baldcypress-water tupelo. More than 45 percent of forests in the Holocene Deposits section are >50 years of age (fig. 3B).

The primary forest type in the Deltaic Plain section, baldcypress-water tupelo, accounts for 36 percent of forest cover in the area (table 3). The next four largest forest types by cover—sweetbay-swamp tupelo-red maple, sugarberry-hackberry-elm-green ash, sweetgum-Nuttall oak-willow oak, and willow (*Salix* L.)—collectively occupy an additional 35 percent of the forest land (table 3). About 56 percent of the forests are >50 years of age (fig. 3C).

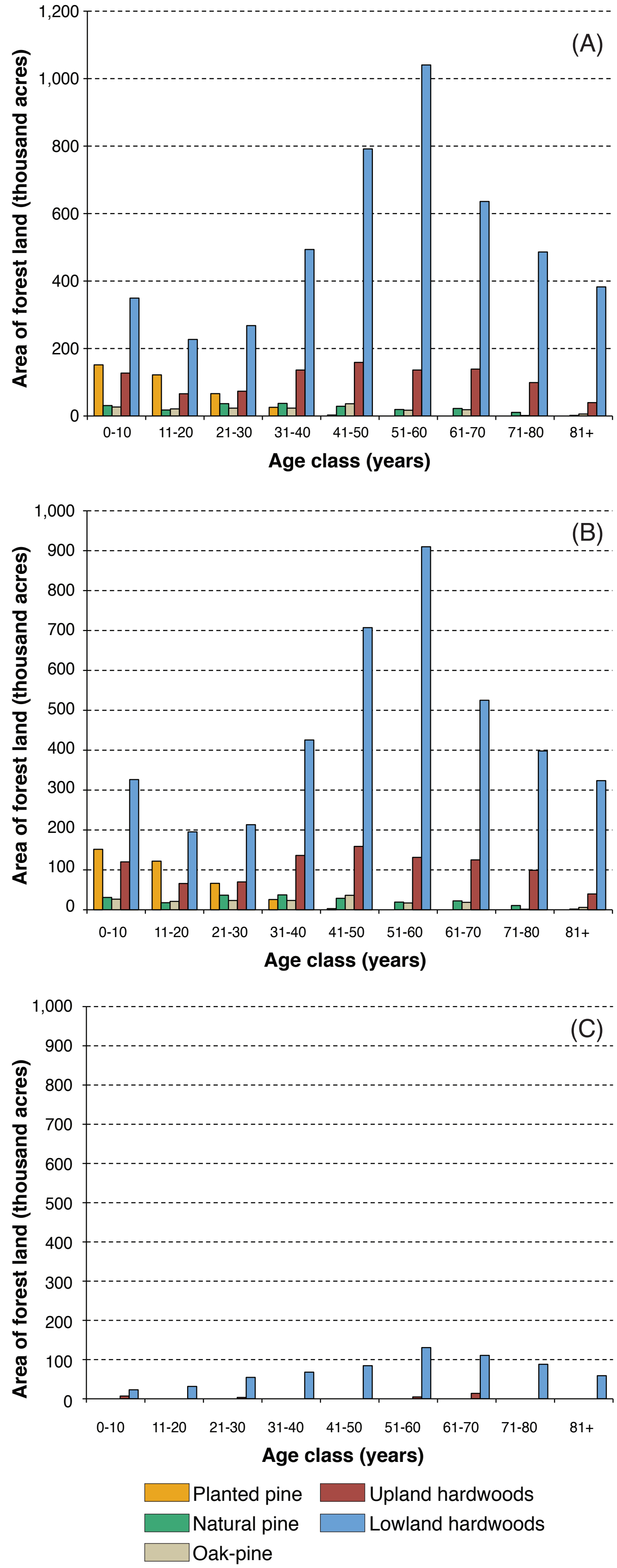

Figure 3—Age structure of forests, 2010 (A) in the U.S. Mississippi Alluvial Valley, (B) in its Holocene Deposits section, and (C) in its Deltaic Plain section. (Source: Forest Inventory and Analysis, Southern Research Station, U.S. Forest Service)

Table 2—Forest acreage by type in the Holocene Deposits section of the U.S. Mississippi Alluvial Valley, 2010

Forest type	Acres
	thousands
Sugarberry/hackberry/elm/green ash	1,076.5
Sweetgum/Nuttall oak/willow oak	1,012.9
Overcup oak/water hickory	628.9
Loblolly pine	559.6
Baldcypress/water tupelo	444.3
White oak/red oak/hickory	331.9
Mixed upland hardwood	324.7
Sycamore/pecan/American elm	284.8
Nonstocked	148.7
Sweetbay/swamp tupelo/red maple	148.3
Post oak/blackjack oak	136.2
Swamp chestnut oak/cherrybark oak	127.7
Willow	126.4
Loblolly pine/hardwood	100.5
Sweetgum/yellow-poplar	72.4
Cottonwood	63.4
Eastern redcedar/hardwood	46.0
River birch/sycamore	37.4
Sassafras/persimmon	35.1
Cottonwood/willow	28.8
Shortleaf pine/oak	27.5
Other nonnative hardwoods	26.0
White oak	23.8
Yellow-poplar/white oak/northern red oak	17.6
Red maple/lowland	13.3
Eastern redcedar	10.6
Silver maple/American elm	5.80
Shortleaf pine	4.12
Red maple/oak	1.6
Yellow-poplar	1.5
Northern red oak	1.4

Source: Forest Inventory and Analysis, Southern Research Station, U.S. Forest Service.

Table 3—Forest acreage by type in the Deltaic Plain section of the U.S. Mississippi Alluvial Valley, 2010

Forest type	Acres
	thousands
Baldcypress/water tupelo	263.6
Sweetbay/swamp tupelo/red maple	80.7
Sugarberry/hackberry/elm/green ash	69.3
Sweetgum/Nuttall oak/willow oak	65.8
Nonstocked	52.1
Willow	36.9
River birch/sycamore	28.2
Sycamore/pecan/American elm	25.4
Other nonnative hardwoods	24.4
Red maple/lowland	23.6
Mixed upland hardwood	22.5
Overcup oak/water hickory	22.5
Baldcypress/pondcypress	7.1
Sweetgum/yellow-poplar	6.8
Swamp chestnut oak/cherrybark oak	2.4

Source: Forest Inventory and Analysis, Southern Research Station, U.S. Forest Service.

HISTORY OF DISTURBANCE AND RESTORATION

The onset of European settlement in the 1700s began a land use pattern that eventually transformed the lower Mississippi Valley into the most extensive agricultural landscape in the South. Deforestation progressed as technological developments and engineering projects expanded transportation, installed drainage, and raised levees to prevent flooding from the Mississippi River and its tributaries (Kelley 1963). More than half of the landscape was deforested by the early 1900s; by the 1970s deforestation had claimed >70 percent (MacDonald and others 1979).

Clearly, agricultural production, which has long been a primary driver of deforestation, continues to dominate other land uses. In 1985, the U.S. Congress passed the Food Security Act of 1985 (Public Law 99-198), which started the decrease in acreage devoted to crop production by establishing the Conservation Reserve Program. This legislation and subsequent “Farm Bills” have motivated many private landowners to enroll acreage into programs that promote afforestation of economically marginal farmland. An estimated million acres of farmland in the Louisiana, Arkansas, and Mississippi portions of the Mississippi Alluvial Valley have been removed from crop production and planted in trees (King and others 2006, Schoenholtz and others 2001).

Commercial timber harvesting was established as a primary use of forests in the lower Mississippi Valley following European settlement for agriculture. The earliest industrial logging operations began in the coastal swamps of the Deltaic Plain where an export market was built around baldcypress lumber in the early 1700s (Brown and Montz 1986). Baldcypress lumbering continued to rise through the 1800s, and by 1913 the annual output by 290 sawmills in Louisiana, Mississippi, Arkansas, and Tennessee was >820 million board feet (Mattoon 1915). The late 1800s and early 1900s also marked a period of rapid expansion of the lumber industry farther north (Putnam 1929); by 1928, >40 operating sawmills were quickly consuming the last of the virgin stands in the Louisiana portion of the Holocene Deposits section (Lentz 1928).

Currently, forests of the lower Mississippi Valley are valued for a variety of nontimber purposes, and landowners maintain forested acreage for reasons including recreation, wildlife conservation, aesthetics, and future heirs in addition to timber products (Butler 2010). More than 80 percent of all land is privately owned, with Federal, State, and local governments holding the remaining acreage (Oswalt 2013). The U.S. Department of the Interior Fish and Wildlife Service, Forest Service, and Louisiana Department of Wildlife and Fisheries maintain some of the largest public forest holdings. These include the 60,000-acre Delta National Forest, the 160,000-acre White River National Wildlife Refuge, and the 76,000-acre Tensas National Wildlife Refuge in the Holocene Deposits section; and the 103,000-acre Maurepas Swamp Wildlife Management Area in the Deltaic Plain section.

CHAPTER 2. The Changing Physical Environment

CLIMATE

A humid, subtropical climate, characterized by cool winters and warm-to-hot summers, prevails over the lower Mississippi Valley (Muller and Grymes 1998). The average annual temperature is highest in the Deltaic Plain section where the range is from 18.8 to 21.2 °C (fig. 4). Temperature decreases northward to range from 15.2 to 16.4 °C near the upper reaches of the Holocene Deposits section (fig. 4). The frost-free period varies by nearly 80 days within the Mississippi Alluvial Valley, averaging 220 days at the northern reach of the Holocene Deposits section in Lake County, TN, and >300 days at the southern extent of the Deltaic Plain section in Plaquemines Parish, LA (Brown and others 1969, Trahan 2000).

Average annual precipitation ranges about 480 mm across the Mississippi Alluvial Valley, lowest in the northern third of the Holocene Deposits section—where it ranges from 1200 to 1302 mm annually—and increasing to between 1302 and 1582 mm across the middle-to-lower reaches of the section (fig. 5). Highest precipitation levels occur over most of the

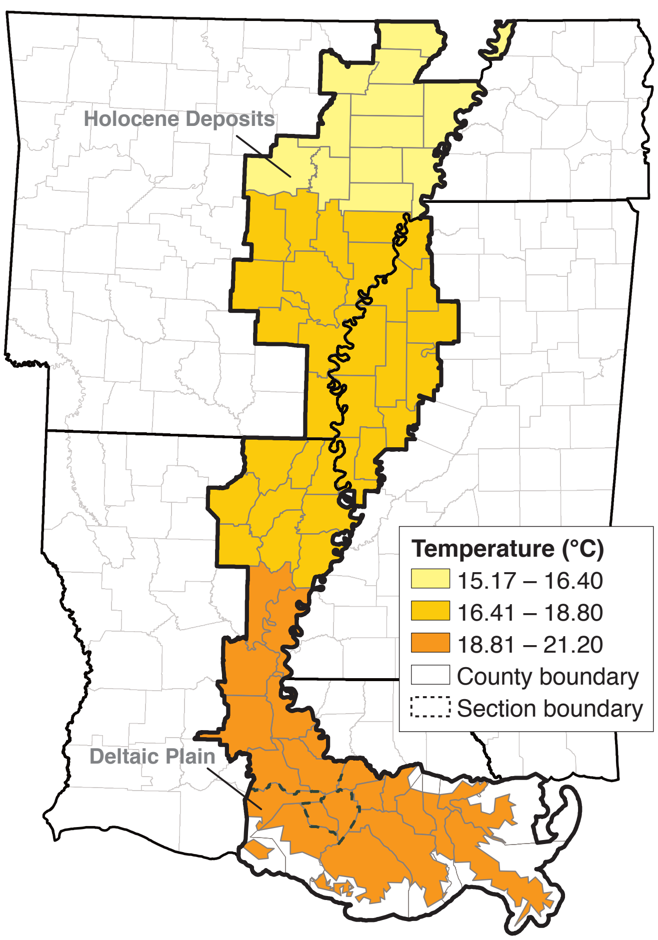

Figure 4—Average annual temperature in the U.S. Mississippi Alluvial Valley and its associated sections, 1997 through 2006. (Source: McNulty and others 2013)

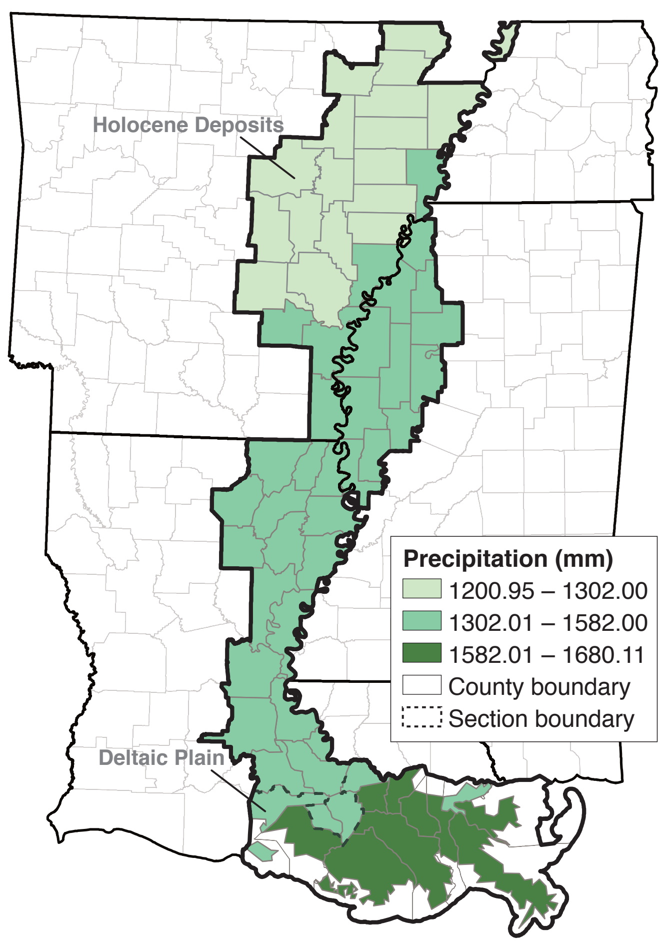

Figure 5—Average annual precipitation in the U.S. Mississippi Alluvial Valley and its associated sections, 1997 through 2006. (Source: McNulty and others 2013)

Deltaic Plain section where it annually ranges from 1580 to 1680 mm (fig. 5) (Brown and others 1969, Trahan 2000). Potential evapotranspiration ranges from 2340 to 2550 mm across the Deltaic Plain section and the southern two-thirds of the Holocene Deposits section, and 2130 to 2340 mm over the northern third of the Holocene Deposits section (fig. 6).

Paleobotanical records confirm the significance of climate as a primary abiotic determinant of vegetative cover in the lower Mississippi Alluvial Valley. The current deciduous hardwood forest is believed to have gained dominance about 5,000 years ago when the prevailing climate shifted from a 3,500-year arid period to the current humid climate (Delcourt and others 1980, King 1981, King and Allen 1977).

Future changes in the prevailing climate would impact forest structure and function in the lower Mississippi Valley. This section provides relatively short-term (50 years) climate forecasts and highlights relevant to the Mississippi Alluvial Valley and its associated sections. A brief overview of methods used to model climate forecasts is also presented. McNulty and others (2013) prepared more detailed synopsis of forecasting methods and projected results for the entire South.

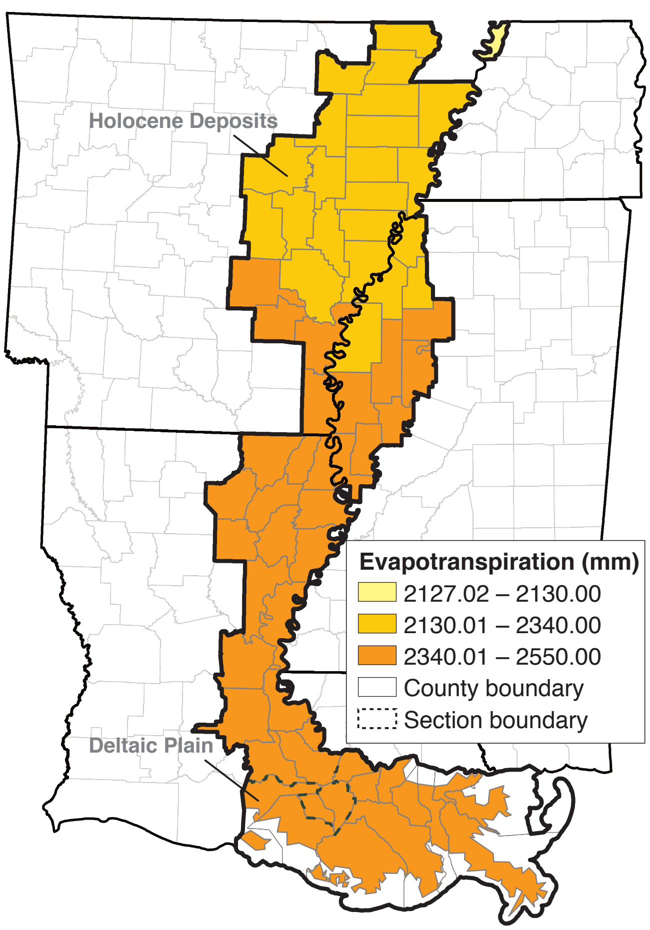

Figure 6—Average potential evapotranspiration in the Mississippi Alluvial Valley and its associated sections, 1997 through 2006. (Source: McNulty and others 2013)

Climate Forecasting Models

Climate forecasts for the Mississippi Alluvial Valley were projected with various general circulation models, which provide relatively coarse spatial resolution predictions of future climate by accounting for physical processes in the atmosphere, oceans, land surface, and cryosphere (frozen portions of the Earth's surface). To develop Cornerstone Futures for the Southern Forest Futures Project, Wear and others (2013) projected climate by selecting an appropriate general circulation model and parameterizing it with an emissions storyline defined by the Intergovernmental Panel on Climate Change (2007):

- **Cornerstone A** assumes high population and income growth (storyline A1B) paired with the MIROC3.2 general circulation model
- **Cornerstone B** assumes high population and income growth (storyline A1B) paired with the CSIROMK3.5 general circulation model
- **Cornerstone C** assumes low population and income growth (storyline B2) paired with the CSIROMK2 general circulation model
- **Cornerstone D** assumes low population and income growth (storyline B2) paired with the HadCM3 general circulation model

Results generated by the general circulation models were scaled to the county level, and decadal averages were computed from the 10 years surrounding each period (McNulty and others 2013). Because the procedures used to model temperature and precipitation for the South were limited in temporal and spatial resolution, analyzing the potential for change in seasonal or daily variations at the local level was beyond the scope of this report.

Climate Forecasts

Climate models parameterized for each Cornerstone Future projected average annual temperatures to rise through 2060 for the entire Mississippi Alluvial Valley (fig. 7A): 2.9 °C under Cornerstone A, about 1.3 °C under Cornerstones C and D, and an intermediate 1.7 °C under Cornerstone B (table 4).

Forecasts for most Cornerstone Futures indicate that a decrease in annual precipitation is likely to accompany the rise in average annual temperature projected for the Mississippi Alluvial Valley (fig. 8A). By 2060, average annual precipitation predicted under Cornerstone A could decrease as much as 24 percent from the current level (table 5), >6 percent for Cornerstone B, and >8 percent for Cornerstone D (table 5). In contrast, average annual precipitation under Cornerstone C

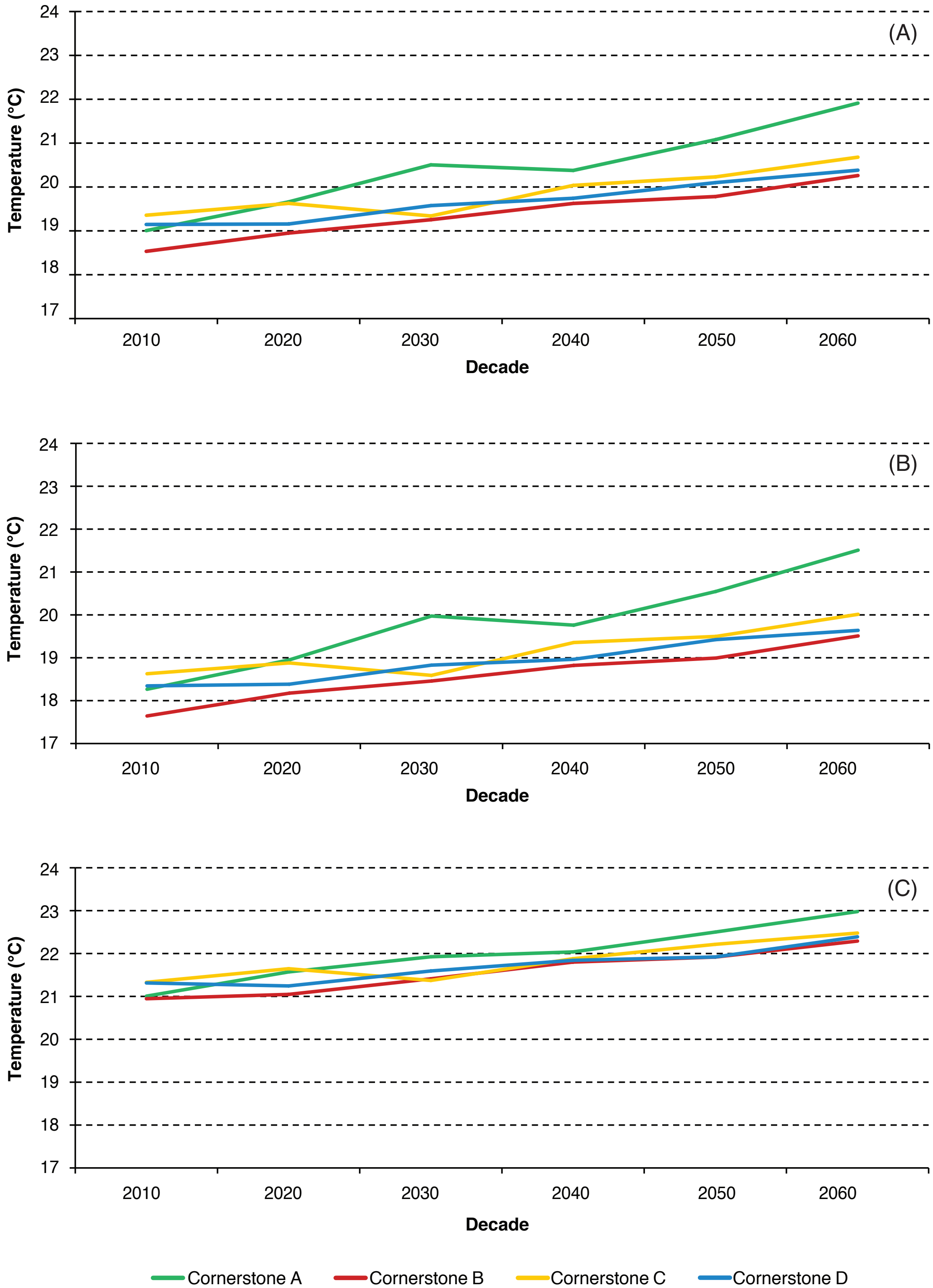

Figure 7—Projected average annual temperature (A) for the U.S. Mississippi Alluvial Valley, (B) for its Holocene Deposits section, and (C) for its Deltaic Plain section as forecasted by four Cornerstone Futures, each of which represents a general circulation model paired with one of two emission scenarios—A1B representing high-population/high-economic growth, high energy use, and B2 representing low growth and use: Cornerstone A is MIROC3.2+A1B, Cornerstone B is CSIROMK3.5+A1B, Cornerstone C is CSIROMK2+B2, and Cornerstone D is HadCM3+B2. (Source: Intergovernmental Panel on Climate Change 2007)

Table 4—Change in average annual temperature from 2010 and 2060 for the U.S. Mississippi Alluvial Valley and its associated sections as forecasted by four Cornerstones Futures[a]

Geographic area	Cornerstone A	Cornerstone B	Cornerstone C	Cornerstone D
Projection for 2010	---------------------- *Temperature (°C)* ----------------------			
Mississippi Alluvial Valley	19.0	18.5	19.4	19.1
Holocene Deposits section	18.3	17.6	18.6	18.3
Deltaic Plain section	21.0	20.9	21.3	21.3
Projected change (2010 to 2060)	---------------- *Change in temperature (°C)* ----------------			
Mississippi Alluvial Valley	2.9	1.7	1.3	1.2
Holocene Deposits section	3.2	1.9	1.4	1.3
Deltaic Plain section	1.9	1.3	1.1	1.1

[a]Each Cornerstone represents a general circulation model paired with one of two emission scenarios (A1B representing high-population/high-economic growth, high energy use, and B2 representing low growth and use): Cornerstone A is MIROC3.2+A1B, Cornerstone B is CSIROMK3.5+A1B, Cornerstone C is CSIROMK2+B2, and Cornerstone D is HadCM3+B2.
Source: Intergovernmental Panel on Climate Change (2007).

Table 5—Change in average annual precipitation from 2010 and 2060 for the U.S. Mississippi Alluvial Valley and its associated sections as forecasted by four Cornerstones Futures[a]

Geographic area	Cornerstone A	Cornerstone B	Cornerstone C	Cornerstone D
Projection for 2010	---------------------- *Precipitation (mm)* ----------------------			
Mississippi Alluvial Valley	1351	1550	1358	1472
Holocene Deposits section	1324	1544	1305	1441
Deltaic Plain section	1427	1509	1507	1558
Projected Change (2010 to 2060)	---------------- *Change in precipitation (mm)* ----------------			
Mississippi Alluvial Valley	-327	-95	13	-126
Holocene Deposits section	-314	-191	-26	-150
Deltaic Plain section	-361	171	123	-58

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

Source: Intergovernmental Panel on Climate Change 2007.

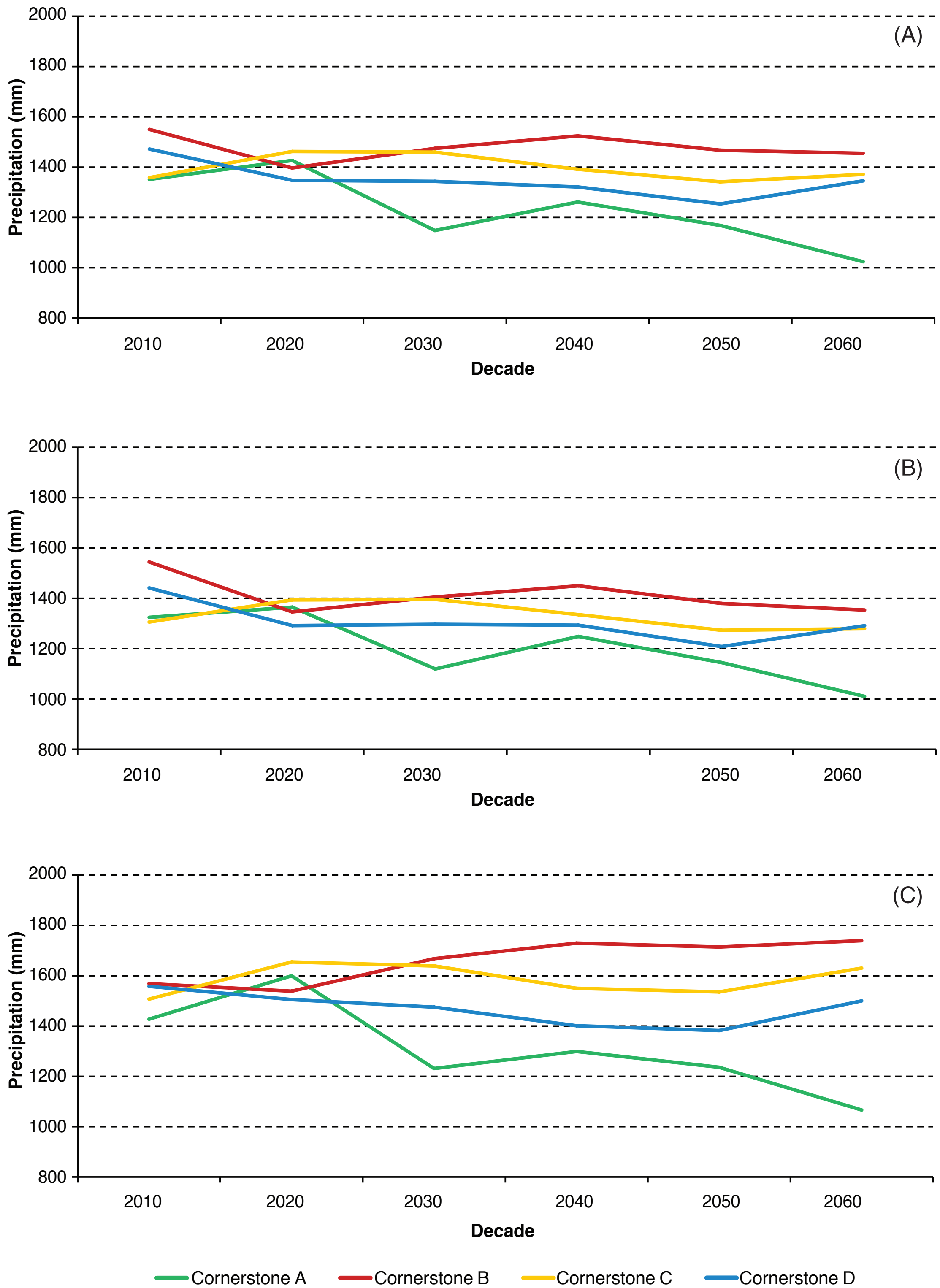

Figure 8—Projected average annual precipitation (A) for the U.S. Mississippi Alluvial Valley, (B) for its Holocene Deposits section, and (C) for its Deltaic Plain section as forecasted by four Cornerstone Futures, each of which represents a general circulation model paired with one of two emission scenarios—A1B representing high-population/high-economic growth, high energy use, and B2 representing low growth and use: Cornerstone A is MIROC3.2+A1B, Cornerstone B is CSIROMK3.5+A1B, Cornerstone C is CSIROMK2+B2, and Cornerstone D is HadCM3+B2. (Source: Intergovernmental Panel on Climate Change 2007)

is not expected to decrease and could remain within 1 percent of the current level (table 5).

Holocene Deposits section—The most extreme increases in average annual temperature across the Mississippi Alluvial Valley are forecast within the Holocene Deposits section (fig. 7B). A 3.2 °C rise in average annual temperature is projected under Cornerstone A, and increases of 1.9 °C for Cornerstone B, 1.4 °C for Cornerstone C, and 1.3 °C for Cornerstone D (table 4).

Annual precipitation would likely decrease through 2060 regardless of Cornerstone Future (fig. 8B). A 23.7 percent decrease in precipitation could potentially be realized under a future defined by Cornerstone A, compared to a more subtle decrease of 2.0 percent projected under Cornerstone C (table 5).

Deltaic Plain section—Climate forecasts for the Deltaic Plain section deviate substantially from those of the Holocene Deposits section. Average annual air temperatures are expected to rise through 2060 (fig. 7C), but at a slower pace than expected for the Mississippi Alluvial Valley as a whole. Projected increases range from 1.1 °C to 1.9 °C, with Cornerstone A predicting the largest potential rise and Cornerstones C and D the smallest potential rises (table 4).

Forecasts for annual precipitation in the Deltaic Plain section are widely disparate adding to the uncertainty of this aspect of the future climate (fig. 8C), with decreases ranging from 25 percent under Cornerstone A to 3.7 percent under Cornerstone D (table 5), and increases ranging from 8.1 percent under Cornerstone C to 10.9 percent under Cornerstone B by 2060 (table 5).

WILDFIRE

The distribution, frequency, and severity of wildfire in bottomland hardwood forests of the lower Mississippi Valley are not well studied or understood. As in the past, humans continue to be the primary source of ignitions today. The destructive effects of human-caused wildfire to the hardwood resource have long been recognized. In reports on hardwood forest conditions in Louisiana, Lentz (1928) noted that evidence of wildfire was nearly omnipresent in bottomland hardwood stands in northeastern Louisiana. At that time, only deforestation was more destructive to the bottomland hardwood forest resource, with damage ranging from complete stand destruction to extensive butt rot that chronically progressed through the boles of less severely burned stands (Lentz 1928). Although deforestation has diminished forests to <28 percent of their original acreage, the risk of wildfire damage continues in remaining bottomland hardwood stands. In addition to the economic and ecological losses associated with damage to bottomland hardwood forests, wildfires also damage structures and present risk of human casualty in the wildland-urban interface. Stanturf and Goodrick (2013) forecasted potential changes in future conditions that drive southern wildland fires for the Southern Forest Futures Project. This section highlights and synthesizes wildland fire information that is relevant to the Mississippi Alluvial Valley and its associated sections.

Current Status

Incidences of wildfire in the Mississippi Alluvial Valley appear to have dramatically decreased since the early 1900s when Lentz (1928) reported that wildfire damage in bottomland hardwood forests was commonplace. About 1,984 wildfires burned an estimated 24,910 acres of forests in the Mississippi Alluvial Valley from 1997 to 2002 (fig. 9)—almost all ignited by people, either accidentally or intentionally. Although the median size of wildfires was 3 acres, the five largest fires impacted 325 to 800 acres. Wildfire burned the most acreage during the autumn months of September, October, and November when almost 40 percent of all events were reported. About 22 percent of

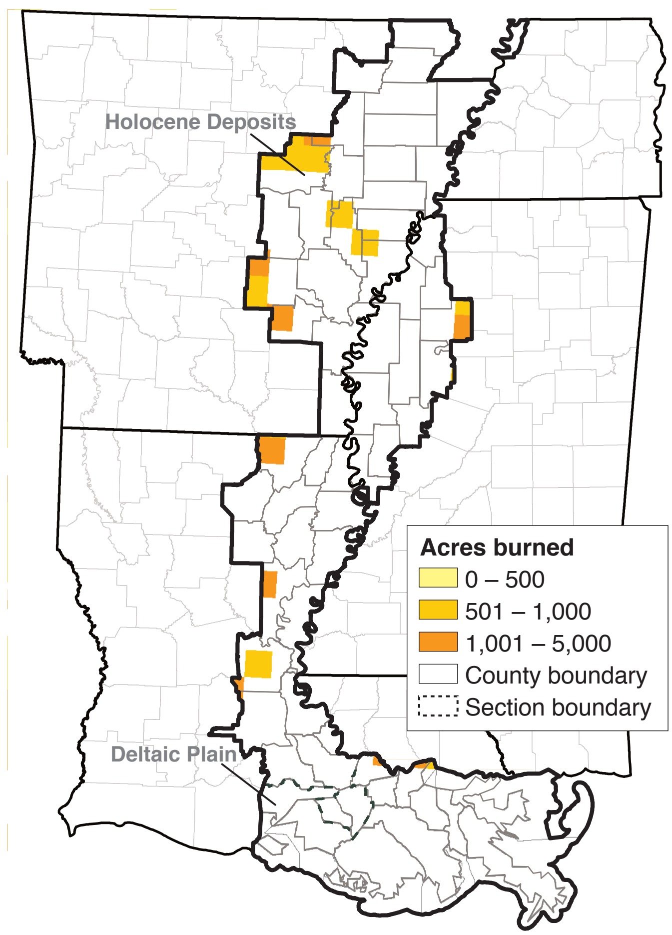

Figure 9—Distribution of forest acreage impacted by wildfire, 1997 to 2002, in the sections of the U.S. Mississippi Alluvial Valley. (Source: Stanturf and Goodrick 2013)

wildfires occurred in the summer (June, July, and August), 19 percent in the spring (March, April, and May), and 19 percent in the winter (December, January, and February).

Wildfire incidence was minimal in the Deltaic Plain section (fig. 9). During this period, <20 fires were reported, impacting 205 acres or <0.03 percent of the total forest area in the section.

In contrast, about 1,965 fires advanced through 24,705 acres (about 0.5 percent) of forests in the Holocene Deposits section, with incidence particularly concentrated in counties adjacent to the Coastal Plain and Mid-South (fig. 9). This distribution suggests that many of these wildfires occurred in upland forests of the counties that constitute the Mississippi Alluvial Valley.

Forecasts

To project the future potential for fire in the South through 2060, Stanturf and Goodrick (2013) used a potential drought index (Liu and others 2009) that provides water balance estimates as a function of potential evapotranspiration and precipitation. Temperature and precipitation values consistent with forecasted climate patterns under Cornerstone Futures A, B, C, and D were used as model inputs, and results were compared to 2010 results.

Stanturf and Goodrick (2013) showed that projected shifts in climate conditions through 2060 are likely to raise the potential for wildfire over much of the Mississippi Alluvial Valley (figs. 10 and 11). General patterns of lower precipitation and higher temperatures will likely increase moisture deficits, particularly in the Holocene Deposits section, with potential drought indices and wildfire risks expected to be most severe in Arkansas (figs. 11 and 12). In this area, the change in potential drought indices consistent with forecasts under Cornerstone A would lead to the largest rise in future potential wildfire risk; conversely, the change in potential drought indices consistent with forecasts under Cornerstone B would minimize increases to future potential wildfire risk (figs. 11 and 12).

In contrast to the Holocene Deposits section, the Deltaic Plain section is expected to experience only minimal changes in potential drought indices and wildfire risks (figs. 11 and 12). Climate conditions forecasted under Cornerstone Futures B through D would actually lead to decreased wildfire potential across this section (figs. 10 and 11). Only under Cornerstone A would conditions be dry enough to raise the potential for wildfire, and then only slightly (fig. 11).

In addition to the forecasted changes in climate that control the potential for wildfire, projected shifts in land use and population density (chapter 3) could lead to increased occurrences of unintentional ignitions in the Mississippi Alluvial Valley. In the Holocene Deposits section, extensive forest restoration activities over the past two decades have increased the area of forest plantations that are adjacent to croplands. Fires set to burn row-crop stubble have occasionally spread into young, fuel-laden plantations; this ignition source will likely continue to threaten plantation health as the conversion of land to forest use progresses.

In the Deltaic Plain section, urban development driven by rapid population growth is expected to reduce forest land use to <50 percent of the total land base by 2020 (chapter 3). The increase in urban development could intensify the risk of wildfire ignition at the wildland-urban interface, raising the likelihood of the changes in potential drought indices and wildfire risks that are predicted under Cornerstone A (defined by high population and economic growth coupled with a warmer and dryer climate).

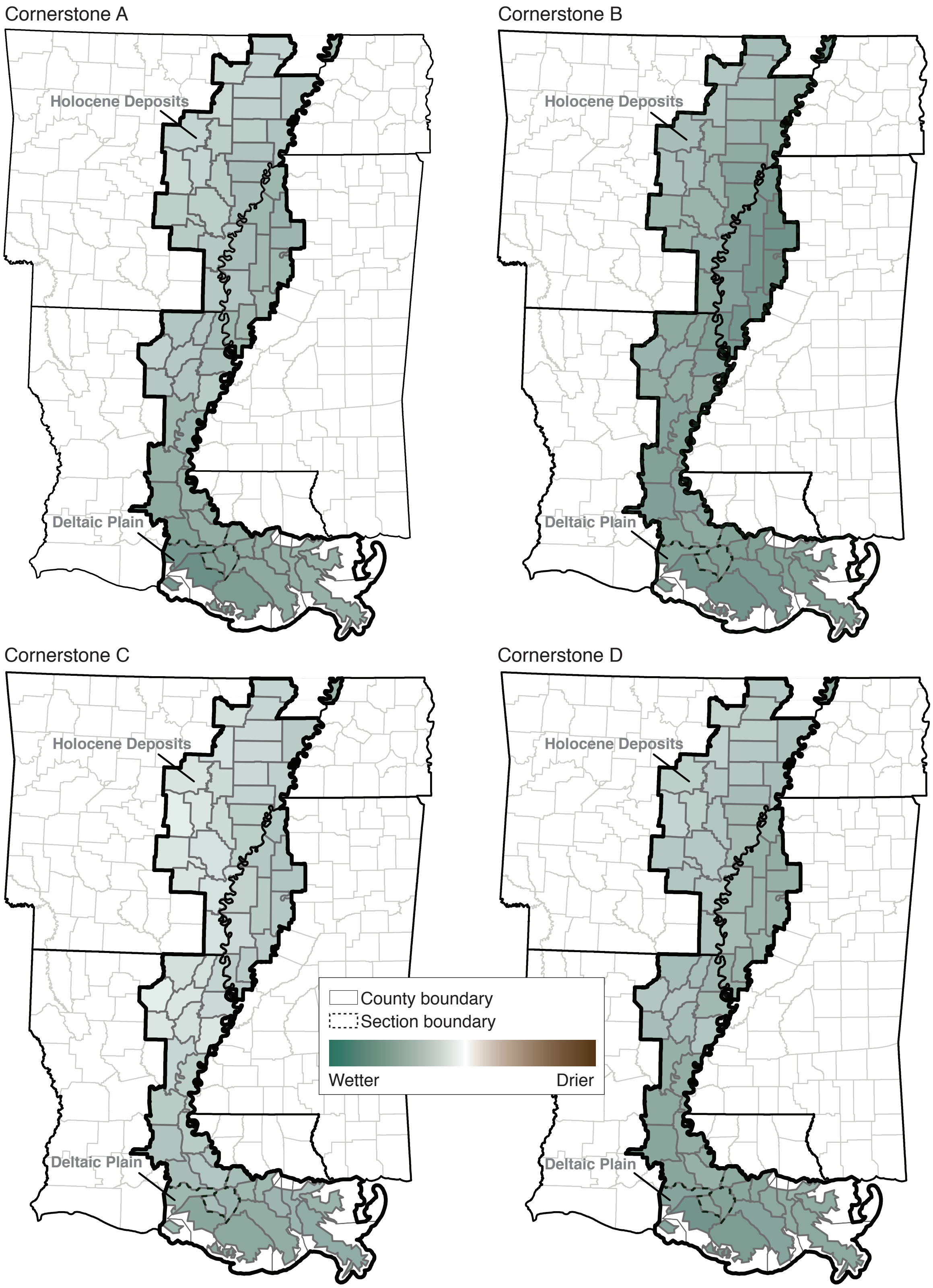

Figure 10—Fire potential in the sections of the U.S. Mississippi Alluvial Valley, 2010, simulated under four Cornerstone Futures (A through D), each of which represents a general circulation model paired with one of two emission scenarios—A1B representing high-population/high-economic growth, high energy use, and B2 representing low growth and use: Cornerstone A is MIROC3.2+A1B, Cornerstone B is CSIROMK3.5+A1B, Cornerstone C is CSIROMK2+B2, and Cornerstone D is HadCM3+B2. (Source: Stanturf and Goodrick 2013)

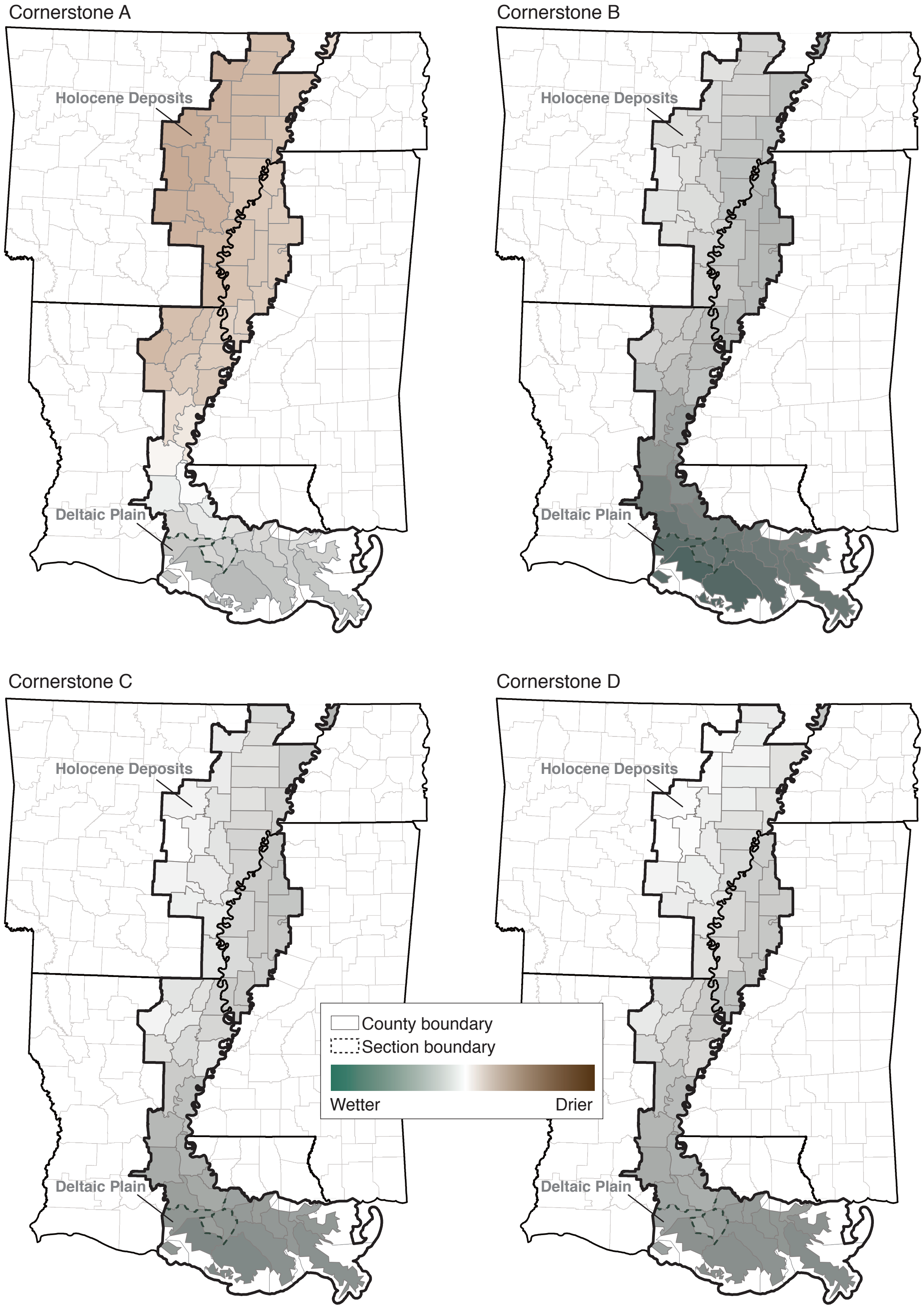

Figure 11—Projected fire potential in the sections of the U.S. Mississippi Alluvial Valley, 2060, under four Cornerstone Futures (A through D), each of which represents a general circulation model paired with one of two emission scenarios—A1B representing high-population/high-economic growth, high energy use, and B2 representing low growth and use: Cornerstone A is MIROC3.2+A1B, Cornerstone B is CSIROMK3.5+A1B, Cornerstone C is CSIROMK2+B2, and Cornerstone D is HadCM3+B2. (Source: Stanturf and Goodrick 2013)

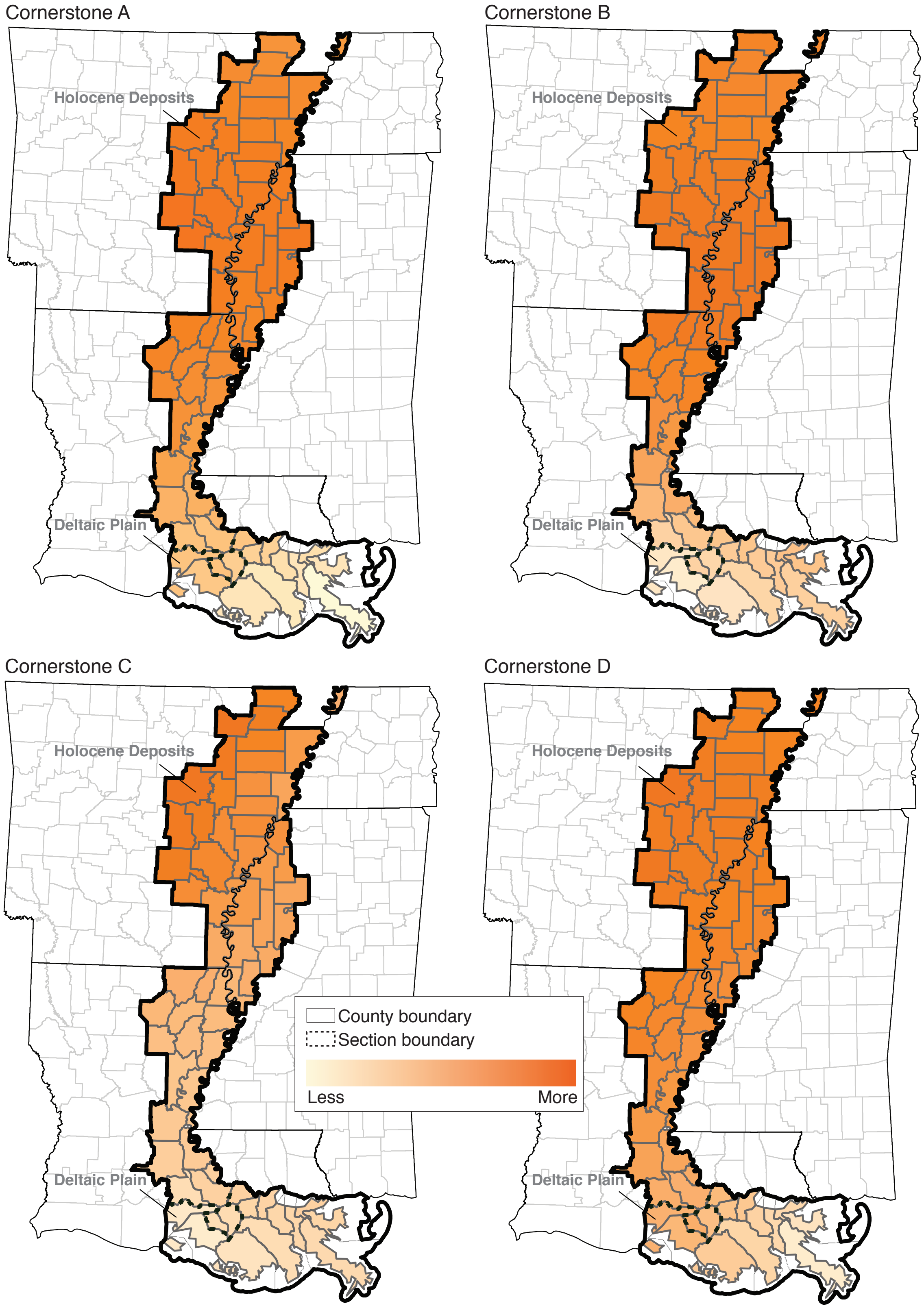

Figure 12—Projected change in fire potential in the sections of the U.S. Mississippi Alluvial Valley, 2010 to 2060, under four Cornerstone Futures (A through D), each of which represents a general circulation model paired with one of two emission scenarios—A1B representing high-population/high-economic growth, high energy use, and B2 representing low growth and use: Cornerstone A is MIROC3.2+A1B, Cornerstone B is CSIROMK3.5+A1B, Cornerstone C is CSIROMK2+B2, and Cornerstone D is HadCM3+B2. (Source: Stanturf and Goodrick 2013).

CHAPTER 3.
The Human Footprint

POPULATION, DEMOGRAPHY, AND ECONOMIC ACTIVITY

Historical and Current Trends

The Mississippi Alluvial Valley is mostly a rural landscape fringed by several population centers; about 52 percent of residents live in the Deltaic Plain section, with the remaining 48 percent in the Holocene Deposits section. In contrast to the growth observed elsewhere in the South (Cordell and others, 2013), the Mississippi Alluvial Valley has experienced population decreases since the 1970s, with a 6-percent decrease reported from 2000 to 2010 (fig. 13). This decrease placed the 2010 population of the Mississippi Alluvial Valley at 2.9 million people. However, adjacent population centers in Louisiana (Alexandria, Baton Rouge, and Lafayette), Mississippi (Jackson), Arkansas (Little Rock), and Tennessee (Memphis) have grown >9 percent—from about 3.4 million people in 2000 to about 3.8 million people in 2010 (U.S. Census Bureau 2013).

In 2010, the Holocene Deposits section—an area that holds some of the lowest population densities in the South—maintained a population of about 45 persons per square mile, a 2-percent decrease from 2000 (fig. 13) (U.S. Census Bureau 2013). Ouachita Parish in Louisiana had the highest density at 252 persons per square mile, and Issaquena County in Mississippi had the lowest at 3 persons per square mile (fig. 14). Population centers in or near the Holocene Deposits section include the Memphis metropolitan area (population 1,316,100) in Tennessee, Mississippi, and Arkansas; Jonesboro (population 121,026), Pine Bluff (population 100,258), and the Little Rock/North Little Rock/Conway area (population 699,757) in Arkansas; Jackson (population 539,057) in Mississippi; Monroe (population 176,441), Alexandria (population 153,922), Lafayette (population 273,738), and Baton Rouge (population 802,484) in Louisiana U.S. Census Bureau 2013).

In contrast, the Deltaic Plain section maintained a population density of about 408 persons per square mile, nearly 10 times higher than the Holocene Deposits section. Orleans Parish had the highest density at 2,029 persons per square mile, and Plaquemines Parish had the lowest at 30 persons per square mile (fig. 14). Population in this section has generally increased since the 1970s, but experienced a sharp decrease in the years following the 2005 hurricane strike (Katrina)—an event that ushered a 9-percent decrease in population from 2000 to 2010 (fig. 13). Notwithstanding, the New Orleans/Metairie/Kenner (population 1,167,764) metropolitan area remains the largest population center in the section (U.S. Census Bureau 2013). With a 2010 population of 208,178, the Houma/Bayou Cane/Thibodaux metropolitan area was the second largest population center in the Deltaic Plain section.

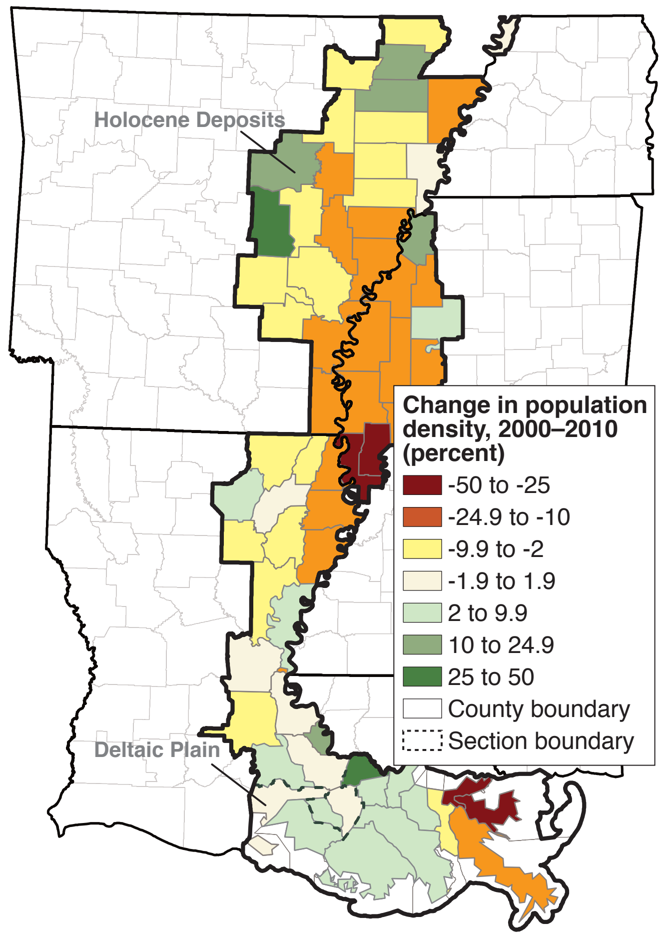

Figure 13—Percent change in population density by county in the U.S Mississippi Alluvial Valley and its associated sections, 2000 through 2010. (Source: http://quickfacts.census.gov. [Date accessed: August 20, 2013])

Per capita personal income in the Mississippi Alluvial Valley averaged $18,040 annually from 2006 to 2010, and almost 21 percent of the population lived below the poverty level (U.S. Census Bureau 2013). Per capita personal income in the Holocene Deposits section averaged $16,904 annually through 2006 to 2010; during this period the poverty level exceeded 24 percent (U.S. Census Bureau 2013). Per capita personal income in the Deltaic Plain section averaged $22,964 annually during 2006 to 2010, and the poverty level exceeded 17 percent (U.S. Census Bureau 2013).

Population Change

Population change for the South is projected to increase by 40 to 60 percent through 2060. Growth would not be evenly distributed, but would occur largely in and around urban centers. Likewise, under Cornerstones A and B, which are parameterized for 60 percent population growth for the South, population change across the Mississippi Alluvial Valley would vary considerably through 2060 (fig. 15). Under these Cornerstone Futures, the largest population change is projected to occur in the Deltaic Plain section where parishes near the New Orleans metropolitan area could experience growth of >750 persons per square mile. In contrast, much of the Holocene Deposits section is not expected to experience population growth. Rather, the population of this largely rural section will likely decrease though 2060; growth of 51 to 100 persons per square mile is projected for Lonoke County and White County, AR in the Little Rock/North Little Rock/Conway metropolitan center, and Craighead County, AR in the Jonesboro metropolitan center.

LAND USES

Current Land Uses

In 1997, farming (62 percent) was the most widespread land use in the Mississippi Alluvial Valley, comprising 65 percent of the Holocene Deposits section and 23 percent of the Deltaic Plain section (table 6, fig. 16). Forest land comprised 28 percent; 26 percent of the Holocene Deposits section and 53 percent of the Deltaic Plain section (fig. 16). Pasture and range occupied 6 percent of the Mississippi Alluvial Valley; urban land occupied 3.6 percent, mostly concentrated in the Deltaic Plain section where it occupied 15 percent (table 6, fig. 16).

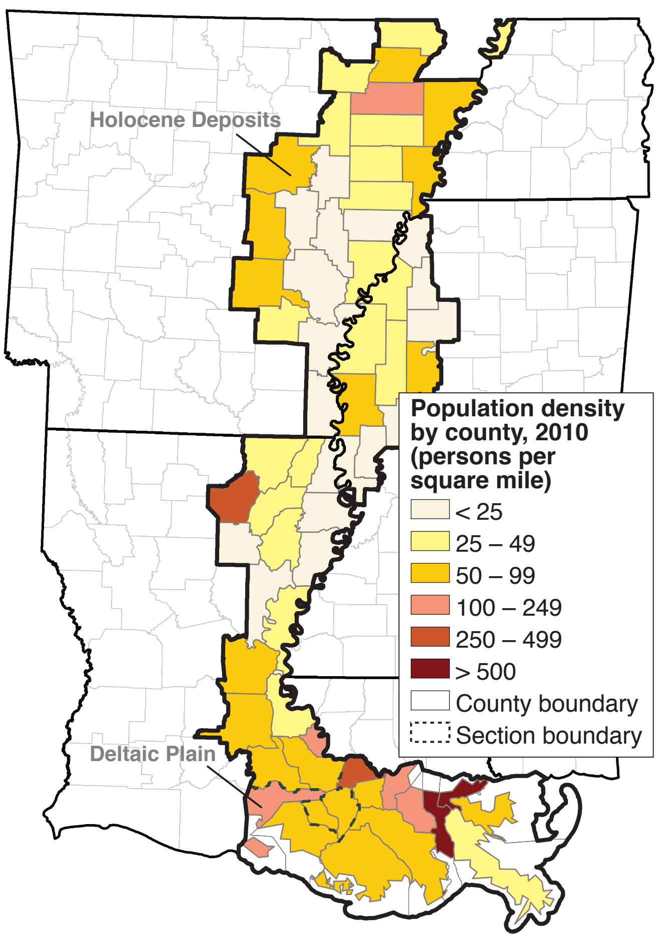

Figure 14—Population density by county in the U.S. Mississippi Alluvial Valley and its associated sections, 2010. (Source: http://quickfacts.census.gov. [Date accessed: August 20, 2013])

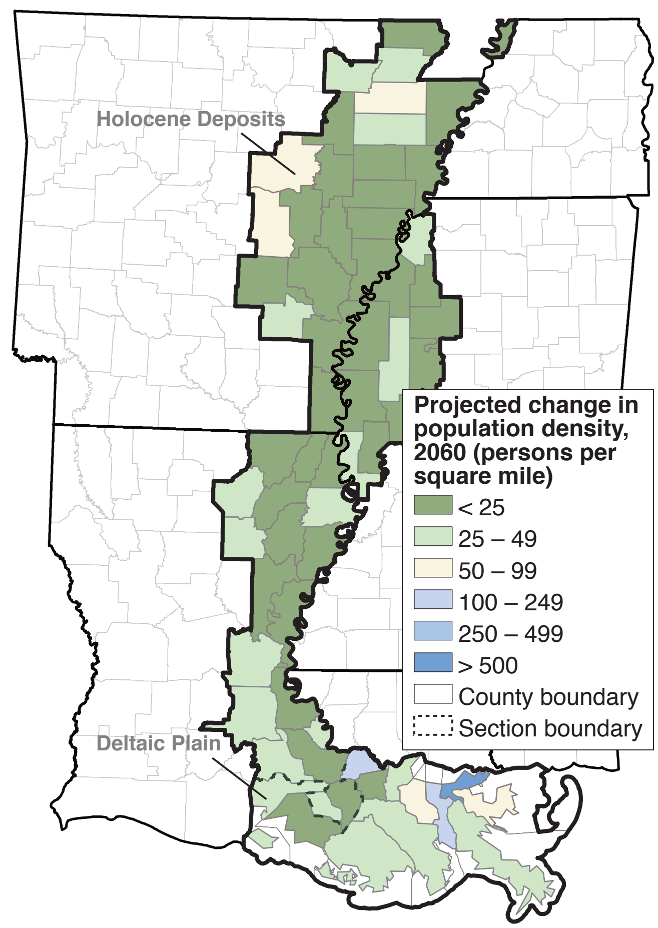

Figure 15—Projected population change in the two sections of U.S. Mississippi Alluvial Valley under a scenario of high population and economic growth. (Source: Cordell and others 2013)

Table 6—Approximate acreage for land use categories in the U.S. Mississippi Alluvial Valley, and its associated sections in 1997

Category	Mississippi Alluvial Valley	Holocene Deposits section	Deltaic Plain section
		---------------------- *acres*[a] ----------------------	
Forest	5,577,248	4,869,416	707,832
Crop	12,444,159	12,141,677	302,483
Pasture	1,174,089	1,049,691	124,398
Range	4,075	0	4,075
Urban	707,981	508,806	199,174

[a]Acreages are not inclusive of public holdings or easements, utility corridors, and water bodies.
Source: National Resources Inventory, Natural Resources Conservation Service (www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/nri/).

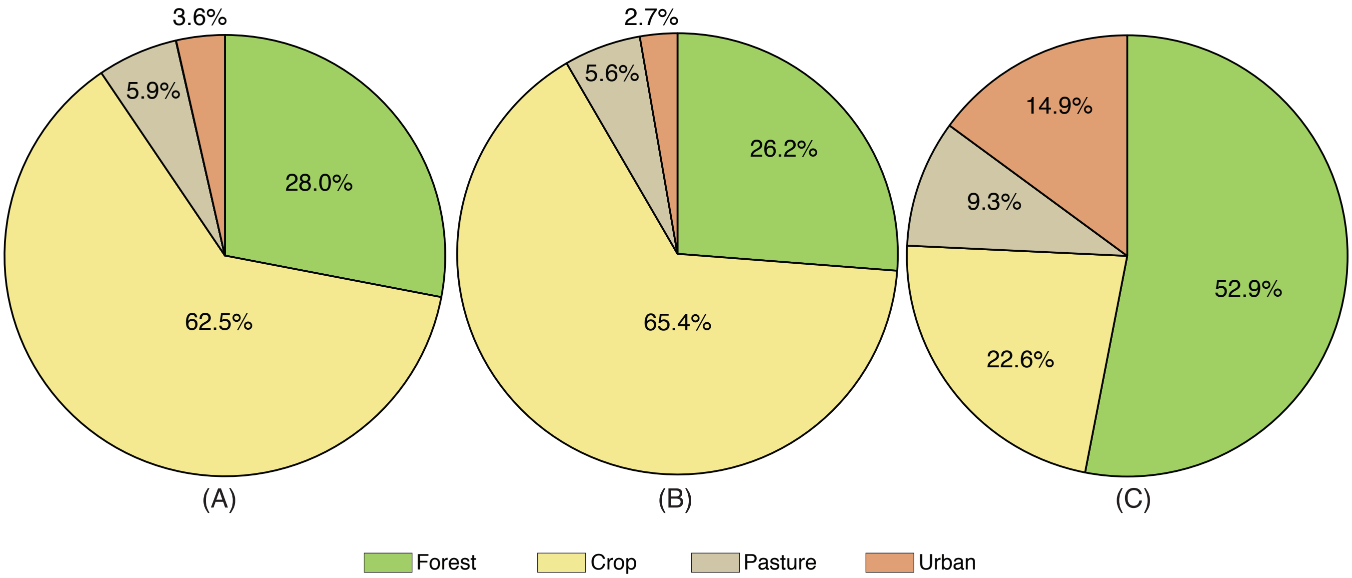

Figure 16—Land use percentages by category, 1997 (A) for the U.S. Mississippi Alluvial Valley, (B) for its Holocene Deposits section, and (C) its Deltaic Plain section. (Source: National Resources Inventory, Natural Resources Conservation Service)

Present-day land use patterns across the largely rural Mississippi Alluvial Valley differ considerably from the rest of the South, because its uniquely rich alluvial soils support a substantial segment of the Nation's agricultural economy. Although this agricultural identity is expected to continue, some level of land use change is certain and future economic and population growth trajectories will control the rate and extent of future change (Wear 2013).

This section provides: a brief synthesis of highlights relevant to the Mississippi Alluvial Valley and its associated sections presented by Wear (2013) for the Southern Forest Futures Project; additional analysis of land use forecasts relevant to the Mississippi Alluvial Valley and its associated sections; and a summary of important findings from the additional analysis.

Land Use Forecasts

As well as describing the effects of urbanization (population and income) on climate (chapter 2), the four Cornerstone Futures (A through D) have underlying assumptions about timber prices that affect forecasts of land use (Huggett and others 2013, Wear and others 2013):

- **Cornerstone A** is characterized by increasing timber prices in addition to high population/income growth.
- **Cornerstone B** is characterized by decreasing timber prices in addition to high population/income growth.
- **Cornerstone C** is characterized by increasing timber prices in addition to low population/income growth.
- **Cornerstone D** is characterized by decreasing timber prices in addition to low population/income growth.

Timber price futures, which address increasing or decreasing scarcity, assume that real prices will progress upward or downward at an orderly rate of 1 percent per year from the 2005 base through 2060. Agriculture commodity markets have historically played a primary role in land use decisions of the Mississippi Alluvial Valley (Hyberg and Riley 2009). The reader should note that real returns to agricultural crops were held constant throughout the forecast analysis. This model constraint likely limited the influence of agricultural markets on projected land use relative to the influence of modeled timber prices. Dosskey and others (2012), Frey and others (2010, 2013), and Hyberg and Riley (2009) provide in depth discussion on the economic determinants driving landowner decisions of agriculture and forestry land use in the Mississippi Alluvial Valley.

Forecasts for the Mississippi Alluvial Valley point to relatively minor shifts in the distribution of acreage among land use categories through 2060 (fig. 17). The largest change in distribution (a 14.6-percentage point shift) would occur under the Cornerstone A assumption of high population and economic growth along with increasing timber prices. Alternatively, Cornerstone D, a future of low population and economic growth and decreasing timber prices, projects the smallest change in distribution of acreage (a 6.5-percentage point shift). Although changes in the distribution of acreage among land use categories are projected to be relatively minor, they could amount to gains or losses in acreage that are substantial within each specific land use category:

● Land-use decisions in the Mississippi Alluvial Valley have historically supported development of the landscape for agricultural production at the expense of forests. All four Cornerstone Futures predict that deforestation is likely to persist, but future clearing will likely be driven by urbanization rather than agricultural development. A

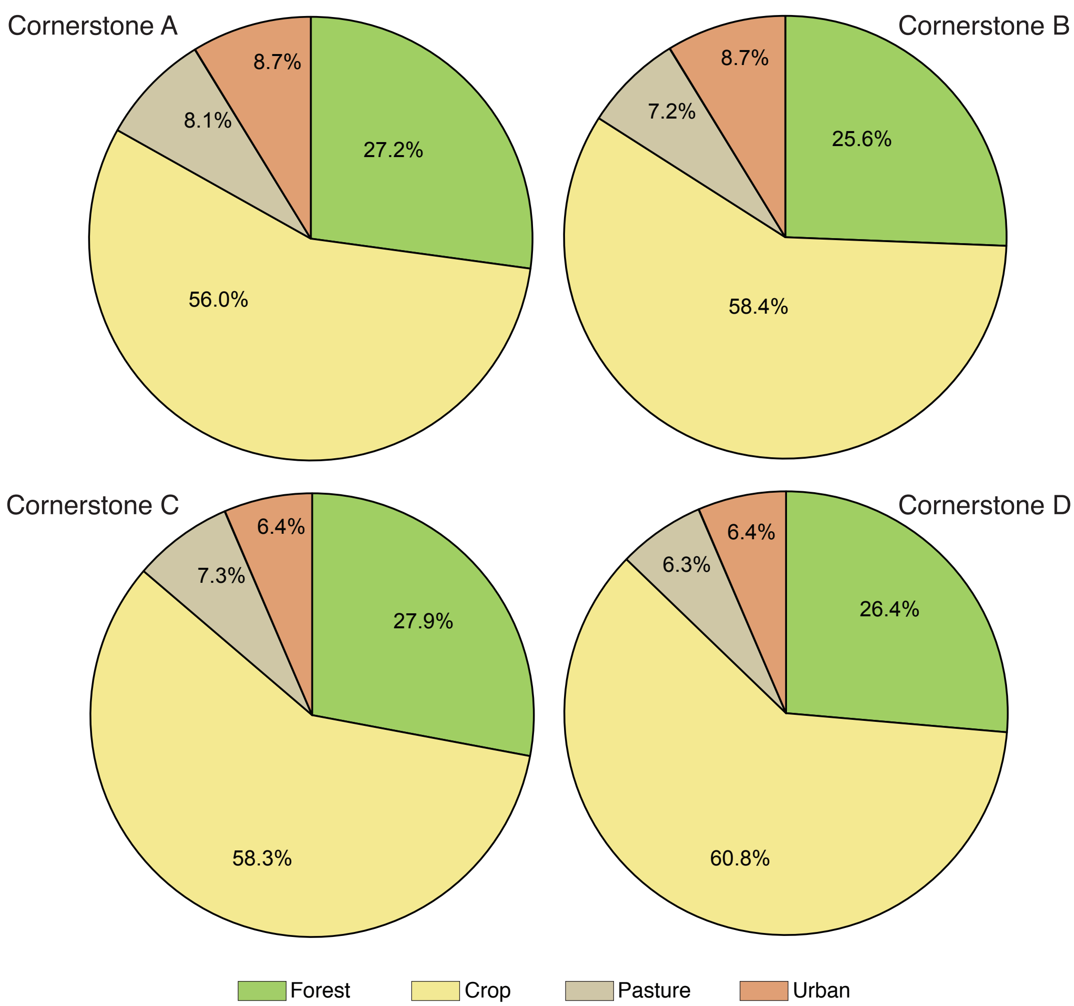

Figure 17—Projected land use percentages by category, 2060, in the U.S. Mississippi Alluvial Valley under four Cornerstone Futures (A through D), each of which represents a general circulation model paired with one of two emission scenarios—A1B representing high-population/high-economic growth, high energy use, and B2 representing low growth and use—and either high or low timber prices: Cornerstone A is MIROC3.2+A1B+high prices, Cornerstone B is CSIROMK3.5+A1B+low prices, Cornerstone C is CSIROMK2+B2+high prices, and Cornerstone D is HadCM3+B2+low prices. (Sources: Intergovernmental Panel on Climate Change 2007, Wear 2013)

future of increasing timber prices would retain the most forest cover (fig. 17). Coupling increasing timber prices with low population and economic growth (Cornerstone C) could keep the decrease in the proportion of forest acreage to as low as 0.1 percentage points—a loss through 2020 followed by slight increases through 2060 (fig. 18) for a 12,000-acre or 0.2-percent loss (table 7). The proportion of forest cover could decrease 0.8 percentage points under the Cornerstone A assumption of increasing timber prices accompanied by high population and economic growth (fig. 17). However, the largest decreases in the relative amount of forest would be expected for futures with decreasing timber prices. Under the Cornerstone B assumption of high population and economic growth and decreasing timber prices, the proportion of forest would decrease by 2.4 percentage points (fig. 17). A land use shift of this magnitude would result in an average decrease of >79,000 forested acres per decade (fig. 18), or a 476,000-acre (8.6-percent) reduction by 2060 (table 7, fig. 18).

● Crop production will continue to be the primary land use in the Mississippi Alluvial Valley, although the proportion of acreage used for agricultural purposes is expected to decrease through 2060 regardless of Cornerstone Future. High population and economic growth along with increasing timber prices (Cornerstone A) could lead to a 6.5-percentage point drop in the proportion of cropland (fig. 17), with losses averaging >216,000 acres per decade (fig. 18) and >1.3 million acres, or 10.4 percent, removed from crop production by 2060 (table 7, fig. 18). Alternatively, a 1.7-percentage point decrease in the proportion devoted to crop production is expected under the Cornerstone D assumption of low population and economic growth and decreasing timber prices (fig. 17). More than 55,000 acres would potentially be removed from agriculture each decade (fig. 18), resulting in >330,000 acres, 2.7 percent of the 1997 base, removed from agricultural production by 2060 (table 7, fig. 18).

● Although the proportion of acreage devoted to forests and crops is expected to decrease, the relative amount of pasture in the Mississippi Alluvial Valley is projected to increase through 2060 under all Cornerstone Futures (fig. 17). Under the Cornerstone A assumption of high population and economic growth with increasing timber prices, pastureland would increase by 2.2 percentage points. An additional 73,000 acres would be converted to pasture each decade, for a total increase of >440,000 acres or 37.5 percent (table 7, fig. 18). Cornerstone D, defined by low population and economic growth and decreasing timber prices, would result in a more modest 0.4-percentage point gain in pasture (fig. 17) for an average increase of >14,500 acres per decade and a 7.5-percent (87,974-acre) rise in pastureland by 2060 (table 7, fig. 18).

● The largest land-use shift in the Mississippi Alluvial Valley over the next 50 years is projected to be towards increased urbanization. Forecasts of relatively low population and economic growth (Cornerstones C and D) would result in a 2.8-percentage point increase, placing urban area on a trajectory to occupy 6.4 percent of the land base by 2060 (fig. 17). At this scale, average increases in development would be >95,000 acres per decade (fig. 18) and urban acreage would have grown by >572,000 acres, an increase of nearly 81 percent over the base acreage in 1997 (table 7, fig. 18). A substantially steeper trajectory is forecast for the assumptions of high population and economic growth under Cornerstones A and B—urban growth could account for a 5.1-percentage point increase in developed acreage, raising urban land use to 8.7 percent of the land base by 2060 (fig. 17). Urban area would increase by nearly 172,000 acres per decade through 2060 (fig. 18), expanding the urban base by >1 million acres, or 145 percent over 1997 (table 7; figs. 17 and 18).

Holocene Deposits section—Consistent with the entire Mississippi Alluvial Valley, change in the distribution of acreage among land use categories in the Holocene Deposits section through 2060 will likely be driven by urban growth. Accordingly, the effect of urbanization on forest land use will depend on the rate of urbanization and the strength of future timber prices (table 8, fig. 19). The largest decrease in forest acreage is projected under the Cornerstone B assumption of high population and economic growth coupled with weak timber prices (table 8; figs. 19 and 20). Losses would average 49,000 acres per decade, resulting in a decrease of >295,000 acres, or 6 percent of the 1997 forested land base (table 8; figs. 19 and 20). In contrast, strong timber prices accompanying a future of low population and economic growth (Cornerstone C) could shift acreage into forest land use (table 8). Gains could be >11,000 acres per decade, and afforestation could increase forest area by 1.4 percent over the 1997 base (table 8; figs. 19 and 20).

All Cornerstone Futures predict that the Holocene Deposits section will undergo substantial loss in cropland through 2060. Losses could range from 300,000 acres under the Cornerstone D assumption of low population and economic growth with weak timber prices, to 1.2 million acres under the Cornerstone A assumption of high population and economic growth with strong timber prices (table 8; figs. 19 and 20). The 2.5-percent decrease projected under Cornerstone D would mean cropland losses averaging almost 50,000 acres per decade, compared to a 9.6-percent (>194,000 acres per decade) decrease projected under Cornerstone A (table 8; figs. 19 and 20).

Sizable gains in pastureland are expected in the Holocene Deposits section over the next several decades, raising the proportion of this land use to between 6 and 8 percent of the section (fig. 19). The amount of pasture could increase between 10.8 percent (Cornerstone D) and 43.1 percent (Cornerstone A) through 2060 (table 8; figs. 19 and 20). The highest rates of growth could be >75,000 acres per decade under the

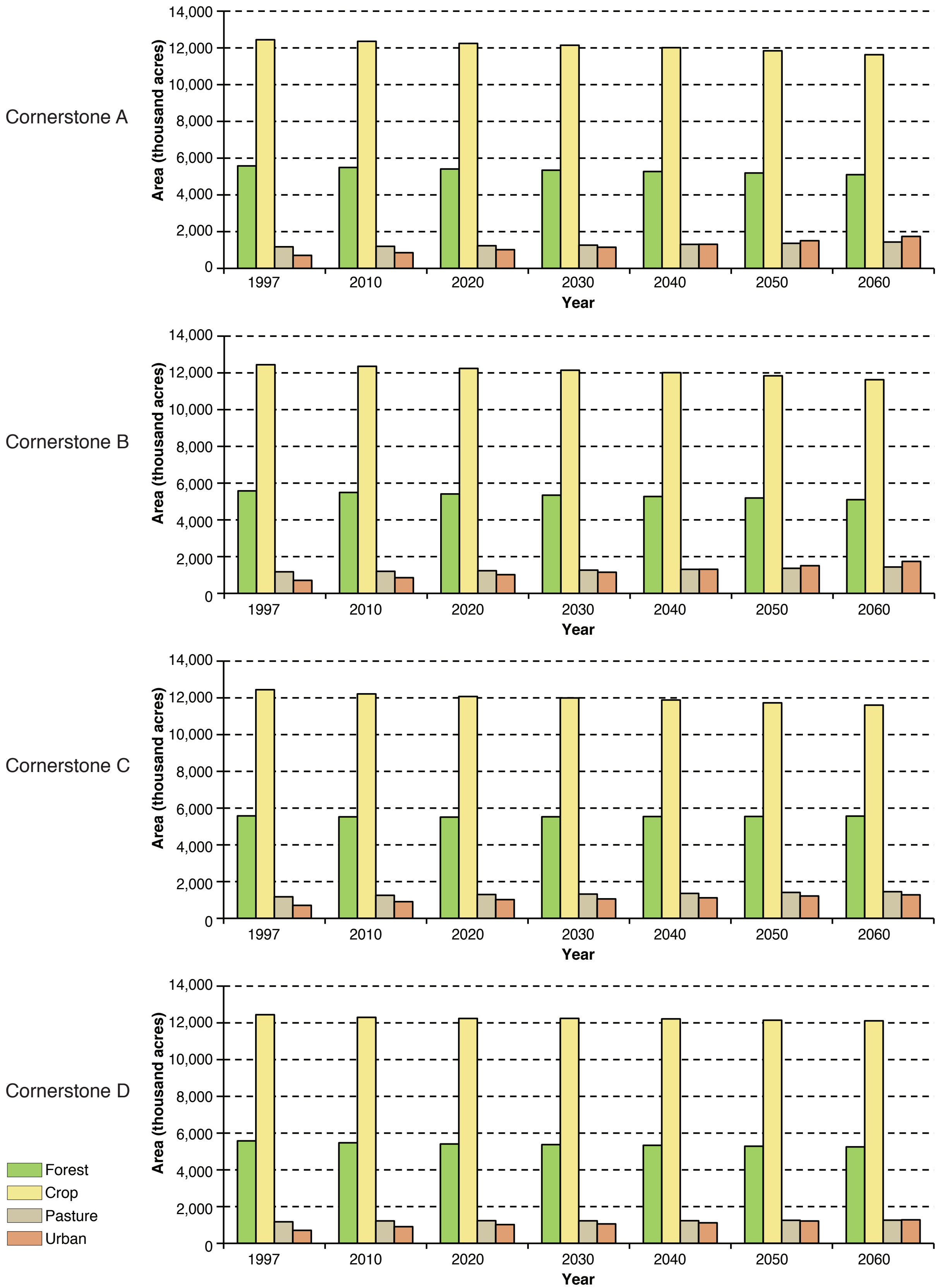

Figure 18—Projected land use by category in the U.S. Mississippi Alluvial Valley under four Cornerstone Futures (A through D), each of which represents a general circulation model paired with one of two emission scenarios—A1B representing high-population/high-economic growth, high energy use, and B2 representing low growth and use—and either high or low timber prices: Cornerstone A is MIROC3.2+A1B+high prices, Cornerstone B is CSIROMK3.5+A1B+low prices, Cornerstone C is CSIROMK2+B2+high prices, and Cornerstone D is HadCM3+B2+low prices. (Sources: Intergovernmental Panel on Climate Change 2007, Wear 2013)

Table 7—Distribution of acreage among land use categories in the U.S. Mississippi Alluvial Valley from 1997 to 2060 as forecasted by four Cornerstone Futures[a]

Change in distribution	Forest	Crop	Pasture	Urban
	Cornerstone A			
Acres[b]	-170,739	-1,300,753	440,037	1,031,455
Percent	-3.1	-10.4	37.5	145.7
	Cornerstone B			
Acres	-476,930	-814,810	260,285	1,031,455
Percent	-8.6	-6.5	22.2	145.7
	Cornerstone C			
Acres	-12,069	-838,887	278,218	572,738
Percent	-0.2	-6.7	23.7	80.9
	Cornerstone D			
Acres	-327,277	-333,434	87,974	572,738
Percent	-5.9	-2.7	7.5	80.9

[a]Each Cornerstone represents a general circulation model paired with one of two emission scenarios (A1B representing high-population/high-economic growth, high energy use, and B2 representing low growth and use—and either high or low timber prices): Cornerstone A is MIROC3.2+A1B+high prices, Cornerstone B is CSIROMK3.5+A1B+low prices, Cornerstone C is CSIROMK2+B2+high prices, and Cornerstone D is HadCM3+B2+low prices.

[b]Forecasts are not inclusive of public holdings or easements, utility corridors, and water bodies.

Sources: Intergovernmental Panel on Climate Change (2007) and Wear (2013).

Table 8—Distribution of acreage among land use categories in the Holocene Deposits section of the U.S. Mississippi Alluvial Valley from 1997 to 2060 as forecasted by four Cornerstone Futures[a]

Change in distribution	Forest	Crop	Pasture	Urban
	Cornerstone A			
Acres[b]	-29,131	-1,166,709	451,966	743,875
Percent	-0.6	-9.6	43.1	146.2
	Cornerstone B			
Acres	-296,024	-738,811	290,961	743,875
Percent	-6.1	-6.1	27.7	146.2
	Cornerstone C			
Acres	68,220	-736,925	279,684	389,020
Percent	1.4	-6.1	26.6	76.5
	Cornerstone D			
Acres	-202,694	-299,442	113,116	389,020
Percent	-4.2	-2.5	10.8	76.5

[a]Each Cornerstone represents a general circulation model paired with one of two emission scenarios (A1B representing high-population/high-economic growth, high energy use, and B2 representing low growth and use—and either high or low timber prices): Cornerstone A is MIROC3.2+A1B+high prices, Cornerstone B is CSIROMK3.5+A1B+low prices, Cornerstone C is CSIROMK2+B2+high prices, and Cornerstone D is HadCM3+B2+low prices.

[b]Forecasts are not inclusive of public holdings or easements, utility corridors, and water bodies.

Sources: Intergovernmental Panel on Climate Change (2007) and Wear (2013).

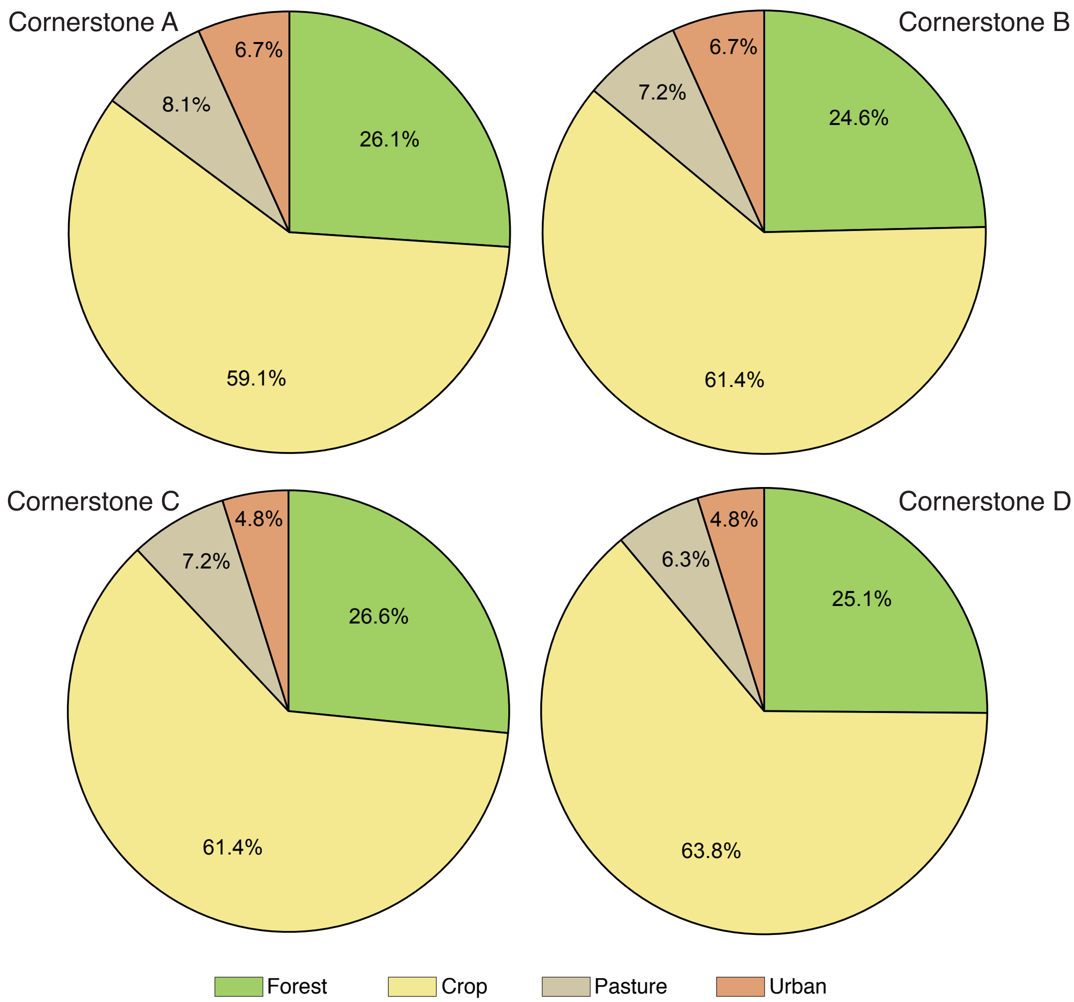

Figure 19—Projected land use percentages by category in the Holocene Deposits section of the U.S. Mississippi Alluvial Valley, 2060, under four Cornerstone Futures (A through D), each of which represents a general circulation model paired with one of two emission scenarios—A1B representing high-population/high-economic growth, high energy use, and B2 representing low growth and use—and either high or low timber prices: Cornerstone A is MIROC3.2+A1B+high prices, Cornerstone B is CSIROMK3.5+A1B+low prices, Cornerstone C is CSIROMK2+B2+high prices, and Cornerstone D is HadCM3+B2+low prices. (Sources: Intergovernmental Panel on Climate Change 2007, Wear 2013)

Cornerstone A assumption of high population and economic growth with increasing timber prices (figs. 19 and 20).

By 2060, the rise in urban growth in the Holocene Deposits section is expected to increase the proportion of urban land use to 4.8 percent under Cornerstones C and D and 6.7 percent under Cornerstones A and B (fig. 19) from 2.7 percent in 1997. If urbanization progressed from the low population and economic growth assumptions of Cornerstones C and D, urban land use averages would approach 65,000 acres per decade and result in a 76.5 percent increase to 389,020 acres (table 8, fig. 20). Progression of urbanization from the high population and economic growth assumptions of Cornerstones A and B could result in averages of nearly 124,000 per decade acres and a 146.2-percent increase to 743,875 acres of urban land (table 8, fig. 20).

Deltaic Plain section—The most significant land use changes in the Mississippi Alluvial Valley are expected to occur in the Deltaic Plain section. As with the Holocene Deposits section, change in the distribution of acreage among land use categories will be primarily driven by urban growth, and acreage distributed among forests, crops, and pastures is expected to decrease in support of urbanization (fig. 21). However, loss in forest acreage will likely be higher than losses predicted for cropland and pastureland under Cornerstones A, B, and D (table 9, fig. 22). Additionally, all Cornerstone Futures predict that the proportion of forest land will decrease below 50 percent of the total land base by 2020.

A future of high population and economic growth coupled with decreasing timber prices would lead to the largest loss of forest acreage. Losses through 2060 would be >30,000 acres per decade, and base forest acreage from 1997 would

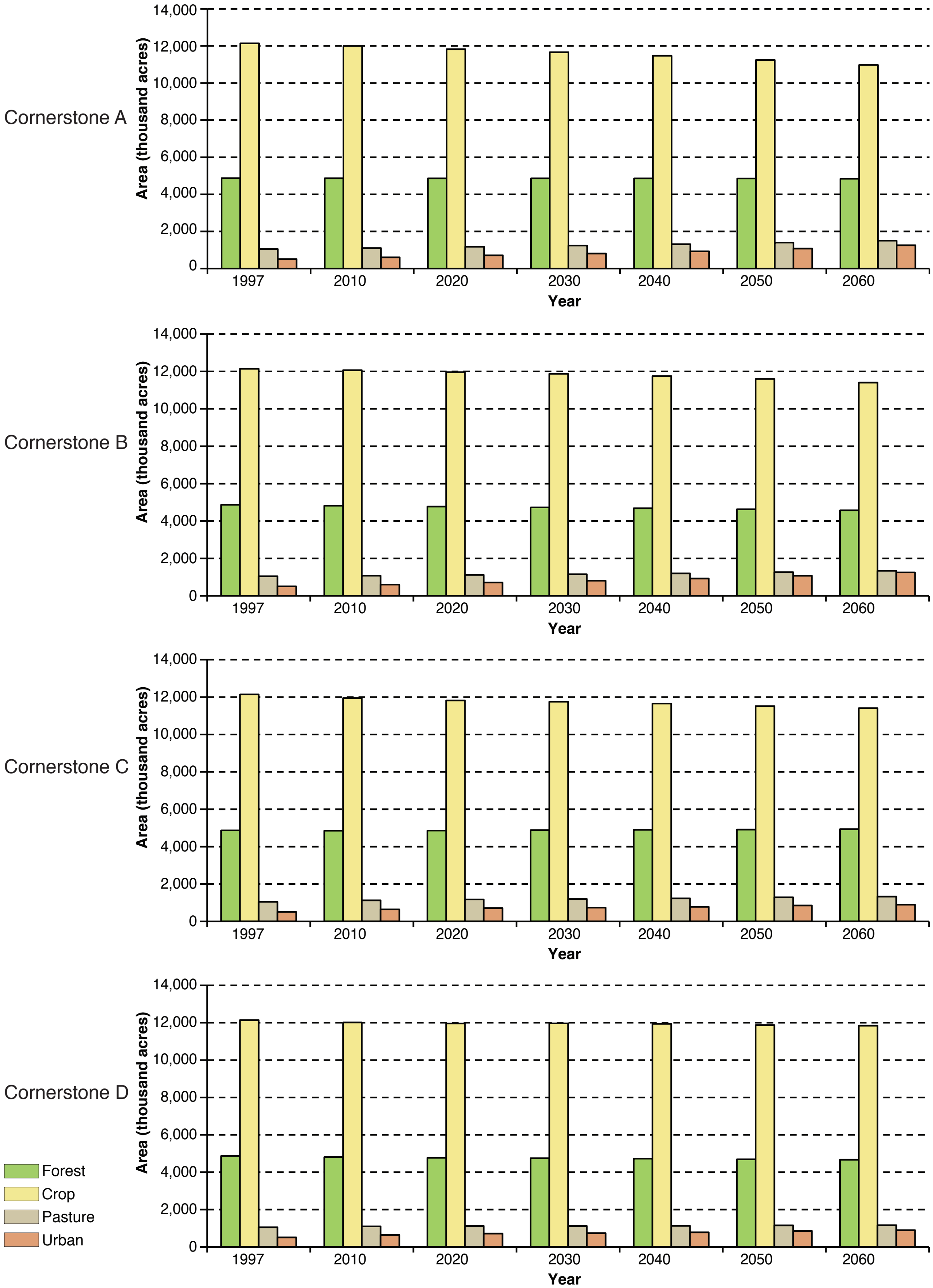

Figure 20—Projected land use by category in the Holocene Deposits section of the U.S. Mississippi Alluvial Valley under four Cornerstone Futures (A through D), each of which represents a general circulation model paired with one of two emission scenarios—A1B representing high-population/high-economic growth, high energy use, and B2 representing low growth and use—and either high or low timber prices: Cornerstone A is MIROC3.2+A1B+high prices, Cornerstone B is CSIROMK3.5+A1B+low prices, Cornerstone C is CSIROMK2+B2+high prices, and Cornerstone D is HadCM3+B2+low prices. (Sources: Intergovernmental Panel on Climate Change 2007, Wear 2013)

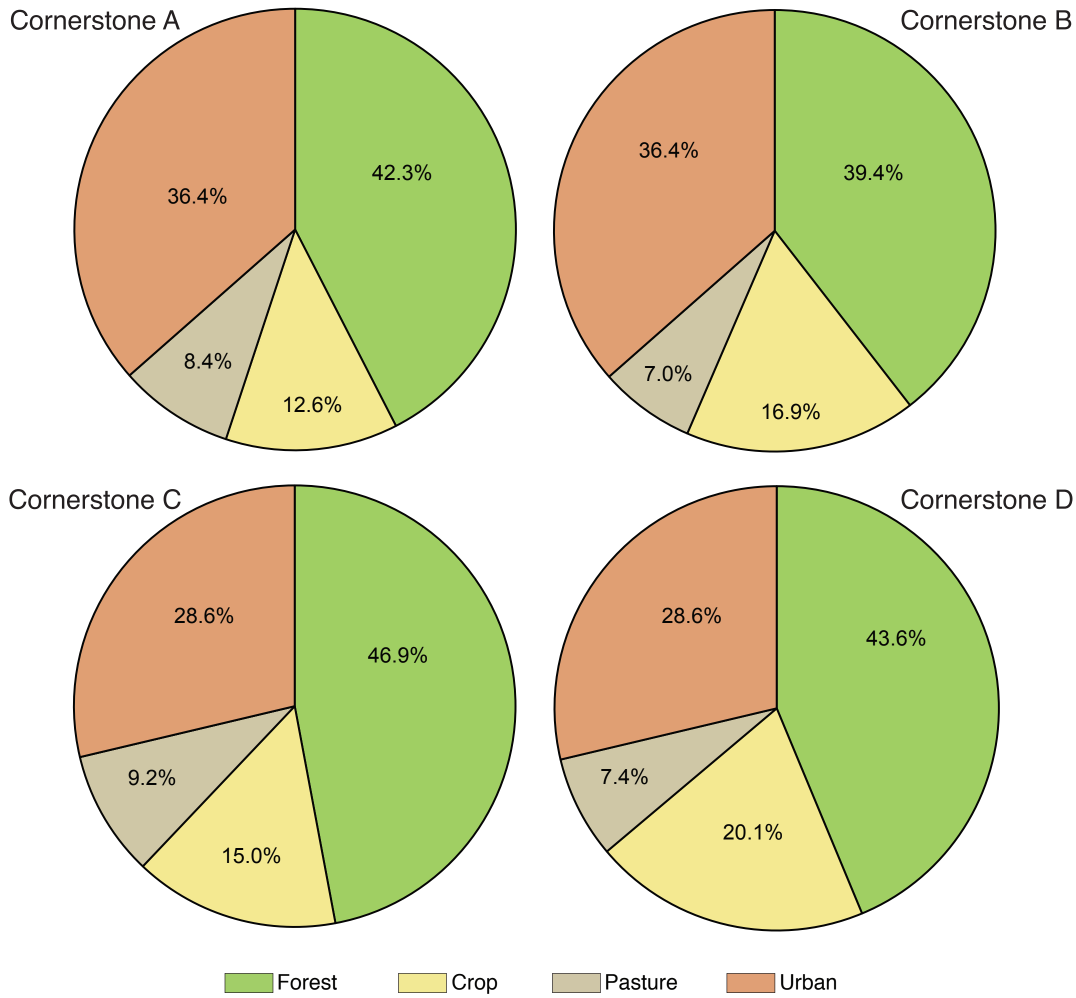

Figure 21—Projected land use percentages by category in the Deltaic Plain section of the U.S. Mississippi Alluvial Valley, 2060, under four Cornerstone Futures (A through D), each of which represents a general circulation model paired with one of two emission scenarios—A1B representing high-population/high-economic growth, high energy use, and B2 representing low growth and use—and either high or low timber prices: Cornerstone A is MIROC3.2+A1B+high prices, Cornerstone B is CSIROMK3.5+A1B+low prices, Cornerstone C is CSIROMK2+B2+high prices, and Cornerstone D is HadCM3+B2+low prices. (Sources: Intergovernmental Panel on Climate Change 2007, Wear 2013)

be reduced by >25 percent (table 9, fig. 22). Cornerstone C, defined by low population and economic growth along with increasing timber prices, projects a lower trajectory of deforestation. Decreases would average about 13,000 acres per decade, and the total loss would reach 80,000 acres by 2060 (table 9, fig. 22).

Interestingly, the increasing timber prices under Cornerstones A and C might not curtail deforestation to the same extent predicted for the Holocene Deposits section (tables 8 to 10) where deforestation appears to be substantially limited and urban growth would advance largely through conversion of cropland. Because cropland is not as available in the Deltaic Plain section, demands from urbanization would be less likely to limit the effects that high timber prices would impose on deforestation (tables 8 to 10).

Although extensive urban growth in the Deltaic Plain section appears to be imminent, the rate and extent of development will depend on population and economic growth. The low population and economic growth under Cornerstones C and D would increase urban land use >30,000 acres each decade and nearly double (92 percent) this land use by 2060 (table 9, fig. 22). The high population and economic growth under Cornerstones A and B would produce a much sharper increase in urban area. Urbanization rates could average nearly 48,000 acres per decade (fig. 22), and urban cover would expand by >144 percent from base acreage by 2060 (table 9, fig. 22).

Table 9—Distribution of acreage among land use categories in the Deltaic Plain section of the U.S. Mississippi Alluvial Valley from 1997 to 2060 as forecasted by four Cornerstone Futures[a]

Change in distribution	Forest	Crop	Pasture	Urban
	Cornerstone A			
Acres[b]	-141,608	-134,043	-11,929	287,581
Percent	-20.0	-44.3	-9.6	144.4
	Cornerstone B			
Acres	-180,906	-75,999	-30,676	287,581
Percent	-25.6	-25.1	-24.7	144.4
	Cornerstone C			
Acres	-80,289	-101,962	-1,466	183,717
Percent	-11.3	-33.7	-1.2	92.2
	Cornerstone D			
Acres	-124,583	-33,993	-25,141	183,717
Percent	-17.6	-11.2	-20.2	92.2

[a]Each Cornerstone represents a general circulation model paired with one of two emission scenarios (A1B representing high-population/high-economic growth, high energy use, and B2 representing low growth and use—and either high or low timber prices): Cornerstone A is MIROC3.2+A1B+high prices, Cornerstone B is CSIROMK3.5+A1B+low prices, Cornerstone C is CSIROMK2+B2+high prices, and Cornerstone D is HadCM3+B2+low prices.

[b]Forecasts are not inclusive of public holdings or easements, utility corridors, and water bodies.

Sources: Intergovernmental Panel on Climate Change (2007) and Wear (2013).

Table 10—Conversion of urban land growth between 1997 and 2060 from forest land in the sections of the U.S. Mississippi Alluvial Valley, based on four Cornerstone Futures[a]

Section	Cornerstone A	Cornerstone B	Cornerstone C	Cornerstone D
	---------------------------- *percent* ----------------------------			
Holocene Deposits section	3.9	39.8	0	52.1
Deltaic Plain section	49.2	62.9	43.7	67.8

[a]Each of which represents a general circulation model paired with one of two emission scenarios (A1B representing high-population/high-economic growth, high energy use, and B2 representing low growth and use—and either high or low timber prices): Cornerstone A is MIROC3.2+A1B+high prices, Cornerstone B is CSIROMK3.5+A1B+low prices, Cornerstone C is CSIROMK2+B2+high prices, and Cornerstone D is HadCM3+B2+low prices.

Sources: Intergovernmental Panel on Climate Change (2007) and Wear (2013).

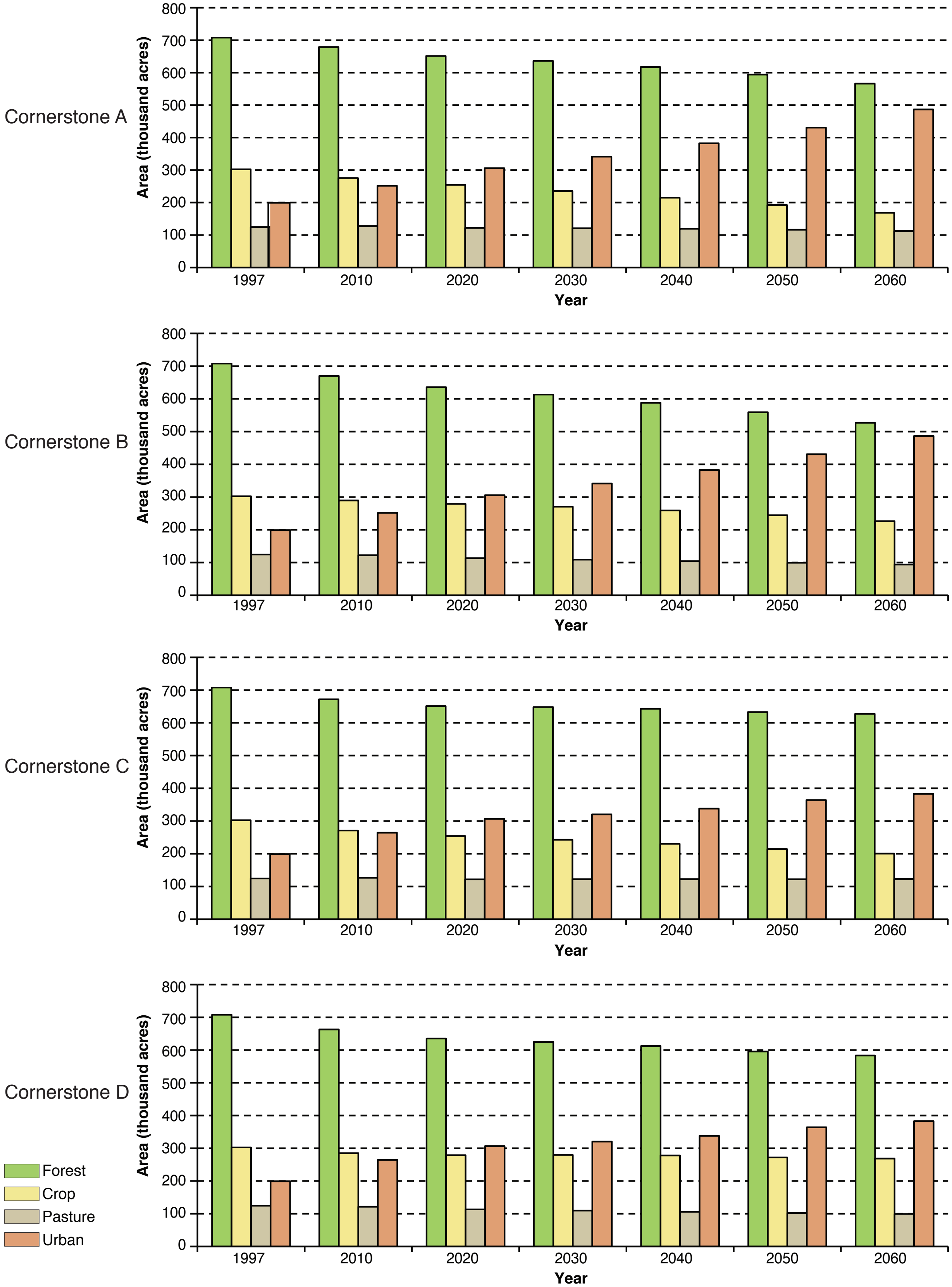

Figure 22—Projected land use by category in the Deltaic Plain section of the U.S. Mississippi Alluvial Valley under four Cornerstone Futures (A through D), each of which represents a general circulation model paired with one of two emission scenarios—A1B representing high-population/high-economic growth, high energy use, and B2 representing low growth and use—and either high or low timber prices: Cornerstone A is MIROC3.2+A1B+high prices, Cornerstone B is CSIROMK3.5+A1B+low prices, Cornerstone C is CSIROMK2+B2+high prices, and Cornerstone D is HadCM3+B2+low prices. (Sources: Intergovernmental Panel on Climate Change 2007, Wear 2013)

CHAPTER 4. Biological Threats

The issue of feral hogs (*Sus scrofa* L.) should be raised in any discussion of biological threats to forests of the Mississippi Alluvial Valley. While a clear understanding of their pervasiveness and impact within the Mississippi Alluvial Valley is lacking, feral hogs are attributed with causing extensive economic damage and ecological degradation in forests around the world. Their rooting, wallowing, rubbing, and predation activities can alter soil chemical, physical, and biological properties; increase soil erosion; destroy forest regeneration pools; facilitate the spread of invasive plants; alter forest structure; establish competition for food with native wildlife; and subject native fauna to predation (Campbell and Long 2009, Siemann and others 2009). Because the feral hog is valued as a game animal, population expansion in the United States has been attributed in part to releases for recreational opportunities (Massei and others 2011). Efforts to limit further establishment and damage will require coordinated and sustained efforts on the part of wildlife damage control agencies, wildlife conservation agencies, and landowners in the Mississippi Alluvial Valley.

INVASIVE PLANTS

A host of human activities, many of them well-intentioned, have resulted in scores of nonnative plants introduced into forested ecosystems. Miller and others (2013) reported that 9 percent of all southern forests harbor at least one species of nonnative plant, with infestations progressing at about 145,000 acres a year. Invasive plants have been implicated in severe alterations in the function and structure of native ecosystems, which in turn impact species richness, productivity, disturbance regimes, soil biogeochemistry processes, and many other forest attributes (Gordon 1998, Vilà and others 2011). Furthermore, values derived from forest ecosystems—including recreation, timber production, carbon sequestration, and water quality—can be greatly diminished when native flora are displaced by nonnative species, resulting in environmental damage, prevention and control, and restoration measures costing millions of dollars (Moser and others 2009, Pimentel and others 2005, Webster and others 2006).

This section examines the findings presented by Miller and others (2013) for the Southern Forest Futures Project, and provides a synthesis of their relevance to the future forests of the Mississippi Alluvial Valley and its associated sections.

Current Status

Since their earliest introductions, some over three centuries ago, nonnative plant species have substantially encroached on the forests of the lower Mississippi Valley. Current inventories indicate that as many as 21 high priority nonnative plants have become well established in forests of the Mississippi Alluvial Valley; they include five trees, five shrubs, seven vines, and four grasses (table 11) and, in aggregate, are estimated to cover >3.1 percent (206,782 acres) of forests. Twenty are established in forests of the Holocene Deposits section, six in the Deltaic Plain section (table 11).

Trees—Invasive trees such as tallowtree (*Triadica sebifera* (L.) Small) are persistently gaining cover and degrading forests in the Mississippi Alluvial Valley. A deciduous broadleaf from China that can grow up to 60 feet tall (Miller and others 2010), tallowtree is the most widespread nonnative tree in the Mississippi Alluvial Valley; it is also the most widespread nonnative plant in forests of the Deltaic Plain section (table 11, fig. 23). Introduced into the United States in the late 1700s, it first appeared in the Mississippi Alluvial Valley in the early 1900s where it was used as a source of seed oil along the Gulf of Mexico (Miller and others 2010). It now covers about 0.6 percent (37,000 acres) of forests and spreads by developing dense, monospecific stands that displace native vegetation (table 11, fig. 23A).

Other high priority nonnative tree species of the South established throughout the Mississippi Alluvial Valley have not yet attacked forest communities with the same aggressiveness as tallowtree. Chinaberry (*Melia azedarach* L.) and silktree (*Albizia julibrissin* Durazz.), although widely distributed, combine to currently cover <1,500 acres (table 11). Princesstree (*Paulownia tomentosa* (Thunb.) Siebold & Zucc. Ex Steud.) and tree-of-heaven (*Ailanthus altissima* (Mill.) Swingle), were also early escapees from cultivation that have naturalized, but these species have not exhibited

Table 11—Estimated cover of high priority invasive plants infesting forests in the sections of the U.S. Mississippi Alluvial Valley, 2010

Taxa	Holocene Deposits section	Deltaic Plain section
	------------- *acres* -------------	
Trees		
Chinaberrytree (*Melia azedarach*)	851	–
Princesstree (*Paulownia tomentosa*)	80	–
Silktree (*Albizia julibrissin*)	604	–
Tallowtree (*Triadica sebifera*)	18,189	19,378
Tree-of-heaven (*Ailanthus altissima*)	13	–
Shrubs		
Bush honeysuckle (*Lonicera* spp.)	1,709	–
Invasive lespedezas (*Lespedeza* spp.)	5,756	–
Invasive privets (*Ligustrum* spp.)	25,409	5,911
Invasive roses (*Rosa* spp.)	562	987
Sacred bamboo (*Nandina domestica*)	339	–
Vines		
Invasive climbing yams (*Dioscorea* spp.)	20	–
Invasive wisterias (*Wisteria* spp.)	1,972	–
Japanese climbing fern (*Lygodium japonicum*)[a]	6,957	7,422
Japanese honeysuckle (*Lonicera japonica*)	88,892	3,628
Kudzu (*Pueraria montana*)	3,051	–
Oriental bittersweet (*Celastrus orbiculatus*)	7	–
Vinca (*Vinca* spp.)	89	–
Grasses and Canes		
Cogongrass (*Imperata cylindrical*)	1,832	–
Invasive bamboos (*Phyllostachys* spp. and *Bambusa* spp.)	6,729	–
Nepalese browntop (*Microstegium vimineum*)	–	1,571
Tall fescue (*Schedonorus phoenix*)	4,824	–

– = No coverage for this species.

[a]Japanese climbing fern is not a vine as defined by a climbing stem. Rather, this climbing fern has fronds that exhibit indeterminate growth as they extend over and twine around supportive structures.

Source: Forest Inventory and Analysis, Southern Research Station, U.S. Forest Service.

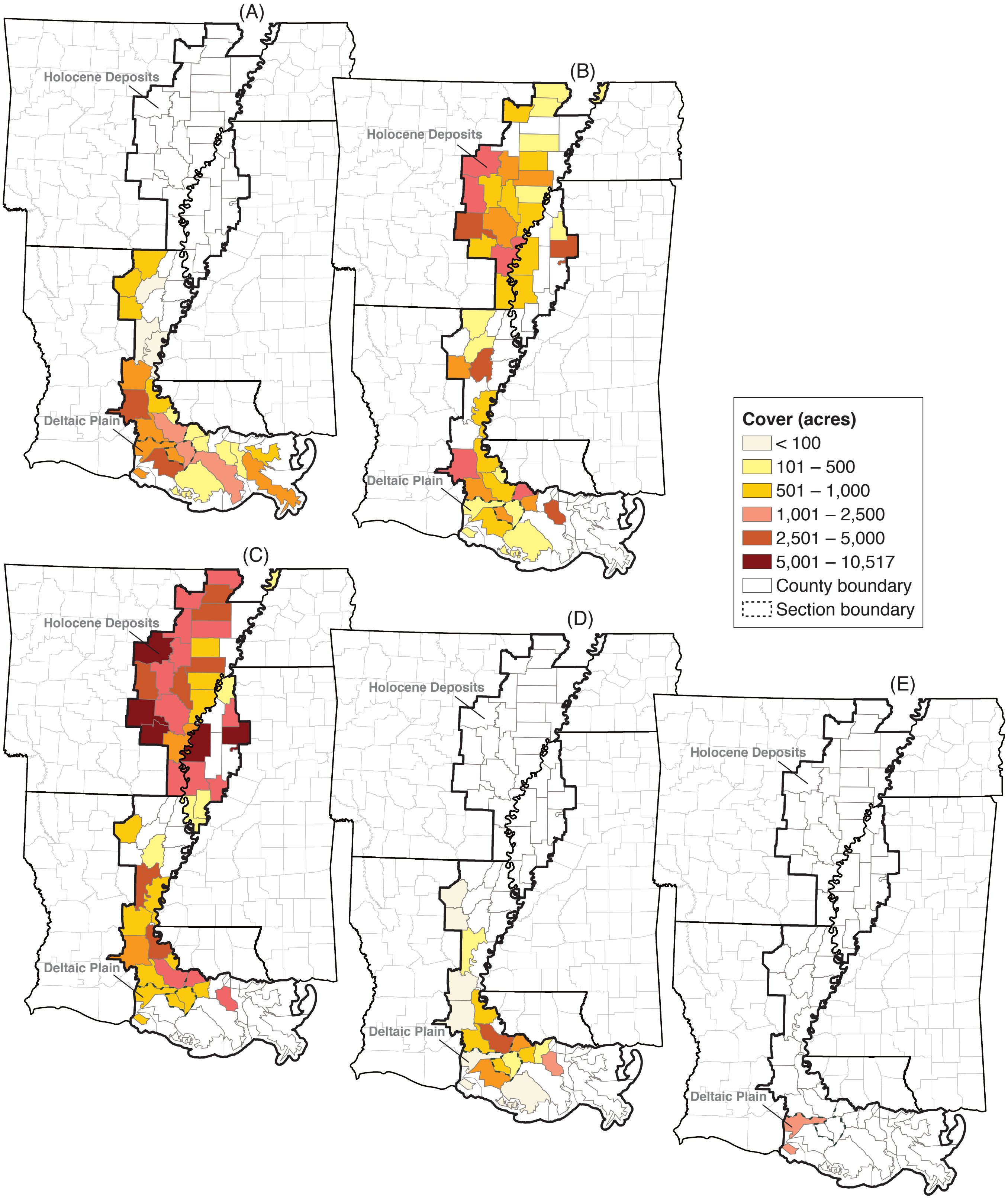

Figure 23—In the U.S. Mississippi Alluvial Valley and its associated sections, cover in forested landscapes, 2010, of (A) tallowtree, (B) nonnative privets, (C) Japanese honeysuckle, (D) Japanese climbing fern, (E) Nepalese browntop. (Source: Forest Inventory and Analysis, Southern Research Station, U.S. Forest Service)

the same aggressive invasion of natural communities in the Mississippi Alluvial Valley as they have in other areas of the South (table 11).

Shrubs—As prevalent as nonnative trees are the nonnative shrubs that occupy the understory and midstory of >40,000 forested acres in the Mississippi Alluvial Valley. Invasive privets (*Ligustrum* L.), primarily Chinese privet (*Ligustrum sinense* Lour.), glossy privet (*Ligustrum lucidum* W.T. Aiton) and Japanese privet (*Ligustrum japonicum* Thunb.), have had the most successful invasions. First introduced in the South during the late 1700s and planted extensively as ornamentals (Miller and others 2010), privets have escaped cultivation and now cover >31,000 acres, mostly in the Holocene Deposits section (table 11, fig. 23B).

Other nonnative shrubs (table 11) that have significantly encroached into forest communities of the Mississippi Alluvial Valley include lespedezas (*Lespedeza* spp. Michaux), bush honeysuckle (*Lonicera* spp. L.), and roses (*Rosa* spp. L.). Although these species are generally not aggressive invaders of lowland forests, they are prevalent farther upland, for example, on Crowley's Ridge and around the margins of the Holocene Deposits section.

Vines—The most successful plant life form to invade natural forest communities of the Mississippi Alluvial Valley are the nonnative vines that cover >112,000 forested acres (table 11). Japanese honeysuckle (*Lonicera japonica* Thunb.), a twining woody vine native to eastern Asia, is the most prevalent nonnative species in the South as well as in the forests of the Mississippi Alluvial Valley. Introduced as an ornamental in the United States in the 1800s (Miller and others 2010), Japanese honeysuckle has naturalized and expanded its range to an estimated 92,520 acres in the Mississippi Alluvial Valley (table 11, fig. 23C). Field records indicate that about 96 percent of this infested acreage is distributed in the Holocene Deposits section (table 11, fig. 23C).

Japanese climbing fern (*Lygodium japonicum* (Thunb.) SW.), which spreads by continually producing twining fronds, is another high priority nonnative aggressively expanding in the Mississippi Alluvial Valley. Native to Asia and tropical Australia, it was introduced as an ornamental in the 1930s (Miller and others 2010). Having first invaded forests in the southernmost portion of the Mississippi Alluvial Valley, it is now advancing northward through wind-carried spores or contaminants on garments (table 11, fig. 23D).

Grasses—Although agricultural landscapes throughout the Mississippi Alluvial Valley have experienced extensive invasions from nonnative grasses such as Johnsongrass (*Sorghum halepense* (L.) Pers.) and annual bluegrass (*Poa annua* L.), invasions into forests have yet to be as successful. High priority nonnative grasses currently occupy about 15,000 acres, roughly 0.2 percent of all forested acreage. Invasive bamboos (*Phyllostachys* spp. Siebold & Zucc. and *Bambusa* spp. Schreb.), introduced from Asia, are the most extensive nonnative grasses in forests of the Mississippi Alluvial Valley, occupying >6,700 acres in the Holocene Deposits section. Some species that have firmly established in other areas of the South are also beginning to spread into the Mississippi Alluvial Valley. For example, Nepalese browntop (*Microstegium vimineum* (Trin.) A. Camus) was introduced into the United States in the early 1900s and has aggressively expanded its cover in southern forests ever since. This species now covers about 1,571 acres in the Mississippi Alluvial Valley (table 11, fig. 23E).

Other species—The Mississippi Alluvial Valley, in addition to suffering infestations by many terrestrial plants, has slough and swamp forests that have also experienced unrelenting invasions by a host of aquatic plants, including water-hyacinth (*Eichhornia crassipes* (Mart.) Solms.), alligatorweed (*Alternanthera philoxeroides* (Mart.) Griseb.), parrot-feather (*Myriophyllum aquaticum* (Vell.) Verdc.), common salvinia (*Salvinia minima* Baker), and hydrilla (*Hydrilla verticillata* (L.f.) Royle.). Assessing and projecting cover by these species is beyond the scope of this report, but their impacts to forest regeneration, wildlife habitat, water quality, recreation, and many other ecosystem functions and values will likely continue to be devastating.

Forecasts

Findings from the Southern Forest Futures Project indicated that nonnative plants would largely assume an increasing trajectory of forest degradation in the Mississippi Alluvial Valley for the next several decades (Miller and others 2013). Suitable habitats remain available for increased occupation by plants poised to respond to a range of factors that includes changing land use patterns, changing climate patterns, forest disturbance regimes, human population growth, and increasing recreational use. Miller and others (2013) constructed models to project the influences of the defined Cornerstone Futures on future range and occupation intensity of five priority nonnative taxa. These taxa—tallowtree, silktree, Japanese climbing fern, nonnative roses, and Nepalese browntop—were chosen because they provide a range of possible responses to future conditions as they include different plant growth forms, hold differing amounts of current forest cover, and exhibit various levels of potential invasiveness for the Mississippi Alluvial Valley (Miller and others 2013).

Tallowtree—Forecast modeling indicated average minimum temperature in January, average annual precipitation, and surface elevation are the most influential variables for predicting the invasive potential of tallowtree (Miller and others 2013). If current climate conditions prevail through

2060, models predict that tallowtree would show a high potential to increase its intensity of occurrence where it presently occurs in forests of the Deltaic Plain and lower Holocene Deposits sections, but the potential for expanding its range farther north in the Holocene Deposits section is rather low (figs. 23 and 24). The highest potential for a northward range expansion would occur under a future defined by maximum temperature increases and maximum precipitation decreases—1.7 °C and 95 mm for Cornerstone B, 2.9 °C and 327 mm for Cornerstone A (tables 4 and 5; fig. 24). In contrast, under the minimal temperature increases (1.2 °C increase in average annual temperature) and drying conditions (126 mm decrease in average annual precipitation) of Cornerstone D, tallowtree would be less aggressive and its highest potential for invasion would be confined to the southernmost portions of Deltaic Plain section (tables 4 and 5; fig. 24).

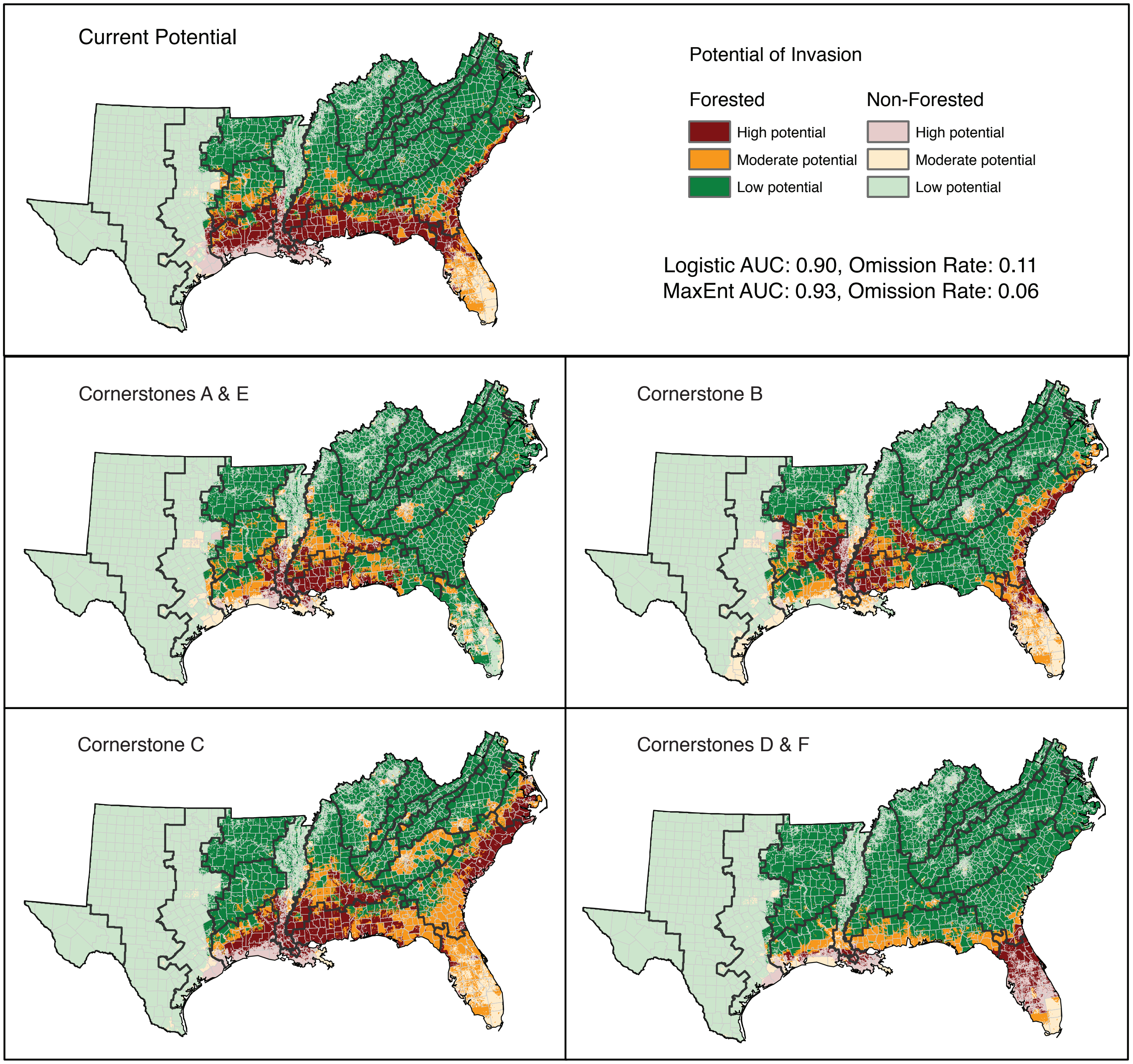

Figure 24—Potential for tallowtree occupation into the U.S. South by 2060, assuming: current potential if current climate continues in the U.S. Mississippi Alluvial Valley; maximal warming and drying projected for Cornerstones A and E; moderate warming and moderate drying projected for Cornerstone B; minimal warming and increased rainfall projected for Cornerstone C; and minimal warming and moderate drying projected for Cornerstones D and F. (Source: Miller and others 2013)

Silktree—Many variables could influence the potential invasion of silktree in the Mississippi Alluvial Valley. Average minimum temperature in January and distance to interstate highways were the strongest contributing variables to the forecast models; average annual rainfall and surface elevation were moderate contributors; and distance to roads, persons per square mile, and proportion of forest in a county were significant but low contributors (Miller and others 2013). If current climate conditions continue, the highest potential for invasion by silktree would remain in the northern portion of the Holocene Deposits section where infestations would be most intense in forests that are adjacent to roads (fig. 25). The maximum increases in temperatures and maximum decreases in rainfall under Cornerstones A and B would likely lessen the invasive potential of silktree by 2060 (tables 4 and 5; fig. 25). In contrast, more moderate increases in annual temperatures could increase the invasive potential of silktree and lead to substantially more occurrences of this species in the northern and central portions of the Holocene Deposits section—1.4 °C under Cornerstone C, 1.3 °C under Cornerstone D (fig. 25).

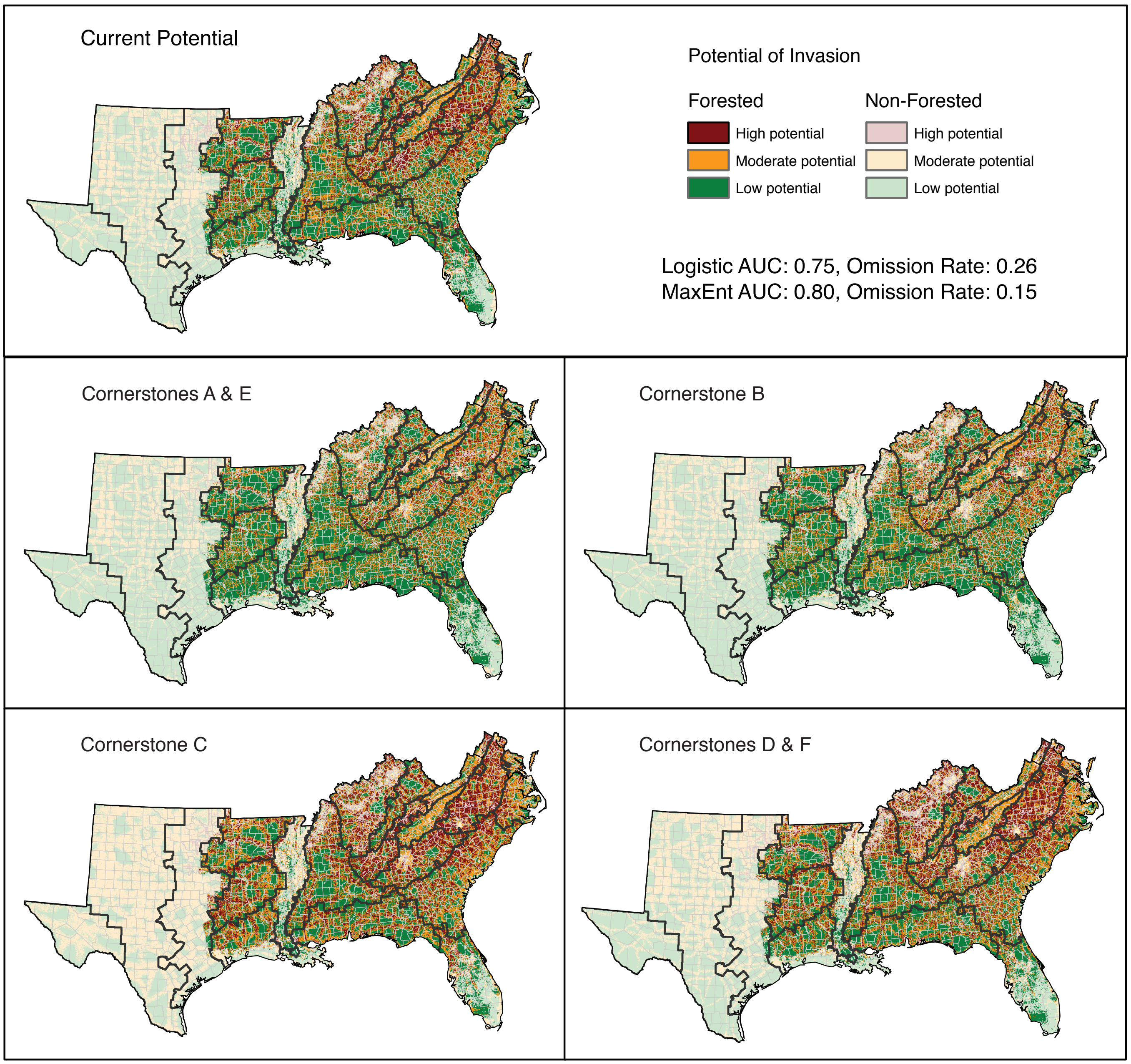

Figure 25—Potential for silktree occupation in the U.S. South by 2060, assuming: current potential if current climate continues in the U.S. Mississippi Alluvial Valley; maximal warming and drying projected for Cornerstones A and E; moderate warming and moderate drying projected for Cornerstone B; minimal warming and increased rainfall projected for Cornerstone C; and minimal warming and moderate drying projected for Cornerstones D and F. (Source: Miller and others 2013)

Nonnative roses—Miller and others (2013) found that rose invasiveness is highly responsive to certain forecast model parameters and that their potential to invade forests is strongly determined by the average minimum temperature in January and to lesser extents by surface elevation and proportion of pasture. If current climate conditions prevail, potential invasiveness would remain relatively low through 2060 in all parts of the Mississippi Alluvial Valley except the northernmost area of the Holocene Deposits section (fig. 26). Under the climate conditions of most Cornerstone Futures (A, B, and C), potential invasiveness could decrease (fig. 26). However, the slight temperature increases and moderate precipitation decreases under Cornerstone D could lead to a dramatic increase in the potential threat of nonnative roses throughout much of the Holocene Deposits section (tables 4 and 5; fig. 26); this would result in moderate-to-high increases in potential invasiveness by 2060, particularly across much of the Holocene Deposits forests (fig. 26).

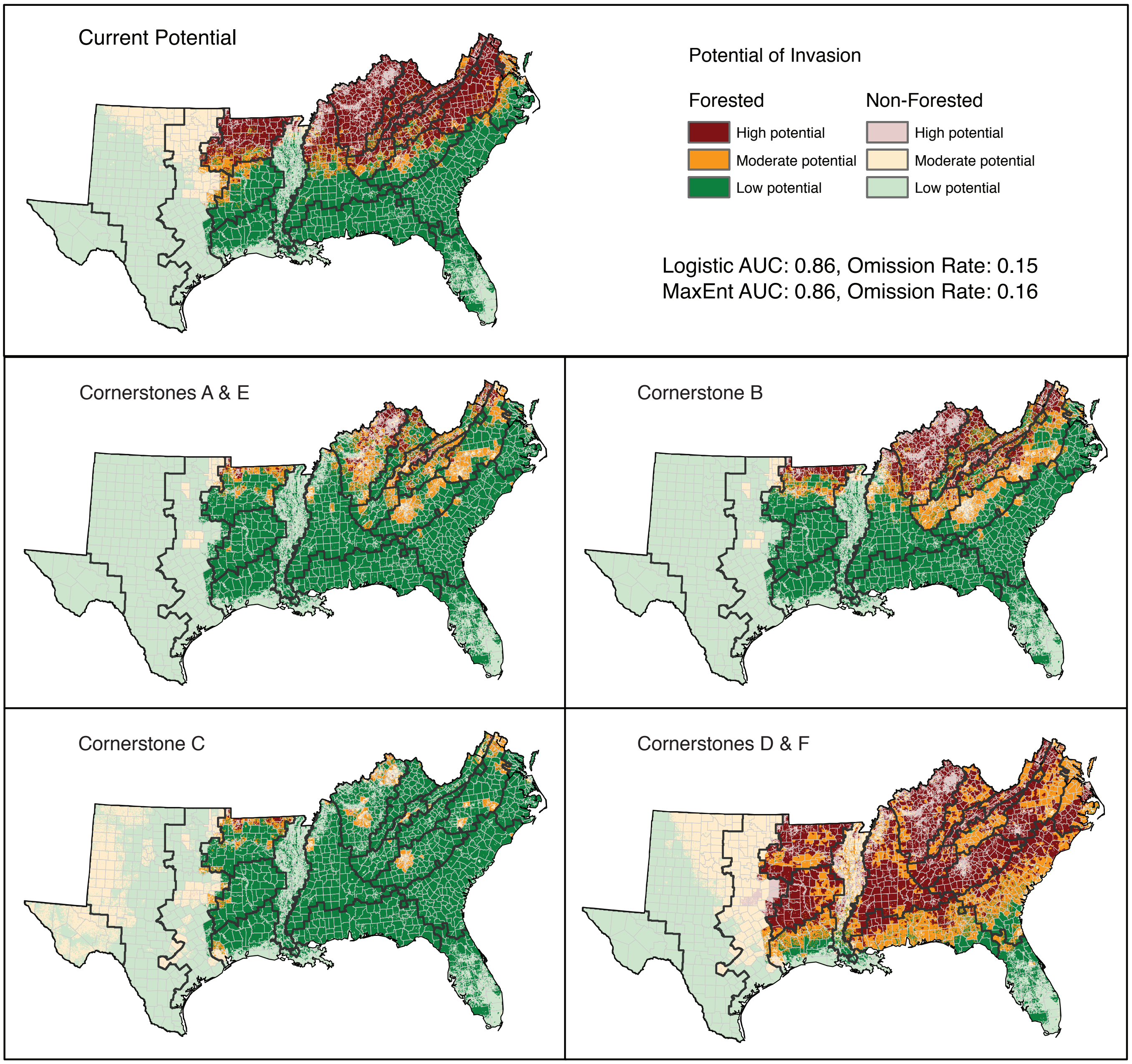

Figure 26—Potential for invasive-rose occupation in the U.S. South by 2060, assuming: current potential if current climate continues in the U.S. Mississippi Alluvial Valley; maximal warming and drying projected for Cornerstones A and E; moderate warming and moderate drying projected for Cornerstone B; minimal warming and increased rainfall projected for Cornerstone C; and minimal warming and moderate drying projected for Cornerstones D and F. (Source: Miller and others 2013)

Japanese climbing fern—Potential invasiveness of Japanese climbing fern in forests of the Mississippi Alluvial Valley is driven by average minimum temperature in January, average annual rainfall, and surface elevation (Miller and others 2013). If current climate conditions continue through 2060, invasiveness of this species would remain highest in forests where it is currently established—the Deltaic Plain section and the lower portion of the Holocene Deposits section—and its range would extend northward into the central forests of the Holocene Deposits section where it has not yet been detected (figs. 23 and 27). In contrast, climate conditions defined by all of the Cornerstone Futures would lead to a decrease in the invasiveness of this species in the Mississippi Alluvial Valley. The largest decrease in potential invasiveness would be observed under the minimal temperature increases and moderate rainfall decreases under Cornerstones D (tables 4 and 5; fig. 27).

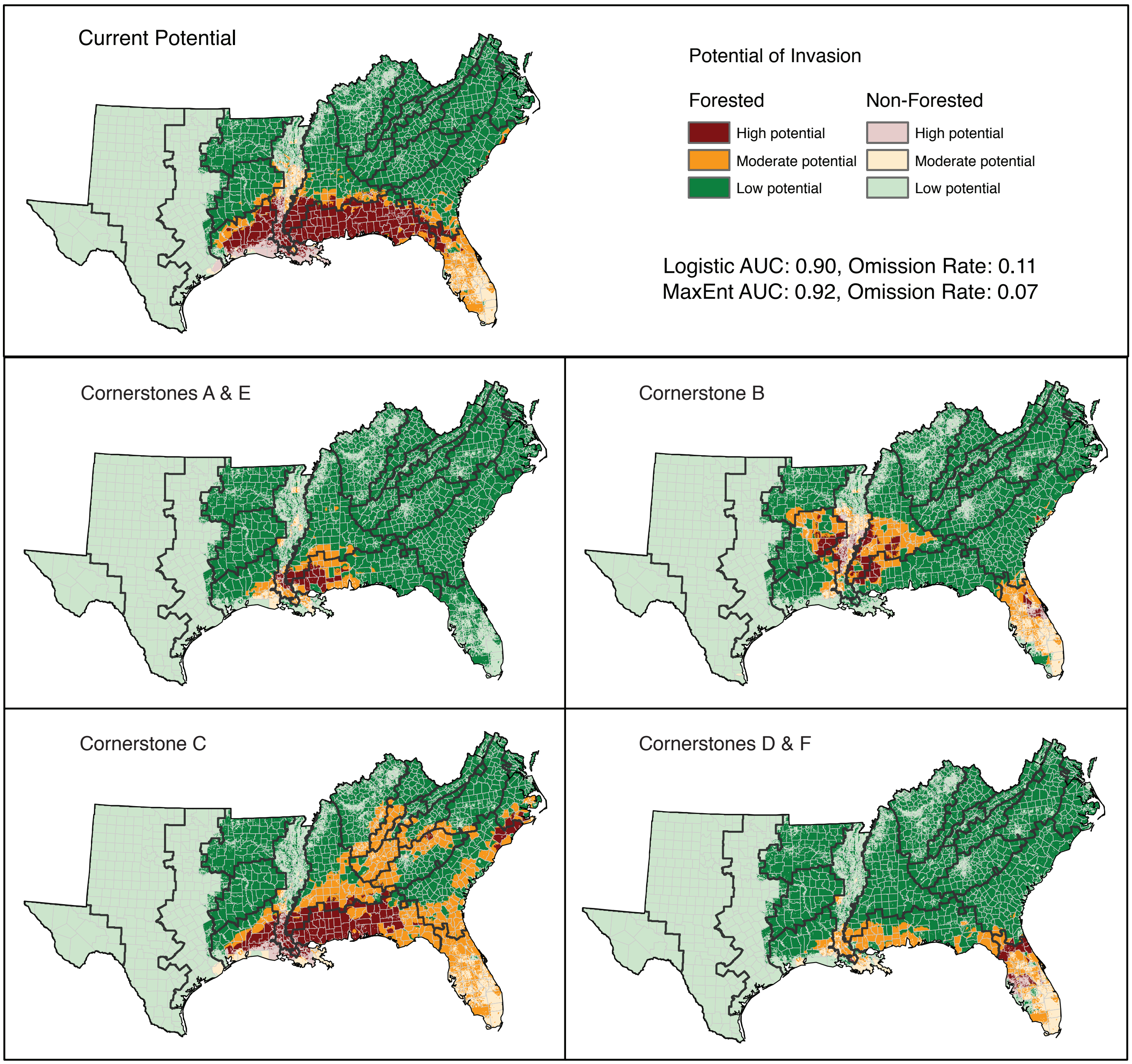

Figure 27—Potential for Japanese climbing fern occupation in the U.S. South by 2060, assuming: current potential if current climate continues in the U.S. Mississippi Alluvial Valley; maximal warming and drying projected for Cornerstones A and E; moderate warming and moderate drying projected for Cornerstone B; minimal warming and increased rainfall projected for Cornerstone C; and minimal warming and moderate drying projected for Cornerstones D and F. (Source: Miller and others 2013)

Nepalese browntop—Occurrences of Nepalese browntop in the forests of the Mississippi Alluvial Valley are limited to the southwestern margin of the Deltaic Plain section. The strongest contributing variable to potential invasiveness for this species is average minimum temperature in January; average annual precipitation, surface elevation, and proportion of forest in county contribute to lesser degrees (Miller and others 2013). If climate conditions continue into 2060, the result would be moderate increases to invasiveness, especially in the northern third of the Holocene Deposits section (fig. 28). In contrast, under most Cornerstone Futures, potential invasiveness would decrease (fig. 28). The exception would be Cornerstone D—under its minimal temperature increases and the moderate precipitation decreases, the potential for invasion would increase across the entire Holocene Deposits section, particularly in Louisiana (tables 4 and 5; fig. 28).

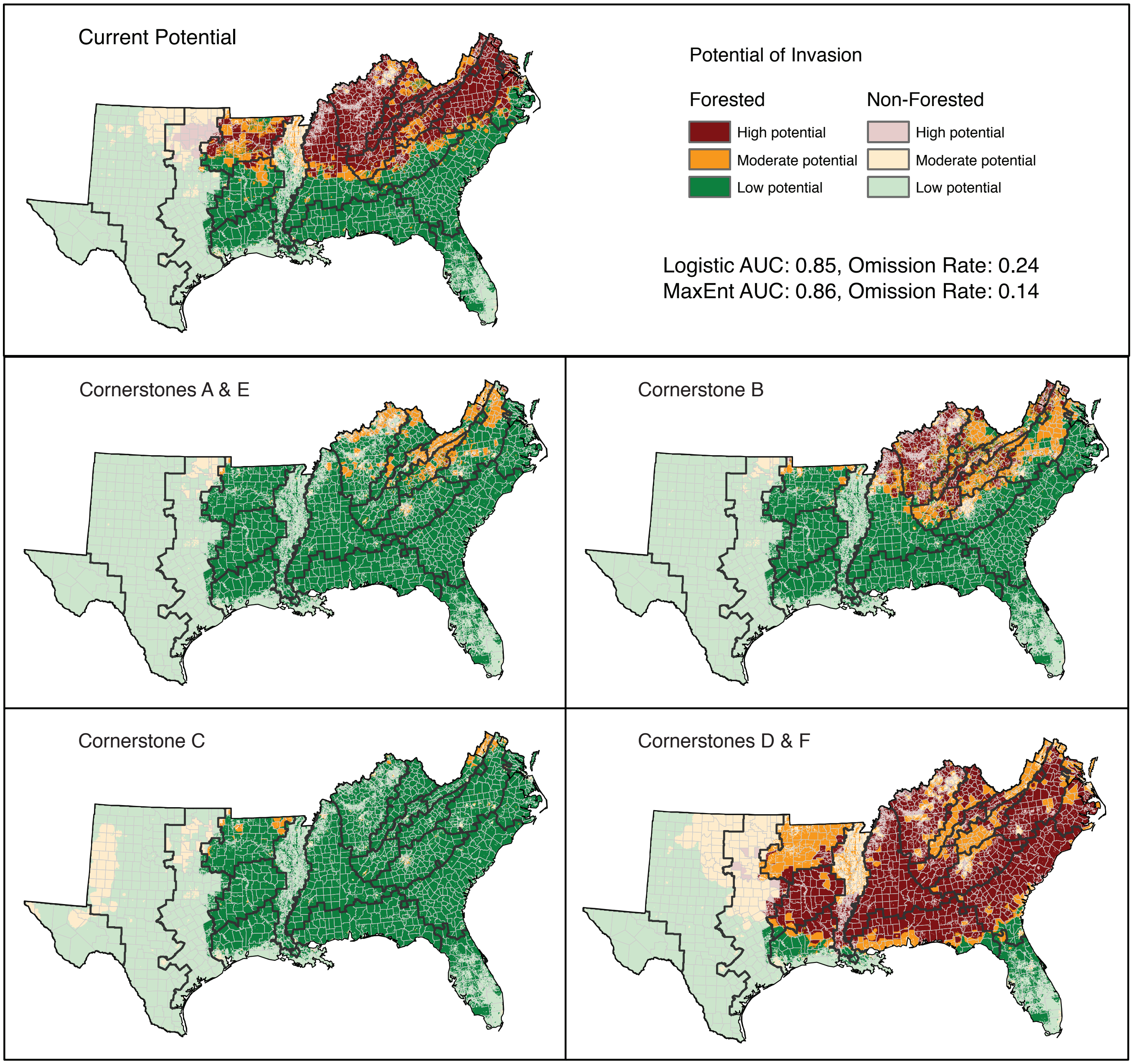

Figure 28—Potential for Nepalese browntop occupation in U.S. South by 2060, assuming: current potential if current climate continues in the U.S. Mississippi Alluvial Valley; maximal warming and drying projected for Cornerstones A and E; moderate warming and moderate drying projected for Cornerstone B; minimal warming and increased rainfall projected for Cornerstone C; and minimal warming and moderate drying projected for Cornerstones D and F. (Source: Miller and others 2013)

INSECT AND DISEASE PESTS

Many diverse native and nonnative insects and disease pathogens threaten forest health throughout the lower Mississippi Valley. Although initial reactions to damaging agents often center on immediate forest health concerns, long-term repercussions can challenge the sustainability of forest management practices and degrade recreational use, water quality, aesthetics, stand merchantability, and other forest values. Damage is often most severe when the insect or disease pathogen opportunistically attacks forests that are already under stress from extended flooding, prolonged drought, wildfire, altered site conditions, or other biotic or abiotic agents. Estimates of the economic damage from forests pests have not been tabulated for the Mississippi Alluvial Valley, but losses stem from many sources including control and sanitation costs, product degrades, reduced stand productivity, delayed stand development, damaged seed crops, and stand mortality.

This section builds on findings prepared by Duerr and Mistretta (2013) for the Southern Forest Futures Project that are relevant to the Mississippi Alluvial Valley and its associated sections, and provides additional discussion on pests that pose the greatest threat of entry into forests.

Current Status

Insect pests—Duerr and Mistretta (2013) highlighted several insects that threaten to damage natural stands of bottomland hardwood forests of the Mississippi Alluvial Valley. Among these high threat pests are two defoliators, the baldcypress leafroller (*Archips goyerana* Kruse) and the forest tent caterpillar (*Malacosoma disstria* Hübner). The baldcypress leafroller, a host-specific moth that completes its lifecycle on baldcypress foliage, primarily occupies the forests of the Deltaic Plain section (Kruse 2000). Although the forest tent caterpillar feeds on a broad variety of broadleaf trees within a range that spans much of the United States and Canada, water tupelo is one of its preferred hosts in the southernmost reaches of the Mississippi Alluvial Valley (Rejmánek and others 1987). The larvae of these two species combine to defoliate an annual average of >300,000 acres of baldcypress-water tupelo swampland in the Deltaic Plain section (Goyer and others 1990, no date). Although single defoliation events may have little impact on long-term forest health, repeated defoliations (>20 years in some forests) by these species promote crown dieback, can reduce radial growth, and place degraded stands at higher risk of damage from other stress agents (Goyer and others 1990, no date).

Many wood boring insects also constitute a large portion of the insect pests that significantly damage the forests of the Mississippi Alluvial Valley. Prominent species include the carpenterworm (*Prionoxystus robiniae* Peck), the red oak borer (*Enaphalodes rufulus* Haldeman), the white oak borer (*Goes tigrinus* De Geer), the redheaded ash borer (*Neoclytus acuminatus* F.), the oak timberworm (*Arrhenodes minutus* Drury), and the Columbian timber beetle (*Corthylus columbianus* Hopkins). The activities of these and other species can inflict wounds or physiological stresses on their hosts, reduce vigor and growth, limit mast crop size, serve as vectors for wood decaying fungi, and transmit other pathogens (Solomon 1995). They also create lumber defects that have tremendous economic implications. For example, an assessment of degrade to oak lumber implicated wood borers for a 15 percent loss in total value of sawn lumber (Morris 1977).

The Mississippi Alluvial Valley harbors several insect pests that do little damage in natural hardwood stands but reach epidemic-level populations in plantations. For example, at least ten species have been distinguished as major pests of eastern cottonwood plantations (Morris and others 1975). The most prevalent of them—the cottonwood leaf beetle (*Chrysomela scripta* F.), the poplar borer (*Saperda calcarata* Say), and the cottonwood borer (*Plectrodera scalator* F.)—are responsible for reduced plantation growth, degraded wood quality, and trees weakened to the point of breakage (Morris and others 1975).

Diseases—The native forest tree species in the lower Mississippi Valley are host to a multitude of disease-causing pathogens. Duerr and Mistretta (2013) described 10 diseases that are well established and have the greatest potential for damaging substantial acreage of southern hardwood forests. None of these currently have epidemic-sized populations in the Mississippi Alluvial Valley. Disease forms most commonly observed include root and butt rots, wilts, cankers, and foliage diseases (Leininger and others 1999, Solomon and others 1993, Solomon and others 1997a). Native pathogens responsible for diseases like hispidus canker (*Inonotus hispidus* (Bull.) P. Karst.), varnish fungus rot (*Ganoderma lucidum* (Curtis) P. Karst.), and hypoxylon cankers (*Hypoxylon* spp. Adans.) are widespread throughout the Mississippi Alluvial Valley and can cause localized damage.

Like some insect pests, several pathogens reach their most damaging levels in hardwood plantations where the host tree species is abundantly available and grown under rather uniform stand and environmental conditions. A damping-off disease caused by a variety of fungi (predominantly *Cylindrocladium* spp. Morgan and *Fusarium* spp. Link) attacks newly germinated hardwood seedlings in nurseries or in plantations established through direct seeding (Solomon and others 1993, Solomon and others 1997a). Fungal pathogens (including *Septoria* spp. Sacc., *Fusarium* spp. Link, *Cytospora* spp. Ehrenb., and *Botryodiplodia* spp.

(Sacc.) Sacc.) are also responsible for a prevalence of canker diseases in eastern cottonwood plantations (Morris and others 1975).

In most circumstances, the potential for plantation damage from disease forming pathogens can be mitigated with oversight followed by timely and appropriate management practices. A notable exception is bacterial leaf scorch (*Xylella fastidiosa* Wells et al., 1987), a disease that has effectively eliminated American sycamore (*Platanus occidentalis* L.) as a viable plantation species in the lower Mississippi Valley. Transmitted by the ubiquitous glassy-winged sharpshooter (*Homalodisca vitripennis* Germar), bacterial leaf scorch readily infects a broad range of hosts causing leaf necrosis that advances to twig, branch, and stem dieback—often followed by mortality (Adams and others 2012). In the Mississippi Alluvial Valley, where bacterial leaf scorch is particularly deleterious to sycamore, cultivation efforts in short-rotation plantations have largely failed because of rapid disease advancement in young stands. However, recent study results on inheritance of resistance hold promise for sycamore breeding efforts that can advance sufficiently resistant clones for plantation production (Adams and others 2012).

The forests of the Mississippi Alluvial Valley are also vulnerable to episodes of decline and dieback syndromes (Ammon and others 1989, Leininger 1998, Solomon and others 1997b). These syndromes generally begin with complex interactions of biotic and abiotic stressors that render the host susceptible to secondary pests. Decline and dieback episodes can affect large acreages; an example is a sugarberry dieback that lasted from 1988 to 1990 and encompassed 3 million acres of forests and urban areas across a portion of the Deltaic Plain section (Solomon and others 1997b). Conversely, oak decline, which has been recognized throughout the Eastern United States since the 1800s (Ammon and others 1989), occurs only infrequently and on a much smaller scale in the Mississippi Alluvial Valley than in forests farther east.

The interacting biotic and abiotic factors that advance decline and dieback syndromes often complicate efforts to recognize early symptoms of decline, gain a clear understanding of causal agents and factors that proliferate spread, and apply approaches to remediation. One episode in Louisiana (Union Parish) involved a complex suite of stresses including extended flooding, a shallow soil profile that produced droughty conditions after floodwaters receded, and attacks to the physiologically stressed oaks by insect and fungal pests (Leininger 1998). Because the forests in the Mississippi Alluvial Valley have been highly degraded through alteration of natural hydrologic regimes and extensive fragmentation and the current age structure of lowland hardwood forests is skewed towards physiological maturity (chapter 1), episodes of oak decline and other decline-and-dieback syndromes will likely increase with future periods of climate-induced stress.

Forecasts

Forecasting a shift in invasiveness of an established pest, or forecasting the risk of a pest invading unoccupied environments are exercises based on high speculation. Biological knowledge of indigenous or nonnative pest species is often insufficient to accurately forecast population dynamics, geographic dispersal patterns, and virulence in new environments. These variables are particularly unpredictable given the uncertainty of future climate forecasts. Duerr and Mistretta (2013) approached this challenge through consideration of host availability projections, pest activity level projections, and the anticipated efficacy of pest prevention, suppression, and eradication practices. In general, climate forecasts through 2060 did not signal significant changes to the geographical range of forest species indigenous to the Mississippi Alluvial Valley. Likewise, there were no strong indications that indigenous insect and disease pests will exhibit near-term climate-induced shifts in virulence towards their hosts. Findings presented by Duerr and Mistretta (2013) indicated that the most probable declines in forest health mediated by insects or disease pests will be realized from pests yet to be introduced into the Mississippi Alluvial Valley.

At least two nonnative insect pests established in other regions of North America could extend their ranges into the Mississippi Alluvial Valley within the next 50 years. The emerald ash borer (*Agrilus planipennis* Fairmaire) and the gypsy moth (*Lymantria dispar* L.) are extremely harmful forest pests whose advances have met little natural resistance—the result being significant ecological and economic damage throughout the continent. Although advancing fronts of these insects have not yet entered the Mississippi Alluvial Valley, its broadleaf forests offer many tree species that would be suitable hosts, and future climate conditions are unlikely to hinder infestations.

As with insect pests, several disease-causing pathogens that have achieved epidemic-sized populations in other U.S. regions would likely have an affinity to many forest species endemic to the Mississippi Alluvial Valley. Among these are the pathogens responsible for laurel wilt disease (*Raffaelea lauricola* T.C. Harr., Fraedrich & Aghayeva), sudden oak death (*Phytophthora ramorum* Werres, DeCock & Man in ‘t Veld), and thousand cankers disease (*Geosmithia morbida* M. Kolařík, E. Freeland, C. Utley & Tisserat). The availability of possible hosts growing under seemingly favorable climate conditions underscores the likelihood that an invasive disease-causing pathogen—either already established or yet to be introduced—could be a force of change in forests over the course of the next 50 years.

Emerald ash borer—The emerald ash borer, an Asian wood-boring beetle thought to have been introduced to North America through wooden packaging materials (Cappaert and others 2005), could become the most severe threat to the hardwood forests of the lower Mississippi Valley. First detected in Michigan and across the Canadian border in Ontario in 2002, its range has expanded—in Canada to encompass parts of Quebec, and in the United States to parts of Minnesota, Wisconsin, Indiana, Ohio, Pennsylvania, New York, West Virginia, Maryland, Virginia, Iowa, Illinois, Missouri, Kentucky, and Tennessee. In the summer of 2012, further expansion was reported in Connecticut, Massachusetts, and Kansas (Emerald Ash Borer Information Network 2013).

Ash trees of all species are heavily damaged throughout the current range of this pest, and mortality approaches 100 percent within 6 years of infestation (Knight and others 2013). Strategies implemented to slow the advancement of emerald ash borer populations into unaffected areas have been somewhat successful in urban and suburban settings (McCullough and Mercader 2012), but these efforts are intensive, expensive, and unsuitable for forest-scale applications. Comprehensive research on approaches to mitigate the spread of this insect and minimize ash mortality has yet to produce environmentally safe strategies for deterring the rapid movement of populations through the North American ash resource (Duan and others 2012, Lyons and others 2012).

Based on its aggressive range expansion, Duerr and Mistretta (2013) surmised that the emerald ash borer has the potential to kill most southern ash trees within the next 50 years. The implications would be catastrophic for the Mississippi Alluvial Valley, where the ash component of its broadleaf forests is primarily made up of green ash with lesser amounts of pumpkin ash (*Fraxinus profunda* (Bush) Bush), white ash (*Fraxinus americana* L.), and Carolina ash (*Fraxinus caroliniana* Mill.). Green ash is a principal component and the most commercially valued species of the sugarberry-hackberry-elm-green ash type, which occupies >1.1 million acres and is the most prevalent forest type in the Mississippi Alluvial Valley (tables 2 and 3). If the emerald ash borer is left unchecked, ash could disappear from bottomland hardwood ecosystems within a timeframe that is shorter than an average stand rotation.

Gypsy moth—Since its introduction into Massachusetts from Europe in 1869 (Tobin and others 2012), the gypsy moth has become a severe forest threat in the Eastern and North Central United States and adjacent regions of Canada. This defoliator occupies a range that includes Maine, Vermont, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, North Carolina, Pennsylvania, Delaware, Maryland, Michigan, Wisconsin, Illinois, Indiana, Ohio, West Virginia, and Virginia. Over the past 10 years, populations have progressively expanded such that populations in Ohio, West Virginia, and Virginia are poised for entry into Kentucky and Tennessee (U.S. Department of Agriculture, Animal and Plant Health Inspection Service 2013).

Because this pest has been established for well over a century across a very large range, the prospect of eradication does not exist with current technology. Instead, active efforts by the U.S. Department of Agriculture Animal and Plant Health Inspection Service, Forest Service, and State agencies focus on slowing its inevitable spread by establishing quarantines to minimize unintentional movement into new areas, suppressing existing populations, eradicating isolated populations that develop outside its contiguous range, and applying barrier zone management strategies (Tobin and others 2012, The Gypsy Moth Slow the Spread Foundation 2013, U.S. Department of Agriculture, Animal and Plant Inspection Service 2013). These efforts have succeeded in slowing the rate of spread from >12 miles per year to <6 miles per year (Sharov and others 2002, The Gypsy Moth Slow the Spread Foundation 2013).

Duerr and Mistretta (2013) predicted that the gypsy moth would likely gain entry into the Mississippi Alluvial Valley within the next 50 years. Whether future climate conditions would deter expansion is less clear. Many of the endemic broadleaf tree species—especially the oaks, sweetgum, willows, hawthorns (*Crataegus* spp. L.), and river birch (*Betula nigra* L.)—could serve as suitable hosts (Liebhold and others 1995, Morin and others 2005). Although some level of invasion into the Mississippi Alluvial Valley appears inevitable, the timing of arrival and the extent of damage are unpredictable.

Asian longhorned beetle—The Asian longhorned beetle (*Anoplophora glabripennis* Motschulsky) is another destructive nonnative insect that belongs on the "watch list" of forest practitioners in the lower Mississippi Valley. Although its threat does not appear as imminent as the emerald ash borer or the gypsy moth, its prospect of becoming established is likely to increase.

The first North American observations of the Asian longhorned beetle occurred in 1996 in New York, apparently introduced on solid wood packaging materials that originated in Asia (Hu and others 2009). From the time of first detection, infestations of the Asian longhorned beetle have spread into New Jersey and Massachusetts on the eastern seaboard and northwest into Ohio, Illinois, and the Canadian province of Ontario (Canadian Food and Inspection Agency 2013, Haack and others 2010, U.S. Department of Agriculture, Animal and Plant Inspection Service 2013). In two of the U.S. States, infestations were aggressively treated, resulting in presumed eradication from Illinois in 2008 and from New Jersey in 2013 (U.S. Department of Agriculture, Animal and Plant Inspection Service 2013).

Many known hosts from the Asian longhorn beetles native range and from infestation areas in North America are closely related to common broadleaves—such as the maples, river birch, the ashes, American sycamore, eastern cottonwood, black willow, and the elms (Haack and others 2010)—of the Mississippi Alluvial Valley, increasing the likelihood that these broadleaf forests will provide suitable habitat for the pest. Nevertheless, Duerr and Mistretta (2013) concluded that the risk of infestation is rather unlikely in the next 50 years. The current range and a predisposition to disperse only short distances will facilitate containment and eradication of infestations. Perhaps the highest risk of infestation within the next 50 years would surface from new introductions within the boundaries of the Mississippi Alluvial Valley or in neighboring subregions.

Laurel wilt disease—Laurel wilt disease, caused by a fungal symbiont of the redbay ambrosia beetle (*Xyleborus glabratus* Eichhoff), apparently gained entry into the United States through solid wood packaging material (Fraedrich and others 2007). This wood-boring beetle was initially detected near Savannah, GA in 2002, followed by extensive mortality of redbay (*Persea borbonia* (L.) Spreng.) in coastal South Carolina the next year (Fraedrich and others 2007). Laurel wilt disease has since reached Georgia, Florida, North Carolina, Alabama, and Mississippi (U.S. Department of Agriculture, Forest Service, Forest Health Protection 2013); and a number of other hosts susceptible to this pathogen have been identified among southern laurels (Fraedrich and others 2011, Peña and others 2012).

Laurels endemic to the lower Mississippi Valley include sassafras (*Sassafras albidum* (Nutt.) Nees), spicebush (*Lindera benzoin* (L.) Blume), and pondberry (*Lindera melissifolia* (Walter) Blume—which is Federally listed as endangered. Although laurel wilt is particularly damaging to redbay, it has also been isolated from symptomatic plants of sassafras and pondberry in the Coastal Plain of Georgia; in addition, laboratory experiments confirm that spicebush is also susceptible (Fraedrich and others 2008, Fraedrich and others 2011). Koch and Smith (2008b) predicted that entry of the redbay ambrosia beetle into the Mississippi Alluvial Valley would occur from 2025 to 2030. However, a 2009 discovery of an outlier beetle population and diseased redbay trees in coastal Mississippi (Harrison County) suggests that invasion could occur much earlier.

Although the range of the redbay ambrosia beetle is likely to extend into the Mississippi Alluvial Valley, the degree to which it will become established is uncertain. One aspect of this uncertainty is the density of potential hosts. Epidemics of laurel wilt disease are most severe in places where stand density is the highest, and attacks on sassafras usually occur when sassafras grows in close proximity to redbay (Koch and Smith 2008). Redbay is uncommon in the Mississippi Alluvial Valley, where it only grows in the Deltaic Plain section, and then infrequently. Sassafras has a much broader range, but is typically found as a sporadic component of mixed-species stands. Pondberry is limited to only nine counties in the Holocene Deposits section. Spicebush is a common understory shrub throughout the Mississippi Alluvial Valley and although it may readily succumb to laurel wilt, it is not known to be a suitable host for brooding by the redbay ambrosia beetle. Thus, hosts capable of supporting high beetle fecundity do not appear to grow in densities that would be favorable for rapid spread of laurel wilt (Koch and Smith 2008b). Further, Koch and Smith (2008b) suggest that the climate of the northern two-thirds of the Mississippi Alluvial Valley may also be unfavorable for population growth of the beetle. Duerr and Mistretta (2013) speculated that laurel wilt would not become epidemic unless it assumes a new insect vector that can transfer the pathogen to host species that are more numerous.

Sudden oak death—A nonnative pathogen that is causing wide spread mortality of oaks along the Pacific Coast could endanger the oaks of the lower Mississippi Valley. Importation of horticultural nursery stock from Europe has led to the establishment of *Phytophthora ramorum*, a fungus-like water mold that is responsible for sudden oak death disease in coastal California and Oregon. First observed in Marin County during 1995, the pathogen was dispersed long distances by wind or wind-driven rain, rivers and streams, and human activities (Grünwald and others 2012); this dispersal has extended the range of sudden oak death to 14 counties in coastal California (U.S. Department of Agriculture, Animal and Plant Inspection Service 2013). Sudden oak death is also established in a single county on the southern coast of Oregon, apparently resulting from a new introduction (Grünwald and others 2012).

The water mold responsible for sudden oak death can elicit a range of symptoms on a vast number of plant species, prompting some scientists to adopt the name Ramorum blight and dieback disease when referencing plant disorders caused by the pathogen. Several genera of common ornamental plants serve as hosts to the pathogen, but the most frequently encountered are rhododendron (*Rhododendron* L.), camellia (*Camellia* L.), viburnum (*Viburnum* L.), and other common ornamentals (Huberli and Garbelotto 2011). Infections on most ornamental plants generally manifest as leaf lesions and shoot dieback (Grünwald and others 2012). In the forests of California and Oregon, the pathogen is most virulent on the red oaks (section Lobatae) and tanoak (*Notholithocarpus densiflorus* (Hook. & Arn.) Manos, Cannon & S.H. Oh) (Hüberli and Garbelotto 2011). Although tanoak infections can manifest as leaf lesions and shoot dieback, mortality of this species and that of infected oaks is typically associated with weeping cankers that lethally disrupt phloem and xylem functions (Grünwald and others 2012). Because the pathogen is not known to produce spores on oaks, its movement through oak populations in coastal California likely stemmed from infections originating on host species that do support spore production (Davidson and others 2005).

Sudden oak death could cause catastrophic ecological and economic damage to the 2.4 million acres of oak dominated forests in the Mississippi Alluvial Valley if it can establish spore-producing populations. However, U.S. risk maps generally indicate that these forests are under low to moderate risk of infection (Kluza and others 2007, Koch and Smith 2008a) based on a low density of hosts seemingly capable of supporting spore production and unfavorable climate conditions, particularly summer temperature extremes. Although the pathogen has been isolated from soil or runoff water near nursery and garden centers in Southern States—North Carolina, South Carolina, Georgia, Florida, Alabama, and Mississippi—its proliferation in natural forest environments has yet to be observed (Jeffers and others 2010). Nevertheless, future introductions into the South through the horticultural industry are highly likely; in addition, the propensity of the pathogen to tolerate adverse conditions (Grünwald and others 2012) and its ability to produce spores on many hosts improve its chances of acclimating to environmental conditions, both in the South and in the Mississippi Alluvial Valley.

Thousand cankers disease—Recently introduced into eastern forests, thousand cankers disease (Kolařík and others 2011) is transmitted to various walnut species by the walnut twig beetle (*Pityophthorus juglandis* Blackman), a bark beetle endemic to the Southwestern United States and Mexico. The 2010 discovery of both the beetle and the disease near Knoxville, TN confirmed the ability of this pathogen to infect black walnut (*Juglans nigra* L.) in eastern forests (Grant and others 2011). The disease has since appeared in other Eastern States including Pennsylvania, Virginia, and North Carolina (North Carolina Forest Service 2013).

During feeding, the walnut twig beetle inoculates the host with the fungus, which produces localized lesions in phloem tissue. Foliage of diseased trees becomes discolored and wilts, followed by branch dieback and eventual tree mortality—a progression that is accelerated by recurring feeding by the beetle (Kolařík and others 2011).

Although black walnut is not a major component of the bottomland forests in the Mississippi Alluvial Valley, it occasionally occurs in mixed stands on high alluvial sites in the northern portion of the subregion and is common in the upland forests of Crowley's Ridge. Duerr and Mistretta (2013) surmised that without development of effective control practices and an aggressive campaign to eradicate this pest, thousand cankers disease would progress through the entire South within the next 50 years. Establishment in the Mississippi Alluvial Valley would eliminate black walnut from forests of the Holocene Deposits section, further degrading communities that are defined by high species richness and exceptional site productivity.

Based on historical patterns, the forests of the lower Mississippi Valley will undoubtedly face challenges by formidable insect and disease pests over the next 50 years. Factors associated with changes in land use, changes in climate conditions, changes in human populations, and changes in economic growth are likely to increase the vulnerability of these forests to incursions by opportunistic insect and disease pathogens. Duerr and Mistretta (2013) suggested that success in sustaining forest health under uncertain—but potentially calamitous—risks will rely on implementation of adaptive management practices that build host resistance, promote forest resilience, and assist forest adaptation to change.

CHAPTER 5.
Effects of Changes on Forests and their Values

FOREST CONDITIONS

In 2010, the Mississippi Alluvial Valley supported an estimated 6.6 million acres of forests, about 89 percent in the Holocene Deposits section and 11 percent in the Deltaic Plain section (table 12). Lowland hardwoods dominated, covering 68 percent of forested acreage in the Holocene Deposits section and 89 percent in the Deltaic Plain section (table 12). In the Holocene Deposits section, upland hardwoods occupied about 16 percent and stands with a pine component occupied nearly 10 percent of forested acreage (table 12). Understocked forests occurred on 3 percent of the forest acreage across the Mississippi Alluvial Valley: 7 percent in the Deltaic Plain section and 2.5 percent in the Holocene Deposits section (table 12).

The volume of growing stock has increased substantially over the last decade in the Mississippi Alluvial Valley to a 2010 stocking of >10.6 billion cubic feet (table 13), 21 percent softwoods and 79 percent hardwoods (table 13). The 2010 estimated volume of hardwood growing stock in the Holocene Deposits section was 7.6 billion cubic feet, a 12 percent increase over the 2000 estimate. The Deltaic Plain section supported about 9 percent of the hardwood growing stock, 786 million cubic feet, which represents an 8 percent increase. From 2000 to 2010, softwood growing stock rose >9 percent to an estimated 1.7 billion cubic feet in the Holocene Deposits section (table 13) but decreased 22 percent to about 449 million cubic feet in the Deltaic Plain section.

Table 12—Approximate forest area by management type in the U.S. Mississippi Alluvial Valley and its associated sections in 2010

Management type	Mississippi Alluvial Valley	Holocene Deposits section	Deltaic Plain section
		acres	
All forests	6,599,775	5,868,101	731,673
Planted pine	368,525	368,525	0
Natural pine	205,786	205,786	0
Oak-pine	174,029	174,029	0
Upland hardwood	975,789	946,395	29,395
Lowland hardwood	4,674,761	4,024,625	650,136
Understocked[a]	200,883	148,741	52,143

[a]Acreage not sufficiently stocked for a determination of forest type.
Source: Forest Inventory and Analysis, Southern Research Station, U.S. Forest Service.

Table 13—Standing volumes and percent change in standing volumes of forests by category in the U.S. Mississippi Alluvial Valley and its associated sections in 2000 and 2010

Volume category	Mississippi Alluvial Valley	Holocene Deposits section	Deltaic Plain section
	----------------- *2000 (thousand cubic feet)* -----------------		
Softwood growing stock	2,175,407	1,599,253	576,153
Hardwood growing stock	7,550,211	6,824,712	725,499
Total growing stock	9,725,618	8,423,965	1,301,652
	----------------- *2010 (thousand cubic feet)* -----------------		
Softwood growing stock	2,200,532	1,751,291	449,241
Hardwood growing stock	8,401,044	7,614,233	786,811
Total growing stock	10,601,576	9,365,524	1,236,052
	----------------- *Change from 2000 to 2010 (percent)* -----------------		
Softwood growing stock	1.2	9.5	-22.0
Hardwood growing stock	11.3	11.6	8.4
Total growing stock	9.0	11.2	-5.0

Sources: Forest Inventory and Analysis, Southern Research Station, U.S. Forest Service.

Forecasts for the Mississippi Alluvial Valley

This section presents forecasted forest conditions for the Mississippi Alluvial Valley and its associated sections, a broad synthesis of the forecasts, and a summary of findings relevant to future forest conditions. Forest conditions forecasts for the entire South have been reported by Huggett and others (2013) for the Southern Forest Futures Project.

As well as describing the effects of urbanization (population and income) and timber prices (chapters 2 and 3), the Cornerstone Futures have underlying assumptions about landowner investments that affect forecasts of forest conditions. Added to Cornerstones A through D are two others that describe investments in tree planting (Huggett and others 2013, Wear and others 2013):

- **Cornerstone A** is characterized by unchanged levels of tree planting in addition to high population/income growth and increasing timber prices.
- **Cornerstone B** is characterized by unchanged levels of tree planting in addition to high population/income growth and decreasing timber prices.
- **Cornerstone C** is characterized by unchanged levels of tree planting in addition to low population/income growth and increasing timber prices.
- **Cornerstone D** is also characterized by unchanged levels of tree planting in addition to low population/income growth and decreasing timber prices.
- **Cornerstone E** has the same assumptions as Cornerstone A, but with 50 percent more tree planting than current levels.
- **Cornerstone F** has the same assumptions as Cornerstone D, but with 50 percent less tree planting than current levels.

Although some new forests could be established through afforestation, substantial changes are also likely to accrue in response to management choices (reforestation). Cornerstones A through D use historical tree planting rates following harvests (by State and forest type) to forecast future planting. The two additional Cornerstones (E and F) depart from these four by increasing or decreasing planting rates from the baseline.

Forest acreage—Depending on the Cornerstone Future, forest acreage could increase by as much as 2.1 percentage points or decrease by as much as 5.8 percentage points—for a range of 7.9 percentage points—by 2060 (table 14, fig. 29). Low population and income growth with increasing timber prices would support gains in forest acreage. This is exemplified under Cornerstone C, which forecasts the largest increase in forest area. Conversely, high population and economic growth with decreasing timber prices would result in losses to forest acreage. Cornerstone B, which projects high population growth and high income growth, could result in a loss of forest acreage that approaches 6 percent (table 14, fig. 29).

Table 14—Change in total forest area and lowland hardwood forest area in the U.S. Mississippi Alluvial Valley from 2010 to 2060, as predicted by six Cornerstone Futures[a]

Change in area	All forests	Lowland hardwoods
	Cornerstone A	
Acres[b]	14,185	-49,006
Percent	0.2	-1.0
	Cornerstone B	
Acres	-385,409	-324,063
Percent	-5.8	-6.9
	Cornerstone C	
Acres	136,869	50,729
Percent	2.1	1.1
	Cornerstone D	
Acres	-263,569	-253,796
Percent	-3.9	-5.4
	Cornerstone E	
Acres	14,185	-129,557
Percent	0.2	-2.8
	Cornerstone F	
Acres	-263,569	-232,464
Percent	-3.9	-4.9

[a]Each Cornerstone represents a general circulation model paired with one of two emission scenarios (A1B representing high-population/high-economic growth, high energy use, and B2 representing low growth and use—and either high or low timber prices and either stable/higher/lower planting rates): Cornerstone A is MIROC3.2+A1B+high prices+stable planting, Cornerstone B is CSIROMK3.5+A1B+low prices+stable planting, Cornerstone C is CSIROMK2+B2+high prices+stable planting, Cornerstone D is HadCM3+B2+low prices+stable planting, Cornerstone E is MIROC3.2+A1B+high prices+higher planting, and Cornerstone F is HadCM3+B2+low prices+lower planting.

[b]Forecasts are based on inventory plots from the Forest Inventory and Analysis Program, Southern Research Station, U.S. Forest Service.

Sources: Intergovernmental Panel on Climate Change (2007) and Wear (2013).

Although lowland hardwood forests are dominant (71 percent) in the Mississippi Alluvial Valley, the changes predicted for them do not always parallel those predicted for the aggregate of all forests (table 14; figs. 29 and 30). Lowland hardwood forest acreage could increase slightly (1.1 percentage points) under the low population and income growth and increasing timber prices of Cornerstone C, but all other Cornerstone Futures predict a decline through 2060. The most significant declines would be expected to occur under the timber price decreases predicted by Cornerstones B and D (table 14; figs. 29 and 30). Loss of lowland hardwood forests would quickly outpace losses experienced by all other forests (fig. 30).

Gains in planted pine acreage are predicted for all Cornerstone Futures (tables 12 and 15; fig. 30). From a 2010 baseline of 368,525 acres, the area managed for planted pine could experience an increase ranging from 103,651 acres under Cornerstone F to 500,475 acres under Cornerstone E (tables 12 and 15). Futures of high income growth and increasing timber prices would provide incentive for expansion of this management type in the Mississippi Alluvial Valley, and additional investment in plantation forestry could expand this management type 136 percent to occupy 13 percent of forest acreage (table 15, fig. 30).

Growing stock—Rather than exhibiting a constant trajectory of change through 2060, growing stock volumes are expected to fluctuate in response to supply and demand variables (fig. 31). Notwithstanding, all Cornerstone Futures consistently predict that softwood inventories will increase and hardwood inventories will decrease. The largest increases in softwood growing stock volumes are projected to occur concurrently with the largest decreases in hardwood growing stock volumes under the increasing timber prices of Cornerstones A and C (table 16, fig. 31). Total growing stock volumes would decrease despite increasing softwood volumes, because hardwoods constitute a much larger proportion of total growing stock (table 16, fig. 31). For example, under the high population growth, strong economy, and increasing timber prices of Cornerstone A, softwood growing stock volume could increase by 40 percent and hardwood growing stock could decrease by 15 percent—resulting in a 3.5 percent decrease in total growing stock volume (table 16).

Conversely, the decreasing timber prices of Cornerstones B and D would produce moderate gains in softwood growing stock volumes that could offset losses to hardwood volumes and result in slight increases in total growing stock inventories through 2060 (table 16, fig. 31). Under Cornerstone D (low population and economic growth and decreasing timber prices), for example, softwood growing stock volumes would increase by >30 percent, hardwood volumes be maintained within 7 percent of current inventories, and total growing stock inventories would increase by about 1 percent (table 16, fig. 31).

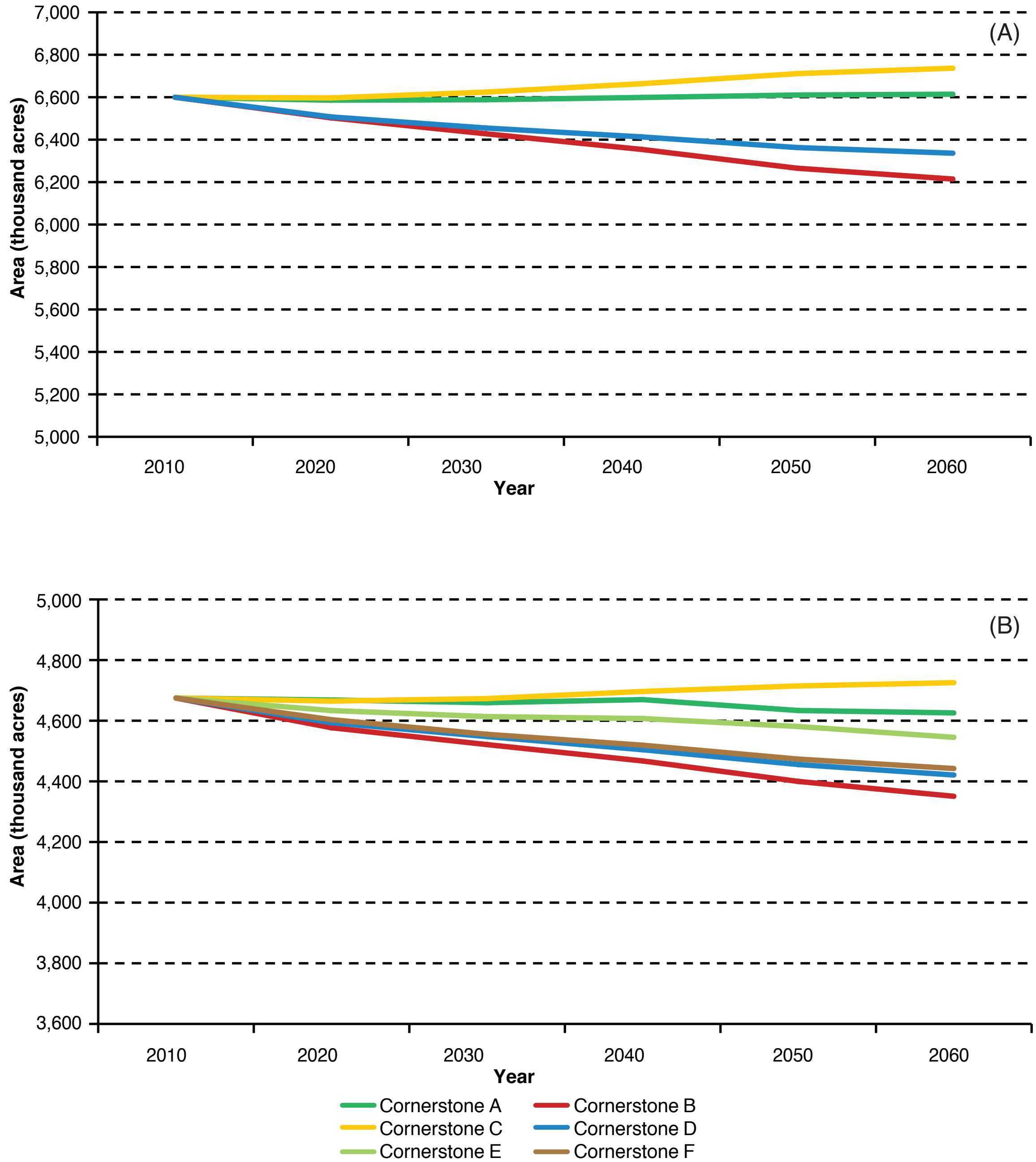

Figure 29—Forecasts of forested acreage in the U.S. Mississippi Alluvial Valley for (A) all forests and (B) for lowland forests under six Cornerstone Futures, each of which represents a general circulation model paired with one of two emission scenarios—A1B representing high-population/high-economic growth, high energy use, and B2 representing low growth and use—and either high or low timber prices and either stable/higher/lower planting rates: Cornerstone A is MIROC3.2+A1B+high prices+stable planting, Cornerstone B is CSIROMK3.5+A1B+low prices+stable planting, Cornerstone C is CSIROMK2+B2+high prices+stable planting, Cornerstone D is HadCM3+B2+low prices+stable planting, Cornerstone E is MIROC3.2+A1B+high prices+higher planting, and Cornerstone F is HadCM3+B2+low prices+lower planting. For (A), results for Cornerstone E are identical to Cornerstone A, and results for Cornerstone F are identical to Cornerstone D. (Sources: Intergovernmental Panel on Climate Change 2007, Wear 2013)

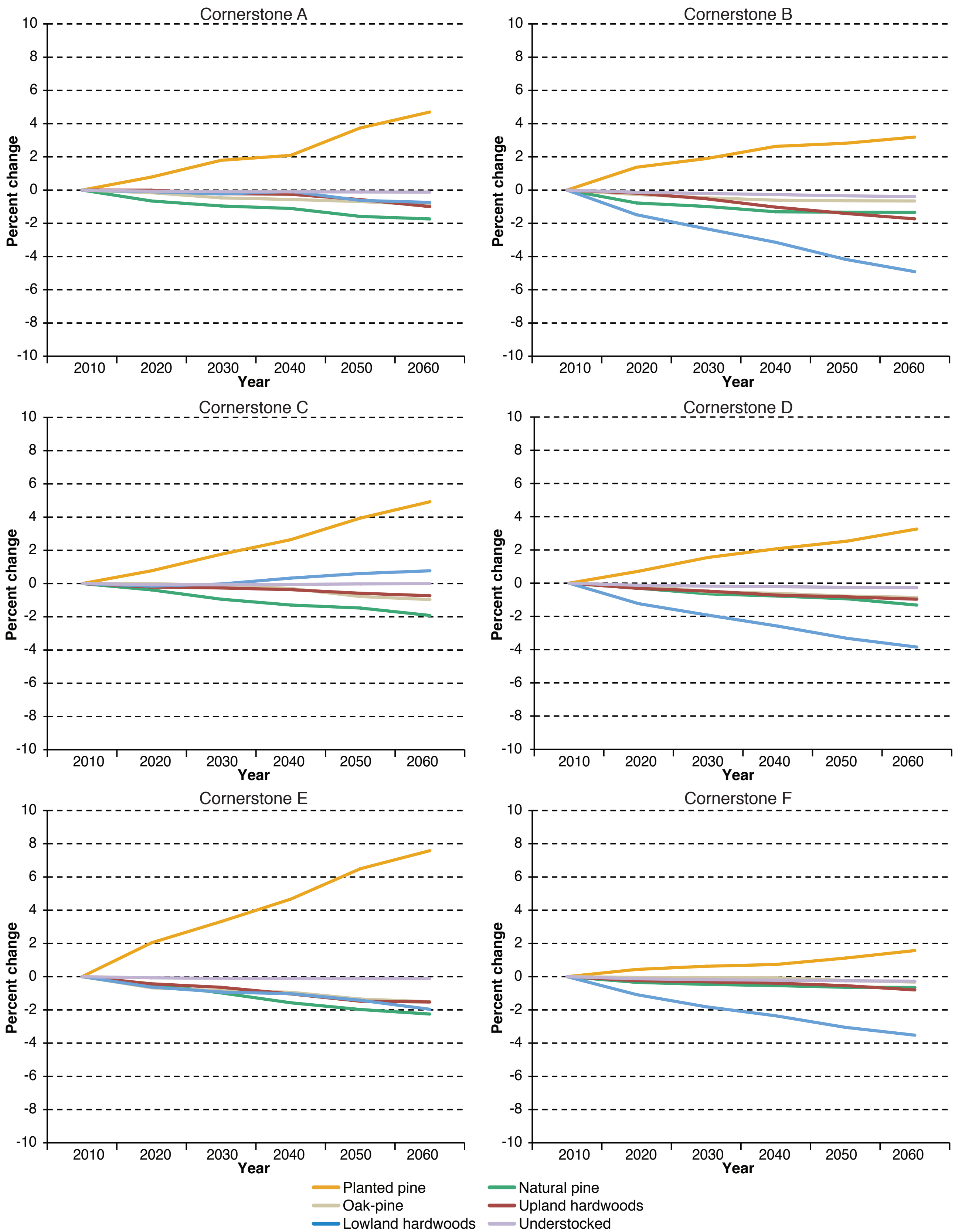

Figure 30—Forecasted change in forested acreage by management type in the U.S. Mississippi Alluvial Valley under six Cornerstone Futures (A through F), each of which represents a general circulation model paired with one of two emission scenarios—A1B representing high-population/high-economic growth, high energy use, and B2 representing low growth and use—and either high or low timber prices and either stable/higher/lower planting rates: Cornerstone A is MIROC3.2+A1B+high prices+stable planting, Cornerstone B is CSIROMK3.5+A1B+low prices+stable planting, Cornerstone C is CSIROMK2+B2+high prices+stable planting, Cornerstone D is HadCM3+B2+low prices+stable planting, Cornerstone E is MIROC3.2+A1B+high prices+higher planting, and Cornerstone F is HadCM3+B2+low prices+lower planting. (Sources: Intergovernmental Panel on Climate Change 2007, Wear 2013)

Table 15—Forest area by management type for the U.S. Mississippi Alluvial Valley and its associated sections in 2060 as predicted by six Cornerstone Futures[a]

Management type	Mississippi Alluvial Valley	Holocene Deposits section	Deltaic Plain section
	------------------------ *acres* ------------------------		
	Cornerstone A		
Planted pine	678,609	674,297	4,312
Natural pine	91,107	91,107	0
Oak-pine	115,289	115,289	0
Upland hardwood	910,258	888,209	22,049
Lowland hardwood	4,625,754	4,047,166	578,588
Understocked[b]	192,941	153,999	38,942
	Cornerstone B		
Planted pine	579,147	571,629	7,518
Natural pine	117,112	117,112	0
Oak-pine	130,796	130,796	0
Upland hardwood	861,506	845,507	15,998
Lowland hardwood	4,350,697	3,842,379	508,318
Understocked	175,107	140,199	34,908
	Cornerstone C		
Planted pine	693,584	687,598	5,986
Natural pine	79,124	79,124	0
Oak-pine	110,547	110,547	0
Upland hardwood	927,464	899,814	27,649
Lowland hardwood	4,725,490	4,102,015	623,476
Understocked	200,436	156,432	44,004
	Cornerstone D		
Planted pine	583,759	572,383	11,376
Natural pine	118,767	118,767	0
Oak-pine	117,568	117,568	0
Upland hardwood	912,150	891,299	20,851
Lowland hardwood	4,420,965	3,868,315	552,650
Understocked	182,995	142,568	40,426
	Cornerstone E		
Planted pine	869,000	856,285	12,715
Natural pine	57,280	57,280	0
Oak-pine	74,354	74,354	0
Upland hardwood	875,180	848,818	26,362
Lowland hardwood	4,545,204	3,979,331	565,873
Understocked	192,941	153,999	38,942
	Cornerstone F		
Planted pine	472,176	472,176	0
Natural pine	163,104	163,104	0
Oak-pine	152,537	152,537	0
Upland hardwood	923,096	897,765	25,331
Lowland hardwood	4,442,297	3,882,751	559,546
Understocked	182,995	142,569	40,426

[a]Each Cornerstone represents a general circulation model paired with one of two emission scenarios (A1B representing high-population/high-economic growth, high energy use, and B2 representing low growth and use—and either high or low timber prices and either stable/higher/lower planting rates): Cornerstone A is MIROC3.2+A1B+high prices+stable planting, Cornerstone B is CSIROMK3.5+A1B+low prices+stable planting, Cornerstone C is CSIROMK2+B2+high prices+stable planting, Cornerstone D is HadCM3+B2+low prices+stable planting, Cornerstone E is MIROC3.2+A1B+high prices+higher planting, and Cornerstone F is HadCM3+B2+low prices+lower planting.

[b]Acreage not sufficiently stocked for determination of a management type.

Sources: Intergovernmental Panel on Climate Change (2007) and Wear (2013).

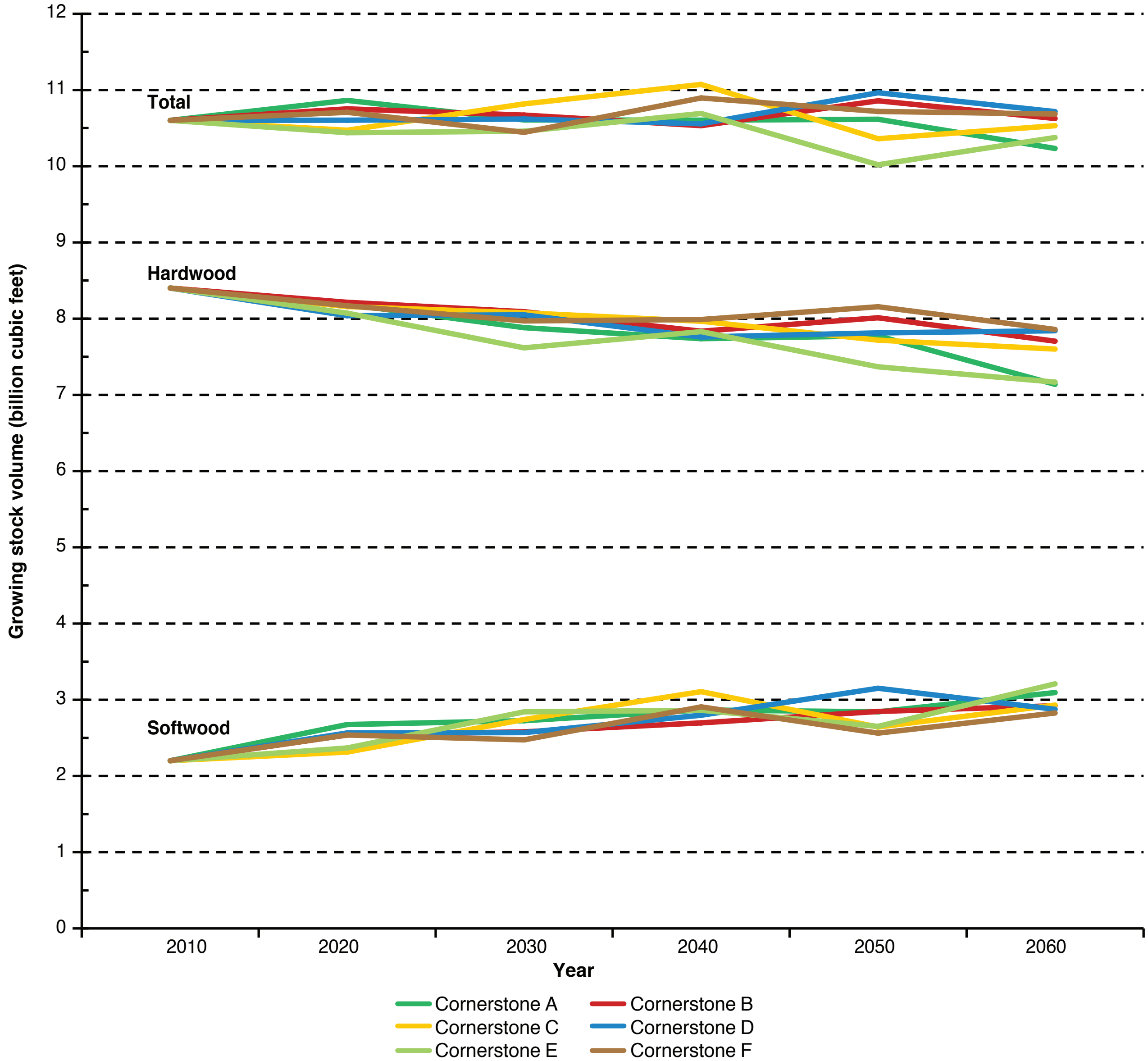

Figure 31—Forecasts of growing stock volumes in the U.S. Mississippi Alluvial Valley, under six Cornerstone Futures, each of which represents a general circulation model paired with one of two emission scenarios—A1B representing high-population/high-economic growth, high energy use, and B2 representing low growth and use—and either high or low timber prices and either stable/higher/lower planting rates: Cornerstone A is MIROC3.2+A1B+high prices+stable planting, Cornerstone B is CSIROMK3.5+A1B+low prices+stable planting, Cornerstone C is CSIROMK2+B2+high prices+stable planting, Cornerstone D is HadCM3+B2+low prices+stable planting, Cornerstone E is MIROC3.2+A1B+high prices+higher planting, and Cornerstone F is HadCM3+B2+low prices+lower planting. (Sources: Intergovernmental Panel on Climate Change 2007, Wear 2013)

Table 16—Change in softwood, hardwood, and total growing stock volume in the U.S. Mississippi Alluvial Valley from 2010 to 2060 as predicted by six Cornerstone Futures[a]

Change in volume	Softwood	Hardwood	Total
		Cornerstone A	
Thousand cubic feet[b]	894,126	-1,263,098	-368,971
Percent	40.6	-15.0	-3.5
		Cornerstone B	
Thousand cubic feet	721,211	-696,853	24,358
Percent	32.8	-8.3	0.2
		Cornerstone C	
Thousand cubic feet	729,744	-800,122	-70,378
Percent	33.2	-9.5	-0.7
		Cornerstone D	
Thousand cubic feet	674,424	-559,722	114,701
Percent	30.6	-6.7	1.1
		Cornerstone E	
Thousand cubic feet	1,008,287	-1,233,376	-225,089
Percent	45.8	-14.7	-2.1
		Cornerstone F	
Thousand cubic feet	625,719	-542,786	82,933
Percent	28.4	-6.5	0.8

[a]Each Cornerstone represents a general circulation model paired with one of two emission scenarios (A1B representing high-population/high-economic growth, high energy use, and B2 representing low growth and use—and either high or low timber prices and either stable/higher/lower planting rates): Cornerstone A is MIROC3.2+A1B+high prices+stable planting, Cornerstone B is CSIROMK3.5+A1B+low prices+stable planting, Cornerstone C is CSIROMK2+B2+high prices+stable planting, Cornerstone D is HadCM3+B2+low prices+stable planting, Cornerstone E is MIROC3.2+A1B+high prices+higher planting, and Cornerstone F is HadCM3+B2+low prices+lower planting.

[b]Forecasts are based on inventory plots from the Forest Inventory and Analysis Program, Southern Research Station, U.S. Forest Service.

Sources: Intergovernmental Panel on Climate (2007) and Wear (2013).

Holocene Deposits Section

Forest acreage—All expansion of forest acreage in the Mississippi Alluvial Valley is projected to occur in the Holocene Deposits section, where forest acreage could increase by 1.7 to 2.8 percent by 2060 if timber prices increase (table 17, fig. 32). Increases would be largest (2.8 percent) under the low population and income growth and increasing timber prices of Cornerstone C. Alternatively, a contraction in forest acreage would occur if timber prices decrease (table 17, fig. 32), which when coupled with high population and income growth (Cornerstone B), could result in a 3.8 percent loss (table 17).

Generally, increasing timber prices are projected to spur a slight increase in lowland hardwood forest acreage in the Holocene Deposits section (tables 15 and 17; fig. 33); the exception would be Cornerstone E, which combines increasing timber prices with high population and economic growth and increased investment in pine plantation establishment (table 17, fig. 33). Reductions in lowland hardwood acreage would also be expected under a future of decreasing timber prices (tables 15 and 17; figs. 32 and 33).

Regardless of future population and economic growth, the amount of acreage managed in planted pine is expected to increase in the Holocene Deposits section (tables 12 and 15; fig. 33). Expansion of this management type could be as low as 28 percent under the low population and income growth, decreased timber prices, and decreased planting rates of Cornerstone F; or as high as 132 percent under the high population and income growth, increased prices, and increased planting rates of Cornerstone E (tables 12 and 15).

Growing stock—Consistent with the Mississippi Alluvial Valley as a whole, the Holocene Deposits section is projected to experience an increase in softwood growing stock volume concurrent with a loss in hardwood growing stock volume through 2060 (table 18, fig. 34). Under Cornerstone A (high population growth with increasing income and timber prices), hardwood volume inventories could decrease by nearly 16 percent, and total forest growing stock volume could decrease by 3.2 percent (table 18). All other Cornerstone Futures predict decreases in hardwood growing stock volumes ranging from 4.5 to 13.9 percent and increases in softwood growing stock volumes ranging from 39.6 to 61.1 percent, which would maintain total growing stock volumes in the section at current or slightly increased levels (table 18, fig. 34). The low population and income growth combined with decreasing timber prices of Cornerstone D would result in a relatively small decrease (4.5 percent) in hardwood growing stock volume and the largest increase (4.4 percent) in total growing stock volume (table 18, fig. 34).

Table 17—Change in total forest area and lowland hardwood forest area in the Holocene Deposits section of the U.S. Mississippi Alluvial Valley from 2010 to 2060 as predicted by six Cornerstone Futures[a]

Change in area	All forests	Lowland hardwood
	Cornerstone A	
Acres[b]	101,967	22,541
Percent	1.7	0.6
	Cornerstone B	
Acres	-220,479	-182,246
Percent	-3.8	-4.5
	Cornerstone C	
Acres	167,428	77,389
Percent	2.8	1.9
	Cornerstone D	
Acres	-157,199	-156,309
Percent	-2.7	-3.9
	Cornerstone E	
Acres	101,967	-45,294
Percent	1.7	-1.1
	Cornerstone F	
Acres	-157,199	-141,874
Percent	-2.7	-3.5

[a]Each Cornerstone represents a general circulation model paired with one of two emission scenarios (A1B representing high-population/high-economic growth, high energy use, and B2 representing low growth and use—and either high or low timber prices and either stable/higher/lower planting rates): Cornerstone A is MIROC3.2+A1B+high prices+stable planting, Cornerstone B is CSIROMK3.5+A1B+low prices+stable planting, Cornerstone C is CSIROMK2+B2+high prices+stable planting, Cornerstone D is HadCM3+B2+low prices+stable planting, Cornerstone E is MIROC3.2+A1B+high prices+higher planting, and Cornerstone F is HadCM3+B2+low prices+lower planting.

[b]Forecasts are based on inventory plots from the Forest Inventory and Analysis Program, Southern Research Station, U.S. Forest Service.

Sources: Intergovernmental Panel on Climate Change (2007) and Wear (2013).

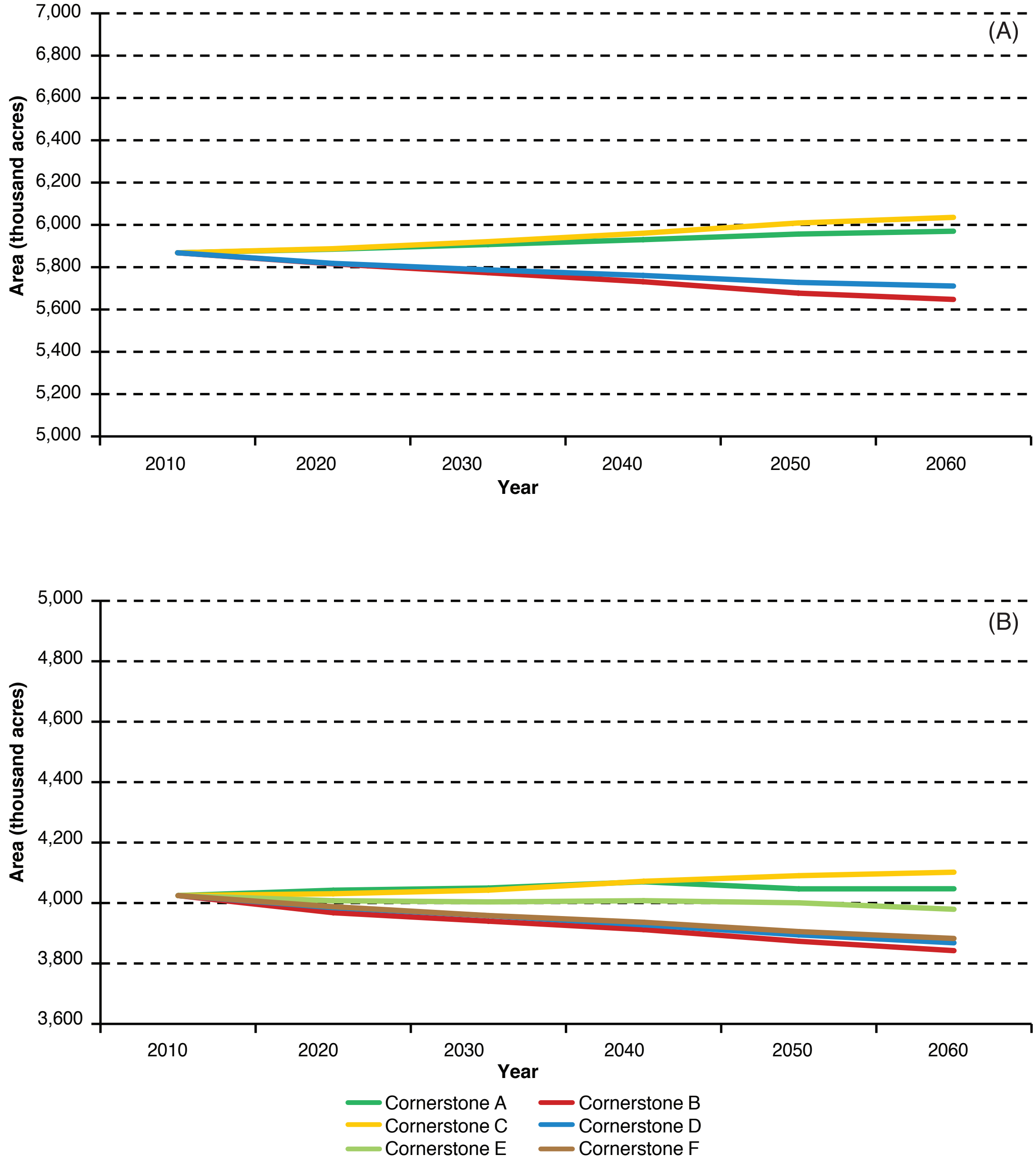

Figure 32—Forecasts of forested acreage by Cornerstone Futures in the Holocene Deposits section of the U.S. Mississippi Alluvial Valley for (A) all forests and (B) for lowland forests under six Cornerstone Futures, each of which represents a general circulation model paired with one of two emission scenarios—A1B representing high-population/high-economic growth, high energy use, and B2 representing low growth and use—and either high or low timber prices and either stable/higher/lower planting rates: Cornerstone A is MIROC3.2+A1B+high prices+stable planting, Cornerstone B is CSIROMK3.5+A1B+low prices+stable planting, Cornerstone C is CSIROMK2+B2+high prices+stable planting, Cornerstone D is HadCM3+B2+low prices+stable planting, Cornerstone E is MIROC3.2+A1B+high prices+higher planting, and Cornerstone F is HadCM3+B2+low prices+lower planting. For (A), results for Cornerstone E are identical to Cornerstone A, and results for Cornerstone F are identical to Cornerstone D. (Sources: Intergovernmental Panel on Climate Change 2007, Wear 2013)

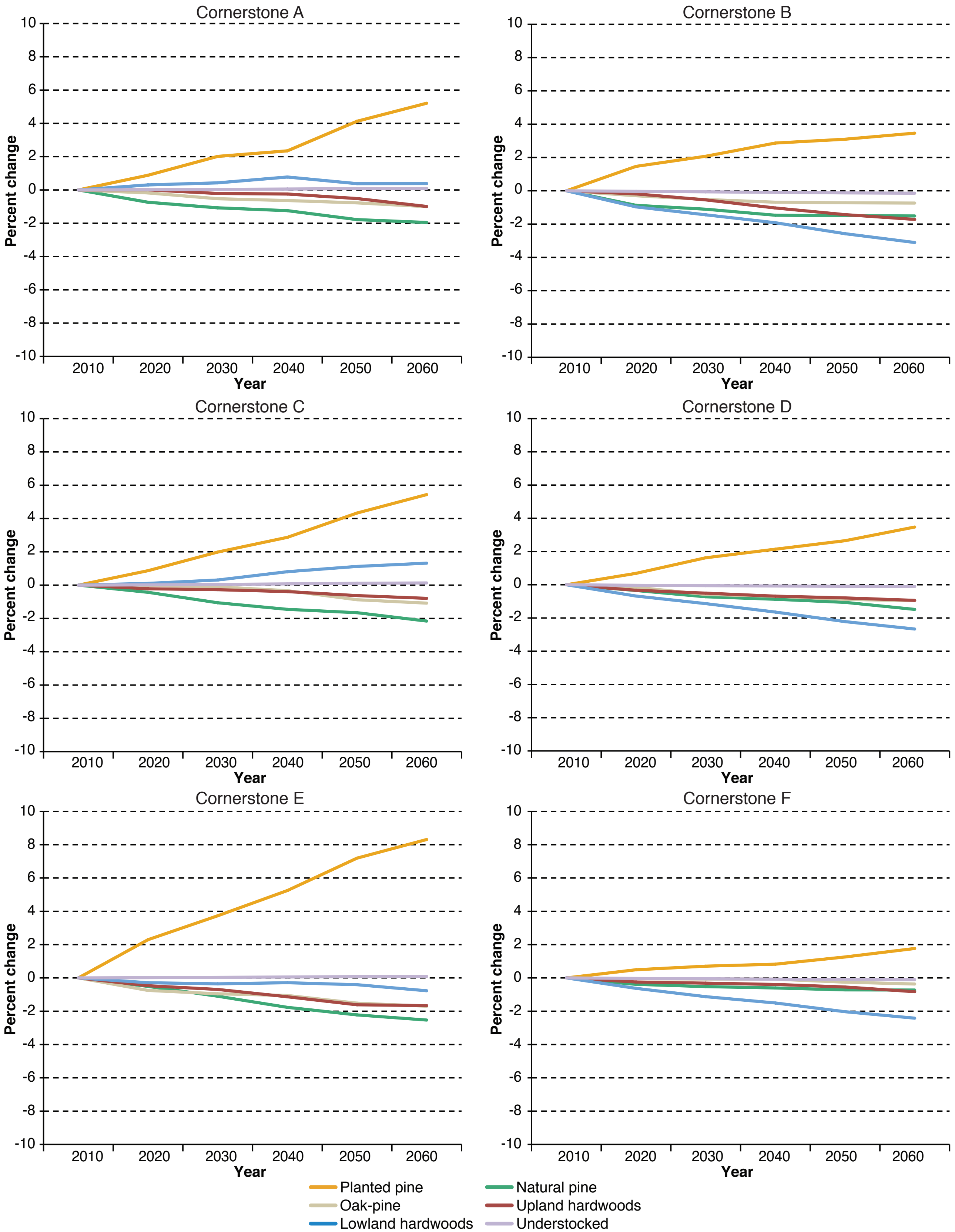

Figure 33—Forecasted percent change in forested acreage by management type in the Holocene Deposits section of the U.S. Mississippi Alluvial Valley under six Cornerstone Futures (A through F), each of which represents a general circulation model paired with one of two emission scenarios—A1B representing high-population/high-economic growth, high energy use, and B2 representing low growth and use—and either high or low timber prices and either stable/higher/lower planting rates: Cornerstone A is MIROC3.2+A1B+high prices+stable planting, Cornerstone B is CSIROMK3.5+A1B+low prices+stable planting, Cornerstone C is CSIROMK2+B2+high prices+stable planting, Cornerstone D is HadCM3+B2+low prices+stable planting, Cornerstone E is MIROC3.2+A1B+high prices+higher planting, and Cornerstone F is HadCM3+B2+low prices+lower planting. (Sources: Intergovernmental Panel on Climate Change 2007, Wear 2013)

Table 18—Change in softwood, hardwood, and total growing stock volume in the Holocene Deposits section of the U.S. Mississippi Alluvial Valley from 2010 to 2060 as predicted by six Cornerstone Futures[a]

Change in volume	Softwood	Hardwood	Total
		Cornerstone A	
Thousand cubic feet[b]	895,986	-1,200,418	-304,432
Percent	51.2	-15.8	-3.2
		Cornerstone B	
Thousand cubic feet	815,097	-492,887	322,209
Percent	46.5	-6.5	3.4
		Cornerstone C	
Thousand cubic feet	759,185	-716,315	42,869
Percent	43.4	-9.4	0.5
		Cornerstone D	
Thousand cubic feet	752,134	-340,336	411,798
Percent	42.9	-4.5	4.4
		Cornerstone E	
Thousand cubic feet	1,070,480	-1,063,059	7,421
Percent	61.1	-13.9	0.1
		Cornerstone F	
Thousand cubic feet	694,259	-564,947	129,312
Percent	39.6	-7.4	1.4

[a]Each Cornerstone represents a general circulation model paired with one of two emission scenarios (A1B representing high-population/high-economic growth, high energy use, and B2 representing low growth and use—and either high or low timber prices and either stable/higher/lower planting rates): Cornerstone A is MIROC3.2+A1B+high prices+stable planting, Cornerstone B is CSIROMK3.5+A1B+low prices+stable planting, Cornerstone C is CSIROMK2+B2+high prices+stable planting, Cornerstone D is HadCM3+B2+low prices+stable planting, Cornerstone E is MIROC3.2+A1B+high prices+higher planting, and Cornerstone F is HadCM3+B2+low prices+lower planting.

[b]Forecasts are based on inventory plots from the Forest Inventory and Analysis Program, Southern Research Station, U.S. Forest Service.

Sources: Intergovernmental Panel on Climate Change (2007) and Wear (2013).

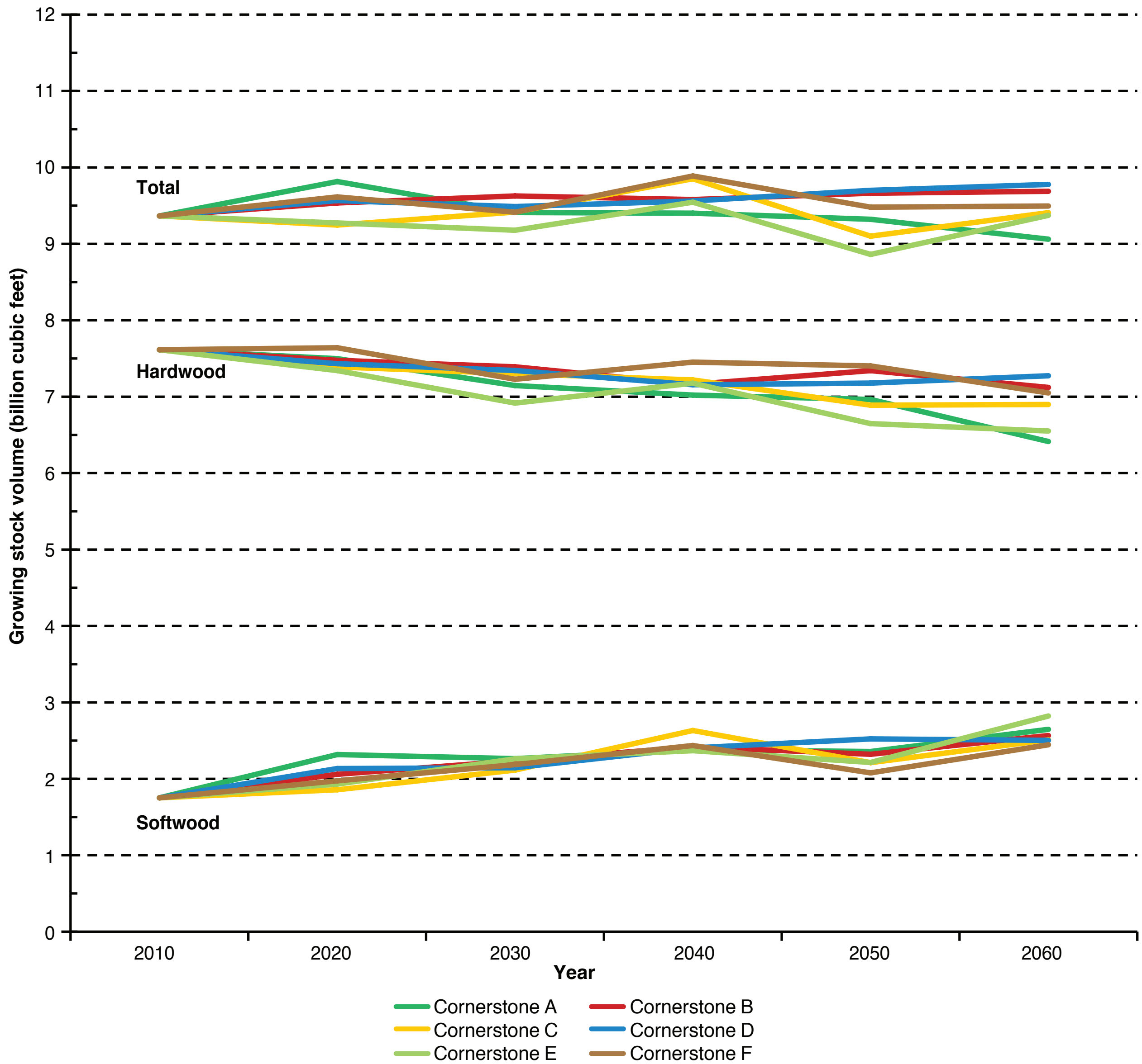

Figure 34—Forecasts of growing stock volumes for the Holocene Deposits section of the U.S. Mississippi Alluvial Valley under six Cornerstone Futures, each of which represents a general circulation model paired with one of two emission scenarios—A1B representing high-population/high-economic growth, high energy use, and B2 representing low growth and use—and either high or low timber prices and either stable/higher/lower planting rates: Cornerstone A is MIROC3.2+A1B+high prices+stable planting, Cornerstone B is CSIROMK3.5+A1B+low prices+stable planting, Cornerstone C is CSIROMK2+B2+high prices+stable planting, Cornerstone D is HadCM3+B2+low prices+stable planting, Cornerstone E is MIROC3.2+A1B+high prices+higher planting, and Cornerstone F is HadCM3+B2+low prices+lower planting. (Sources: Intergovernmental Panel on Climate Change 2007, Wear 2013)

Deltaic Plain Section

Forest acreage—The increased opportunities for expansion of forest acreage provided by higher timber prices in the Holocene Deposits section would not apply in the Deltaic Plain section. All Cornerstone Futures predict that forest acreage in the Deltaic Plain section will decrease through 2060 (table 19, fig. 35). Losses could approach 22 percent under the high population and income growth coupled with decreasing timber prices of Cornerstone B, compared to only about 4 percent under the low population and income growth coupled with increasing timber prices of Cornerstone C (table 19, fig. 35).

Because lowland hardwood forests account for 89 percent of all forests in the Deltaic Plain section, the changes predicted for them are expected to parallel those predicted for the aggregate of all management types (table 19, fig. 35). The largest decreases would occur with decreasing timber prices (table 19). However, increasing timber prices would only temper lowland hardwood losses if accompanied by low population growth (table 19). The tendency of robust timber prices to maintain forest acreage is not strong because the Deltaic Plain section is dominated by lowland hardwood forests.

Because lowland hardwoods are prevalent in the Deltaic Plain section, projected losses in their acreage would greatly exceed losses anticipated for other forests (tables 12 and 15; fig. 36). The only management type that would increase by 2060 is planted pine. However, the 12,715-acre increase in planted pines projected under Cornerstone E would amount to <2 percent of the forested acreage in the Deltaic Plain section, and this gain would be at the expense of other forests (table 15, fig. 36).

Growing stock—In contrast to forecasts for the Holocene Deposits section, inventories of all growing stock volumes in the Deltaic Plain section are largely expected to decrease through 2060. The sharpest decreases in hardwood growing stock volumes (25.9 to 27.9 percent) would be expected under the decreasing timber prices of Cornerstones B and D (table 20, fig. 37). Conversely, the increasing timber prices of Cornerstones A and C would reduce losses to hardwood growing stock to between 7.9 and 10.6 percent of current inventories (table 20, fig. 37).

Table 19—Change in total forest area and lowland hardwood forest area in the Deltaic Plain section of the U.S. Mississippi Alluvial Valley from 2010 to 2060 as predicted by six Cornerstone Futures[a]

Change in area	All forests	Lowland hardwood
	Cornerstone A	
Acres[b]	-87,782	-71,548
Percent	-11.9	-11.0
	Cornerstone B	
Acres	-164,930	-141,817
Percent	-22.5	-21.8
	Cornerstone C	
Acres	-30,558	-26,660
Percent	-4.2	-4.1
	Cornerstone D	
Acres	-106,369	-97,486
Percent	-14.5	-14.9
	Cornerstone E	
Acres	-87,782	-84,263
Percent	-11.9	-12.9
	Cornerstone F	
Acres	-106,369	-90,589
Percent	-14.5	-13.9

[a]Each Cornerstone represents a general circulation model paired with one of two emission scenarios (A1B representing high-population/high-economic growth, high energy use, and B2 representing low growth and use—and either high or low timber prices and either stable/higher/lower planting rates): Cornerstone A is MIROC3.2+A1B+high prices+stable planting, Cornerstone B is CSIROMK3.5+A1B+low prices+stable planting, Cornerstone C is CSIROMK2+B2+high prices+stable planting, Cornerstone D is HadCM3+B2+low prices+stable planting, Cornerstone E is MIROC3.2+A1B+high prices+higher planting, and Cornerstone F is HadCM3+B2+low prices+lower planting.

[b]Forecasts are based on inventory plots from the Forest Inventory and Analysis Program, Southern Research Station, U.S. Forest Service.

Sources: Intergovernmental Panel on Climate Change (2007) and Wear (2013).

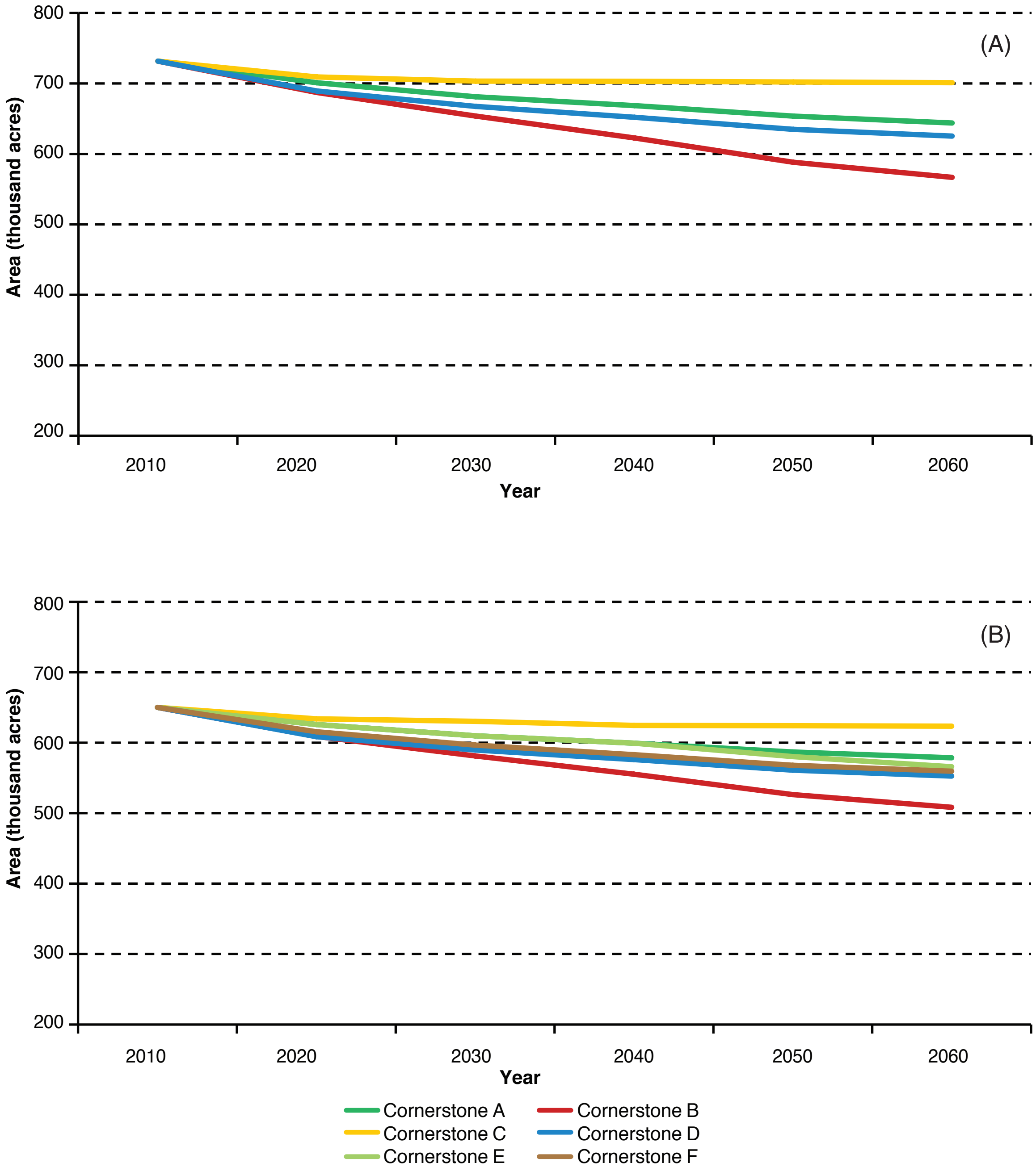

Figure 35—Forecasts of forested acreage in the Deltaic Plain section of the U.S. Mississippi Alluvial Valley for (A) all forests and (B) for lowland forests under six Cornerstone Futures, each of which represents a general circulation model paired with one of two emission scenarios—A1B representing high-population/high-economic growth, high energy use, and B2 representing low growth and use—and either high or low timber prices and either stable/higher/lower planting rates: Cornerstone A is MIROC3.2+A1B+high prices+stable planting, Cornerstone B is CSIROMK3.5+A1B+low prices+stable planting, Cornerstone C is CSIROMK2+B2+high prices+stable planting, Cornerstone D is HadCM3+B2+low prices+stable planting, Cornerstone E is MIROC3.2+A1B+high prices+higher planting, and Cornerstone F is HadCM3+B2+low prices+lower planting. For (A), results for Cornerstone E are identical to Cornerstone A, and results for Cornerstone F are identical to Cornerstone D. (Sources: Intergovernmental Panel on Climate Change 2007, Wear 2013)

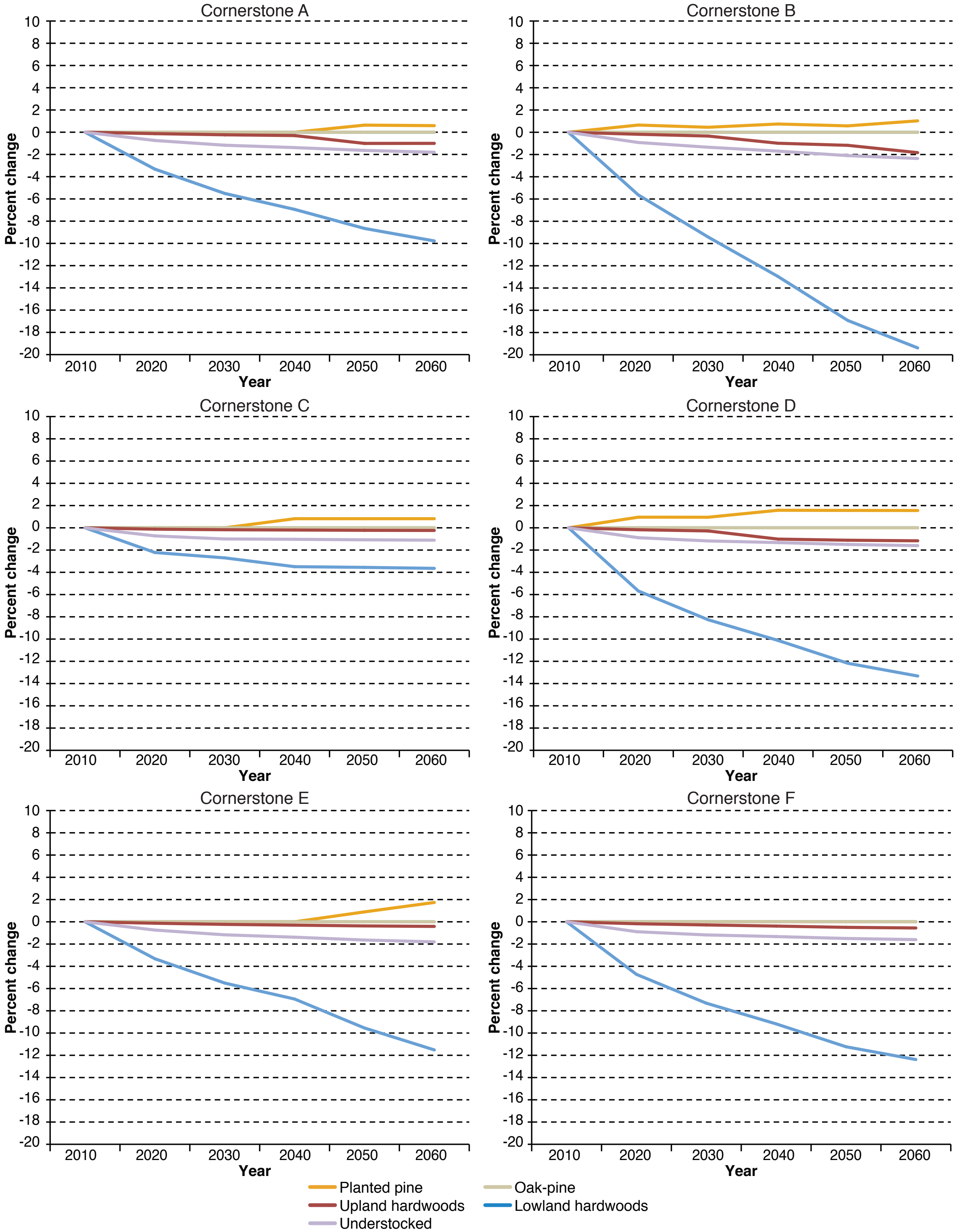

Figure 36—Forecasted percent change in forested acreage in the Deltaic Plain section of the U.S. Mississippi Alluvial Valley by management type under six Cornerstone Futures (A through F), each of which represents a general circulation model paired with one of two emission scenarios—A1B representing high-population/high-economic growth, high energy use, and B2 representing low growth and use—and either high or low timber prices and either stable/higher/lower planting rates: Cornerstone A is MIROC3.2+A1B+high prices+stable planting, Cornerstone B is CSIROMK3.5+A1B+low prices+stable planting, Cornerstone C is CSIROMK2+B2+high prices+stable planting, Cornerstone D is HadCM3+B2+low prices+stable planting, Cornerstone E is MIROC3.2+A1B+high prices+higher planting, and Cornerstone F is HadCM3+B2+low prices+lower planting. The natural pine management type does not occur in the Deltaic Plain section of the U.S. Mississippi Alluvial Valley. (Sources: Intergovernmental Panel on Climate Change 2007, Wear 2013)

Table 20—Change in softwood, hardwood, and total growing stock volume in the Deltaic Plain section of the U.S. Mississippi Alluvial Valley from 2010 to 2060 as predicted by six Cornerstone Futures[a]

Change in volume	Softwood	Hardwood	Total
		Cornerstone A	
Thousand cubic feet[b]	-1,859	-62,679	-64,539
Percent	-0.4	-7.9	-5.2
		Cornerstone B	
Thousand cubic feet	-93,886	-203,966	-297,852
Percent	-20.9	-25.9	-24.1
		Cornerstone C	
Thousand cubic feet	-29,441	-83,807	-113,248
Percent	-6.6	-10.6	-9.2
		Cornerstone D	
Thousand cubic feet	-77,710	-219,386	-297,096
Percent	-17.3	-27.9	-24.0
		Cornerstone E	
Thousand cubic feet	-62,194	-170,316	-232,509
Percent	-13.8	-21.6	-18.8
		Cornerstone F	
Thousand cubic feet	-68,539	22,161	-46,379
Percent	-15.2	2.8	-3.8

[a] Each of which represents a general circulation model paired with one of two emission scenarios (A1B representing high-population/high-economic growth, high energy use, and B2 representing low growth and use—and either high or low timber prices and either stable/higher/lower planting rates): Cornerstone A is MIROC3.2+A1B+high prices+stable planting, Cornerstone B is CSIROMK3.5+A1B+low prices+stable planting, Cornerstone C is CSIROMK2+B2+high prices+stable planting, Cornerstone D is HadCM3+B2+low prices+stable planting, Cornerstone E is MIROC3.2+A1B+high prices+higher planting, and Cornerstone F is HadCM3+B2+low prices+lower planting.

[b] Forecasts are based on inventory plots from the Forest Inventory and Analysis Program, Southern Research Station, U.S. Forest Service.

Sources: Intergovernmental Panel on Climate Change (2007) and Wear (2013).

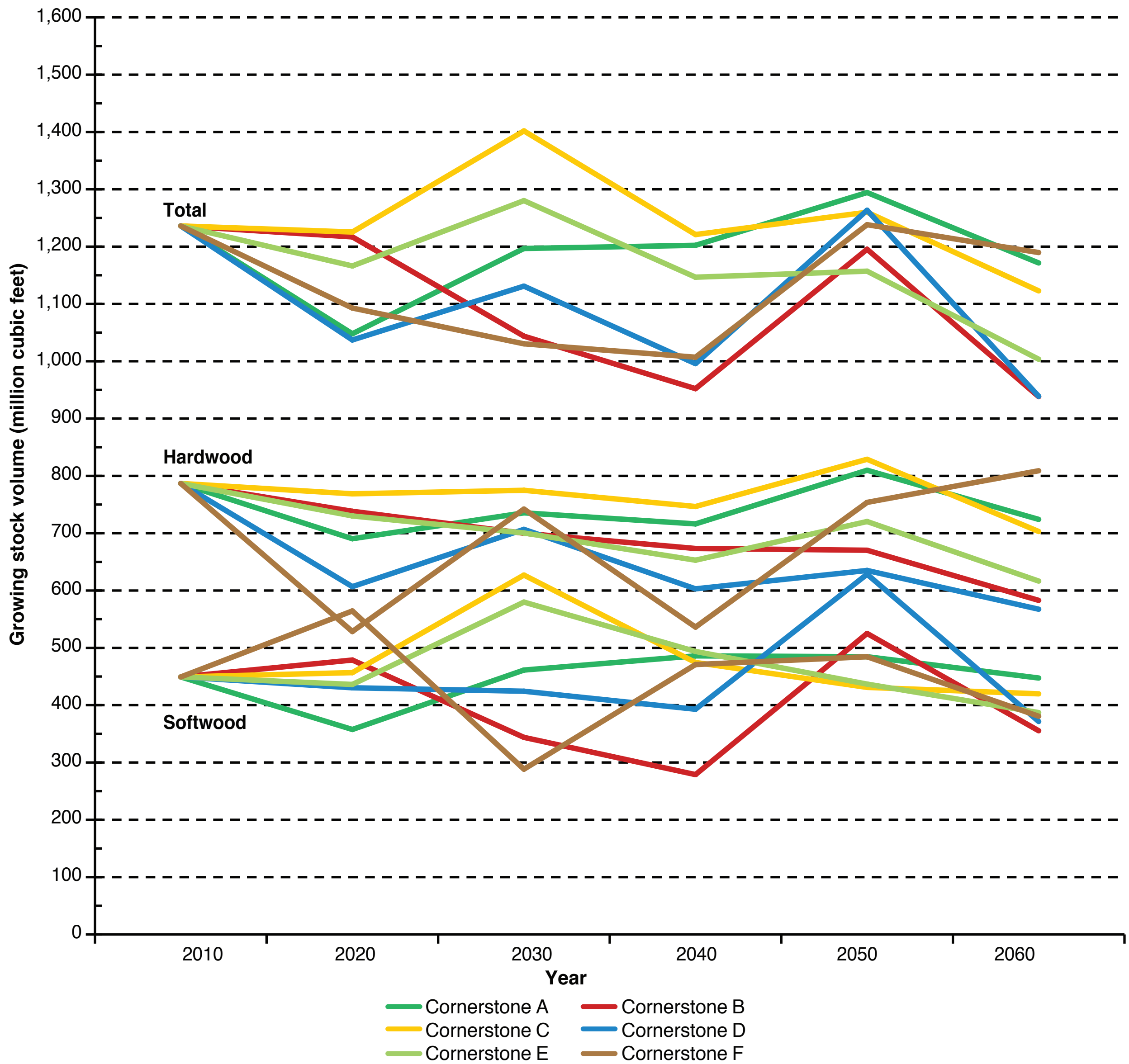

Figure 37—Forecasts of growing stock volumes in the Deltaic Plain section of the U.S. Mississippi Alluvial Valley under six Cornerstone Futures, each of which represents a general circulation model paired with one of two emission scenarios—A1B representing high-population/high-economic growth, high energy use, and B2 representing low growth and use—and either high or low timber prices and either stable/higher/lower planting rates: Cornerstone A is MIROC3.2+A1B+high prices+stable planting, Cornerstone B is CSIROMK3.5+A1B+low prices+stable planting, Cornerstone C is CSIROMK2+B2+high prices+stable planting, Cornerstone D is HadCM3+B2+low prices+stable planting, Cornerstone E is MIROC3.2+A1B+high prices+higher planting, and Cornerstone F is HadCM3+B2+low prices+lower planting. (Sources: Intergovernmental Panel on Climate Change 2007, Wear 2013)

WILDLIFE AND FOREST COMMUNITIES

The lower Mississippi Valley supports the largest expanses of bottomland hardwood forest habitats in North America, and underpins the southern portion of one of four migratory bird flyways. Private forest holdings in the Mississippi Alluvial Valley amount to nearly 5.3 million acres, and an additional 478,188 acres under Federal easement now support bottomland hardwood plantations that have replaced cropland. Furthermore, >775,000 acres of Federal holdings in the wildlife refuges (557,622 acres), the national forests (83,498 acres), and lands managed by the Army Corps of Engineers (134,535 acres) are distributed throughout the inland stretches of the Mississippi Alluvial Valley; stewardship of these lands is largely focused on forested habitats.

This section provides a synthesis and expansion of those aspects of the Southern Forest Futures Project wildlife analysis (Trani Griep and Collins 2013) that are relevant to the Mississippi Alluvial Valley and its associated sections, identifies four forest communities that have experienced significant acreage loss, and describes the implications of Cornerstone Future forecasts for these forest communities.

Current Status for Animal Species

The Mississippi Alluvial Valley provides habitat for roughly 500 native terrestrial vertebrate species, approximately 49 percent of all terrestrial vertebrates indigenous to the South (Trani Griep and Collins 2013). Birds account for >60 percent of the fauna with >300 species (fig. 38). Other vertebrate classes have considerably fewer species: 72 reptiles, 62 amphibians, and 61 mammals (fig. 38) (Trani Griep and Collins 2013). Of the two Mississippi Alluvial Valley sections, the Holocene Deposits section supports more terrestrial vertebrates (475 species), including about 287 birds, 59 amphibians, 67 reptiles, and 60 mammals (fig. 38); the much smaller Deltaic Plain section supports 432 terrestrial vertebrates, including 285 birds, 43 amphibians, 62 reptiles, and 42 mammals (fig. 38).

The Mississippi Alluvial Valley apparently lacks species endemism: all of its native terrestrial vertebrate species are also indigenous to other areas of the South. At the subspecies level, the known population of the Louisiana black bear (*Ursus americanus luteolus* Griffith) occurs primarily within the Mississippi Alluvial Valley. Migrants that spend only a portion of each year in the Mississippi Alluvial Valley account for a large percentage of its faunal richness: >85 percent of all indigenous birds (about 270 species) and about 8 percent of all indigenous mammals (5 bat species) are migratory.

At least 11 species and subspecies (2.2 percent) of the vertebrates in the Mississippi Alluvial Valley are Federally listed as threatened or endangered (Trani Griep and Collins 2013). Six bird species—the piping plover (*Charadrius melodus* Ord), the interior least tern (*Sternula antillarum athalassos* Burleigh & Lowery), the red-cockaded woodpecker (*Picoides borealis* Vieillot), the Atwater's prairie chicken (*Tympanuchus cupido attwateri* Bendire), the Bachman's warbler (*Vermivora bachmanii* Audubon), and the ivory-billed woodpecker (*Campephilus principalis* L.)—are all at some level of imperilment, as are two sea turtle species that are indigenous to coastal beaches— the loggerhead (*Caretta caretta* L.) and the Kemp's Ridley (*Lepidochelys kempii* Garman). Mammals listed as threatened or

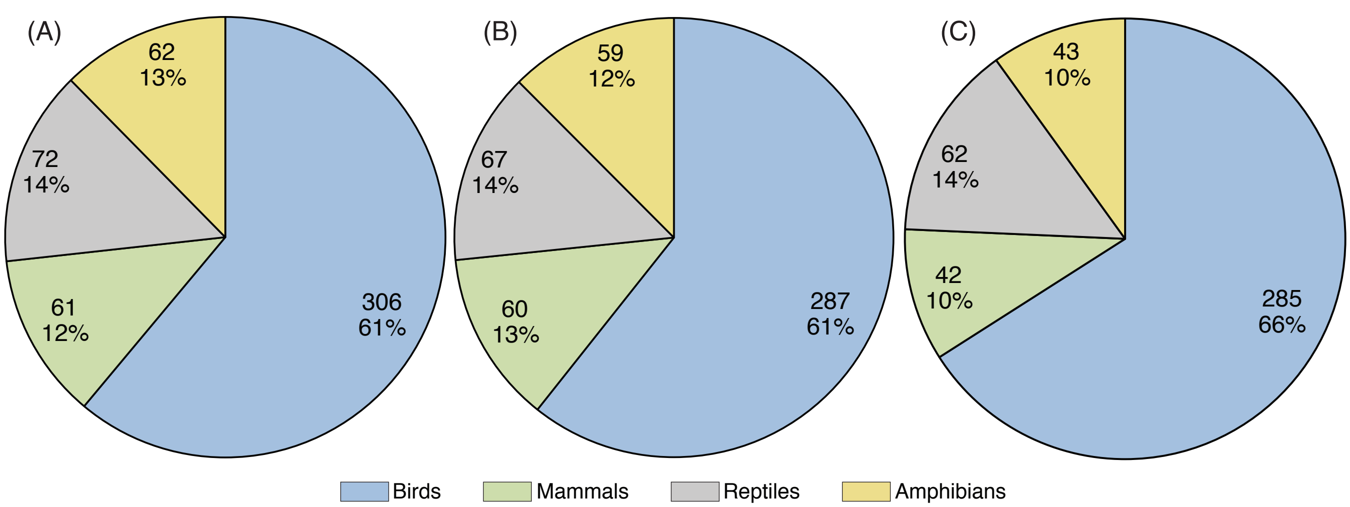

Figure 38—Number and percentage of terrestrial species by class (A) for the U.S. Mississippi Alluvial Valley, (B) for its Holocene Deposits section, and (C) for its Deltaic Plain section. (Source: Trani Griep and Collins 2013)

endangered in the Mississippi Alluvial Valley are the gray bat (*Myotis grisescens* A.H. Howell), the Louisiana black bear, and the West Indian manatee (*Trichechus manatus* L.) No amphibians are classified as either threatened or endangered (Trani Griep and Collins 2013).

Some imperiled vertebrates have traditional ranges largely peripheral to the Mississippi Alluvial Valley and most are not associated with its bottomland forest habitats. The three listed vertebrates that historically exhibit habitat preference for bottomland hardwood forests are the Bachman's warbler, the ivory-billed woodpecker, and the Louisiana black bear.

The Bachman's warbler was placed on the Endangered Species list by the U.S. Fish and Wildlife Service in 1973 (Hamel 1995). Observations of breeding populations of this species were somewhat common before the 1920s, but extensive deforestation since that time—both in the United States and on its wintering range in Cuba—is thought to have greatly diminished its habitat (Hamel 1995). The last confirmed sighting of this species was near Charleston, SC in 1961, and some authorities now consider the species to be extinct (Hamel 1995).

Historical records of the ivory-billed woodpecker demonstrate its strong affinity for large tracts of old-growth bottomland hardwood forests (Jackson 2002), which logging and subsequent deforestation during the 19th and 20th centuries have relegated to relatively small, fragmented remnants apparently incapable of maintaining breeding populations. According to Jackson (2002), the last confirmation of a breeding population in the United States occurred in the early 1940s in northeast Louisiana (Holocene Deposits section). Unsubstantiated sightings in the United States and Cuba have surfaced somewhat regularly (Jackson 2002), and compelling evidence of the bird was reported as recently as 2004 from the Arkansas portion of the Mississippi Alluvial Valley (Fitzpatrick and others 2005). However, with no confirmed sightings of a breeding population in more than six decades and with no independently verifiable evidence of survival, some authorities consider the species to be extinct (Collinson 2007, McKelvey and others 2008).

In contrast to the Bachman's warbler and the ivory-billed woodpecker, the survival of breeding subpopulations has facilitated recovery efforts for the Louisiana black bear (U.S. Department of the Interior Fish and Wildlife Service 2009), with habitat restoration and bear relocation projects resulting in recent population gains (Benson and Chamberlain 2007). The U.S. Fish and Wildlife Service estimates that the current population is 400 to 700 animals, and has declared most subpopulations are stable or expanding (U.S. Department of the Interior Fish and Wildlife Service 2009).

Current Status for Plant Species

Of the 140 southern plants that are Federally listed as threatened or endangered (Trani Griep and Collins 2013), only pondberry is native to the Mississippi Alluvial Valley (Trani Griep and Collins 2013). This colony-forming member of the laurel family has always been considered to be rare based on the relatively small number of specimens catalogued in herbaria (Steyermark 1949). It currently occurs in Mississippi (Bolivar County and Sharkey County) and in Arkansas (Clay County, Craighead County, Crittenden County, Jackson County, Lawrence County, Poinsett County, and Woodruff County), but also ranges northward into southeastern Missouri and eastward into the Coastal Plain where extant populations are found in Alabama, Georgia, South Carolina, and North Carolina (Echt and others 2011). Recent and ongoing research—revealing much about its reproductive biology, ecology, physiology, and genetics (Hawkins and others 2007)—has increased the likelihood for future conservation and recovery to a more sustainable status. However, a recent introduction of the laurel wilt fungus (chapter 4) is damaging other laurel species in the Coastal Plain and could seriously threaten surviving pondberry colonies (Fraedrich and others 2011).

Forecasts and Implications for Highly Impacted Forest Communities

The imperilment of animal and plant species appears to have progressed with the degradation and disproportionate decline of certain forest communities. Deforestation has unquestionably had the most pervasive impact to forested habitats with forest land now only occupying about 28 percent of the nearly 25-million-acre Mississippi Alluvial Valley. This suggests that future changes in the amount and quality of forested habitat will be heavily influenced by land use dynamics, fragmentation and isolation of forested tracts, conversion from natural stands to plantations, fluctuations in age class distributions of forested acreage, intensity of reforestation and afforestation practices, climate-driven impacts to forests, invasive species, land subsidence along coastal areas, and restrictions on forest management that emerge with expansion of the wildland-urban interface.

Land use and population projections (chapter 3) indicate the Mississippi Alluvial Valley will likely experience additional losses of forest acreage, primarily from urban development (table 7). The most extensive deforestation is projected for the Deltaic Plain section where losses could range from 11.3 to 25.6 percent depending on future economic and population growth (table 9). Additionally, conversion of forests to pine plantations could potentially alter >0.5-million acres of natural pine and oak-pine habitat in the Holocene Deposits section through 2060 (tables 12 and 15). Broad application of the forecasts generated under the Cornerstone Futures enables development of possible implications for the most impacted forest communities in the Mississippi Alluvial Valley.

Although comprehensive data are not available to describe earlier forest conditions, a basic assessment of change in occurrence of some forest communities can be drawn from inventories published in the early 1930s (Rudis 2001). The communities that have probably incurred the most severe impacts since European settlement of the Mississippi Alluvial Valley include bottomland hardwood associations of relatively high alluvial sites, baldcypress-water tupelo associations of coastal swamps, eastern cottonwood and black willow associations on sites where sediments accumulate, and oak-dominated mixed bottomland hardwood associations.

Bottomland hardwoods on higher alluvial sites—The higher elevation sites on the alluvial floodplain of the Mississippi River possibly supported mesic forest communities with the highest levels of productivity and species richness. In addition to a rich suite of overstory species, these sites were likely important to development of the extensive patches of switchcane (*Arundinaria gigantea* [Walter] Muhl.) that once grew in the lower Mississippi Valley (Tingle and others 2001). Over the years, the natural levees along meander scars, distributary channels, and other higher elevation landforms have experienced some of the most severe deforestation in the Mississippi Alluvial Valley (Hodges 1997, Rudis 2001). The progression of deforestation began on sites with the most arable soils that were least prone to flooding (Eldredge 1938, Rudis 2001, Winters and others 1938); this disproportionate clearing of the "highest and driest" acreage enabled early settlers to establish the agricultural economy that still defines the primary land use throughout the Mississippi Alluvial Valley today. Although the soils that traditionally support higher elevation species associations occur on >2.7 million acres, the most common higher elevation forest type—swamp chestnut oak/cherrybark oak, (*Quercus michauxii* Nutt.–*Q. pagoda* Raf.)—currently occupies only about 130,000 acres on these sites (tables 2 and 3).

Because higher elevation alluvial sites are the most productive for agricultural crops and the most desirable for urbanization, restoration of forest communities on these sites appears doubtful. In fact, pressure from urbanization in the Mississippi Alluvial Valley could drive additional deforestation of higher elevation alluvial sites—particularly in the Holocene Deposits section where >98 percent of swamp chestnut oak/cherrybark oak forests occur. This outcome would be most likely under the decreasing timber prices of Cornerstones B and D (table 15). In addition to deforestation, a future of high population and economic growth along with increasing timber prices and high planting rates (Cornerstone E) could make these higher elevation alluvial sites attractive for conversion to planted pine (table 15).

Baldcypress-water tupelo associations of coastal swamps—Baldcypress-water tupelo swamps in coastal Louisiana are vital to the ecological and economic sustainability of the Deltaic Plain section. In addition to the many hydrologic, biogeochemical, and biotic functions they provide, baldcypress-water tupelo swamps are immensely important for recreation, storm abatement, commercial fisheries, wood and fiber production, and other ecosystem services (Chambers and others 2005). Notwithstanding these values, deforestation and drainage of their hydric sites for conversion to agricultural and urban uses, encroachment of invasive plant and animal species, and unsustainable logging practices have all impacted these forest communities (Conner and Toliver 1990). Perhaps even more pervasive have been the engineered controls over river flow and discharge dynamics, together with the development of coastal areas for oil and gas production (Day and others 2000). The impacts of these activities on natural hydrologic regimes and sediment depositional patterns have exacerbated the effects of sea-level rise and land subsidence in the coastal zone (Conner and Brody 1989; Day and others 2000, 2012). The resulting change in hydroperiod and saltwater intrusion have contributed to the conversion of coastal swamp communities into marshland and open water, and has increased the threat to bottomland hardwood communities that are farther inland (Conner and Day 1988, Day and others 2000, Hoeppner and others 2008). The severity and permanency of these impacts have led to ongoing concerns about the sustainability of coastal swamp forests in light of increasing flood depths and durations that disrupt regeneration processes (Chambers and others 2005, Faulkner and others 2009, Keim and others 2006).

Estimates of the historical extent of coastal baldcypress-water tupelo swamp forests vary considerably, but a conservative interpolation of a 1935 survey suggests that these forest communities once occupied >1 million acres in the Deltaic Plain section (table 21). More recent surveys, which also vary considerably because of disparities between sampling protocols and data interpretation methods, estimated that baldcypress-water tupelo swamps have been reduced to <270,000 acres (table 21). However, Faulkner and others (2009), who used remote sensing methods to inventory forest cover, found nearly the same acreage (262,280 acres) of baldcypress-water tupelo swamp forest in an approximate 610,190-acre portion of the 833,000-acre Lower Atchafalaya Basin Floodway. Added to the uncertainty is the caveat that the magnitude of degradation sustained by these communities is not reflected in reports of acreage lost (Faulkner and others 2009), but can be inferred from an analysis by Chambers and others (2005) of the history, current status, and issues surrounding the sustainability of these coastal forests.

Table 21—Forest area estimates from the 1930s and from 2010 forest inventory surveys for critical forest associations in the U.S. Mississippi Alluvial Valley that have experienced substantial disturbances

Forest association	1930s	2010
	----------- *acres*	-----------
Total forests	13,507,600	6,599,775
Coastal baldcypress and water tupelo	1,092,100	263,600
Eastern cottonwood and black willow	1,378,900	255,500
Oak dominated associations	6,943,300	2,372,700

Sources: Eldredge (1938), Stover (1942), Winters (1939a,b), Winters and others (1938).

All Cornerstone Futures predict that urban expansion will claim substantial forested acreage in the Deltaic Plain section through 2060 (table 10). Deforestation could reduce lowland forests by >140,000 acres under the high population and economic growth and decreasing timber prices of Cornerstone B (table 19). Because baldcypress-water tupelo forests make up the majority of these lowland forests (table 3), these swamp communities would likely experience substantial drainage and deforestation.

More significant than the threats from urbanization, the baldcypress-water tupelo forests of the Deltaic Plain section are expected to continue receding along coastal Louisiana—the result of rapidly subsiding sediment-starved land and rising sea levels. The projected sea-level rise of >3 feet over the next century would cause permanent flooding and saltwater intrusion farther inland and increase impacts to coastal baldcypress-water tupelo communities (Doyle and others 2010). In 1998, the Louisiana Coastal Wetlands Conservation and Restoration Task Force (1998) estimated that >230,000 acres of swamp forests could be lost by 2050. More recently, Doyle and others (2010) predicted that losses to freshwater forests would range from 73,000 to 134,500 acres with a mere 4-inch rise in sea level. These projections have led many authorities to surmise that the existing baldcypress-water tupelo swamps of coastal Louisiana will not persist into the later part of this century without immediate implementation of large-scale restoration and conservation initiatives akin to those proposed by Chambers and others (2005).

Eastern cottonwood and black willow associations—Eastern cottonwood and black willow grow rapidly in relatively short-lived associations on sites formed from recent and unconsolidated alluvium (Hodges 1997, Putnam and Bull 1932). These pioneering communities initiate many ecological functions as they catalyze soil formation processes, forest succession processes, forest habitat development, and sediment and nutrient retention processes. Management practices designed to favor navigation and flood abatement have disrupted natural channel migration of the Mississippi River (Smith and Winkley 1996) that had once caused its characteristic meandering and gave rise to sites suitable for eastern cottonwood and black willow (Tingle and others 2001). Consequently, present-day accretion is concentrated around structures built to train (constrain and redirect) the river's sediment loads (Kesel 2003) rather than distributed to the natural point bar and river front sites that traditionally supported eastern cottonwood and black willow associations. Historical acreage of these forest communities is not known, but the 1934/1935 inventories estimated that eastern cottonwood and black willow types accounted for about 10.2 percent of forested acres in a 13,507,600-acre portion of the Mississippi Alluvial Valley (table 21). In comparison, inventory data from 2010 estimated that forest types dominated by eastern cottonwood and black willow occupied <4 percent of the forested acreage in the Mississippi Alluvial Valley (table 21).

Because most eastern cottonwood and black willow sites occur within the confines of the batture (the portion of the floodplain between the constructed levees), future establishment of these forests will likely depend on the number of engineering projects designed to contain the main channel and control depositional processes of the lower Mississippi River. Smith and Winkley (1996) concluded that routine channel maintenance and dredging would maintain the current sediment dynamics of this highly trained system. The engineered stability of the lower Mississippi River may necessitate incorporation of conservation elements in future projects if monitoring shows that ephemeral forest associations require additional sediment deposition and accretion along channel margins.

Oak-dominated hardwoods—On a more subtle level than the extensive deforestation and degradation experienced by some forest communities, the oak component—particularly the red oaks (Section Lobatae)—in mixed bottomland hardwood associations appears to be in chronic decline. This decline can be attributed to many factors, but the two most likely causes are destructive logging practices such as "high grading" and the use of silvicultural practices such as "selective cutting" that favor the more shade tolerant tree species (Meadows and Stanturf 1997, Oliver and others 2005). The magnitude of decline in oak dominance has not been quantified within the Mississippi Alluvial Valley, but a comparison of the former extent of oak-dominated types to the current extent of oak-dominated types provides a coarse indication of the scope of the issue. Forest inventories during the 1930s revealed that oak-dominated forest types were represented on >51 percent of forested acreage (table 21). Since that time, oak-dominated forest types have decreased 15 percent to account for <36 percent of the forested acreage (table 21). This decrease in forested acreage dominated by oaks was disproportionately larger than the decrease in total forest acreage. Total forest acreage decreased to 49 percent of the 1930s level while acreage dominated by oak types decreased to 34 percent of the 1930s level (table 21).

Conservation and restoration of oak-dominated forests will require increased landowner awareness and implementation of silvicultural practices that favor oak regeneration and the development of oak reproduction into canopy positions. Current logging practices that minimize canopy disturbance actually perpetuate stand degradation through "high grading" and creation of conditions that favor shade-tolerant species (Oliver and others 2005). These degraded stands require intensive practices such as canopy manipulations, vegetation control, and supplemental planting to restore the oak component (Dey and others 2012).

In addition to these counterproductive logging practices, urban development is likely to claim substantial acreage of oak-dominated forests. Loss of forest acreage to urban development in the Mississippi Alluvial Valley would be most extensive (>161,000 acres) under the decreasing timber prices of Cornerstones B and D (tables 10 and 14). Conversion of lowland hardwood management types to planted pine could also contribute to a reduction in acreage of oak-dominated forests, but forecasts generally indicate conversion to planted pine will be limited to other management types (table 15).

Afforestation efforts—Since the signing of the 1985 and 1990 Farm Bills, the U.S. Department of Agriculture has implemented long-range policies to accomplish a range of environmental benefits by reducing the amount of acreage managed for row crop production. For the Mississippi Alluvial Valley, afforestation of marginally economical cropland has been the primary mechanism for removing acreage from production. This has been achieved through the creation of the Conservation Reserve Program in 1985 and the Wetlands Reserve Program in 1990. Under both programs, landowners are subsidized for removing land from production through land rental payments and cost sharing for afforestation practices. Afforestation has substantially increased the forested area in the Mississippi Alluvial Valley, often placing priority on lands that help strengthen wildlife corridors, expand larger forested tracts, or buffer sensitive forested habitats.

The Arkansas portion of the Mississippi Alluvial Valley has experienced the highest level of afforestation—>167,000 acres planted under the Wetlands Reserve Program since 1990—followed by Louisiana (159,288 acres) and Mississippi (151,900 acres). Although the models used to predict land use for this report did not account for the impact of yet-to-be developed policies, future legislation will likely lead to continued funding of Federal programs aimed at removing land from agricultural production and restoring bottomland forest habitats. Still, the establishment of conventional plantations that have resulted from Federal incentives can only be seen as an initial step towards forest restoration (Stanturf and others 2001). Much still needs to be learned about developing sustainable bottomland hardwood forest habitats on these afforestation sites (Gardiner and Oliver 2005). For example, as plantations begin to age, new management challenges arise such as reversing poor stocking or low merchantable quality that has resulted from establishment protocols, and dealing with easements that restrict management options. Thus, afforestation is likely to continue in the Mississippi Alluvial Valley, but will likely be accompanied by formidable constraints to the access and flexibility needed for producing targeted stand structures that achieve desired and sustainable outputs.

WATER RESOURCES

Water could very well have had a more profound effect on the lower Mississippi Valley than anywhere else in North America. Geomorphic processes driven by several episodes of glacial and interglacial cycles have shaped its physiography into the largest fluvial system on the North American continent. Vegetative communities dominating this fluvial system have similarly shifted with the glacial and interglacial cycles, principally responding to the effects that climate has had on the water cycle. Still, the riverine forests that currently dominate the area are not merely a product of this fluvial system; they also directly impact water balance and functionally provide values to society such as water storage and water quality maintenance.

A number of factors are increasingly threatening water resources in the Mississippi Alluvial Valley: modern regulation of the hydrologic dynamics of the Mississippi River, alterations impacting the connectivity between the Mississippi River and its floodplain, degradation through inputs of nonpoint source pollutants, changing land use, shifts in climate patterns, and growing demands on water supplies. Lockaby and others (2013) used a water accounting model, Water Supply Stress Index (WaSSI) (Sun and others 2008), to quantify the current status and forecast potential impacts of future climate change, land use change, and population growth on water resources for the Southern Forest Futures Project.

WaSSI, which models the ratio of water demand relative to water supply, was useful in illustrating the spatial arrangement of hydrologic responses to a host of factors that influence water availability on landscapes (Lockaby and others 2013, Sun and others 2008). Lockaby and others (2013) described the process for modeling both the sources that contribute to the water supply of a basin—total surface water supply, groundwater supply, and return flow from seven water use sectors (commercial, domestic, industrial, irrigation, livestock, mining, and thermoelectric)—and the withdrawals from the supply by each of the seven sectors. The structure of WaSSI allowed modeling parameterization for future climate, population, and land use associated with the Cornerstone Futures.

This section focuses on results that are relevant to the Mississippi Alluvial Valley and its associated sections, and forecasts changes in demand and supply of water resources through 2050.

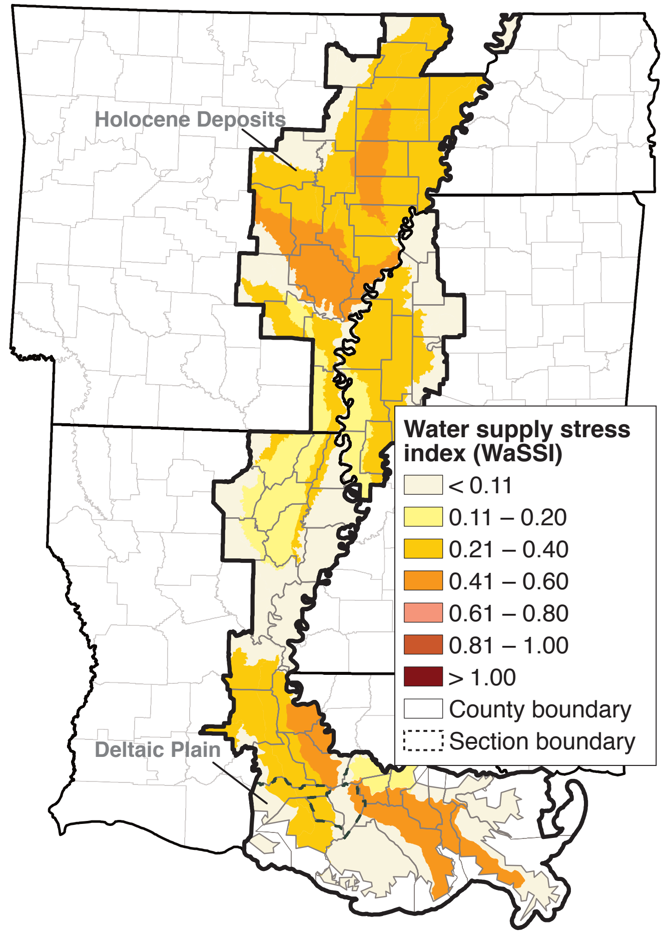

Figure 39—Water supply stress (water demand divided by water supply) in the U.S. Mississippi Alluvial Valley, 1995 to 2005. (Source: Lockaby and others 2013)

Current Status

The Mississippi Alluvial Valley is currently experiencing low to moderate (<0.6) water supply stress (fig. 39). Areas experiencing the highest stress levels—0.41 to 0.60—include the Grand Prairie and the Western Lowlands of Arkansas, the portion of the Atchafalaya Basin immediately west of the Baton Rouge metropolitan area, and the Barataria Basin of the Deltaic Plain section (fig. 39); this level of water supply stress is considerably higher than most forested areas of the South. The relatively high level in the upper portion of the Holocene Deposits section may be attributed to intensive agricultural production. Concurrently, the highest level of water supply stress observed in the Deltaic Plain section may be attributable to urbanization, particularly in the New Orleans and Baton Rouge metropolitan areas.

Areas currently experiencing very low water supply stress are scattered throughout the Mississippi Alluvial Valley and include the eastern counties of the Yazoo Basin in Mississippi, the parishes along the Mississippi River in the Tensas Basin of northeastern Louisiana, the Terrebonne Marsh, the Pontchartrain Basin, and the Delta Lobe (fig. 39). For these areas, the ratio of water demand to water supply is <0.11, which is the lowest level of water supply stress in the South (fig. 39).

Water Supply Forecasts

Implications of climate predictions—Climate forecasts for the Mississippi Alluvial Valley generally project increasing temperatures and decreasing precipitation through 2060 (chapter 2). The anticipated shifts in climate conditions will likely drive changes to water supply stress, with changes potentially approaching 200 percent by 2050. The largest increases to the water supply stress would occur under Cornerstone A (fig. 40), which forecasts a 2.1 °C rise in average annual temperature and a 183-mm decrease in average annual precipitation. The likely result would be accelerated evapotranspiration, causing a 10- to 100-percent increase in water supply stress for the entire Mississippi Alluvial Valley and a 100- to 200-percent increase in localized portions of the Holocene Deposits section as well as portions of the Atchafalaya Basin and Terrebonne Marsh in the Deltaic Plain section (fig. 40).

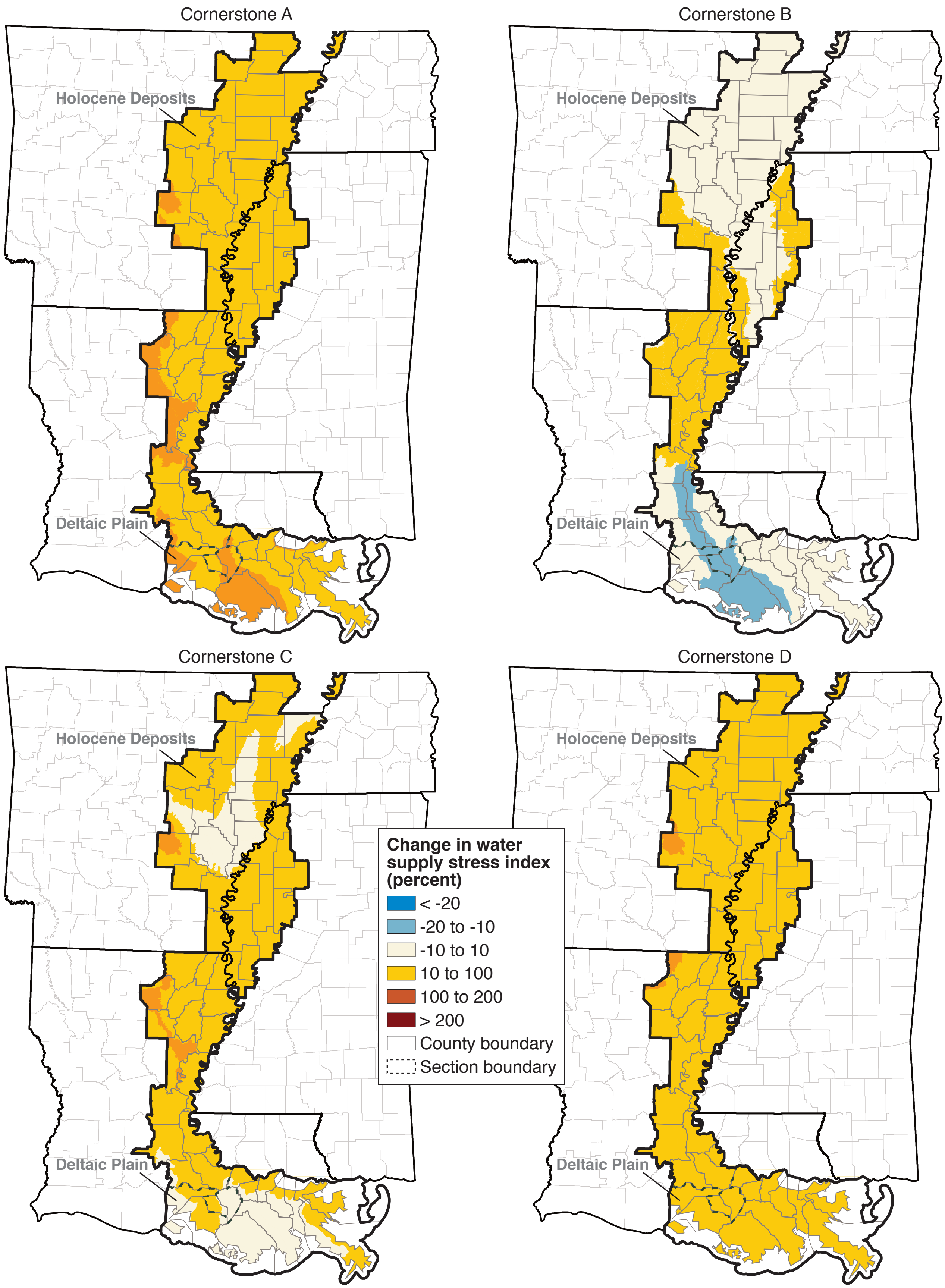

Figure 40—Forecasted change in water supply stress (water demand divided by water supply) in the U.S. Mississippi Alluvial Valley, 2050, under four Cornerstone Futures (A through D), each of which represents a general circulation model paired with one of two emission scenarios—A1B representing high-population/high-economic growth, high energy use, and B2 representing low growth and use: Cornerstone A is MIROC3.2+A1B, Cornerstone B is CSIROMK3.5+A1B, Cornerstone C is CSIROMK2+B2, and Cornerstone D is HadCM3+B2. (Source: Lockaby and others 2013)

Under Cornerstone B, which projects a 1.2 °C increase in average annual temperature and an 83-mm decrease in average annual precipitation through 2050 (see Climate section of this report), relatively minor changes in water supply stress would occur in the Mississippi Alluvial Valley. The largest increases (10 to 100 percent) would occur in portions of the Holocene Deposits section—central and northern Louisiana, southern Arkansas, and the southwestern and eastern most portions of the Yazoo Basin in Mississippi (fig. 40). The remainder of the Mississippi Alluvial Valley would remain at current levels. The exceptions are the Atchafalaya Basin and the Terrebonne Marsh, where water stress would decrease by 10 to 20 percent (fig. 40), apparently driven by a 9-percent increase in precipitation anticipated for the Deltaic Plain section.

Water supply stress would increase moderately across the Mississippi Alluvial Valley under Cornerstones C and D, which assume that average annual temperatures will increase by 0.9 °C and annual precipitation will decrease by 16 to 218 mm. The result would be a 10- to 100-percent increase in the water supply stress index, with some localized areas remaining at current levels or increasing up to 200 percent (fig. 40). Interestingly, portions of the Mississippi Alluvial Valley where water supply stress is highest are not expected to experience the largest increases, regardless of climate forecast (figs. 39 and 40).

Implications of projected land use change—The largest land use shift in the Mississippi Alluvial Valley is expected to be towards increased urbanization, especially in the Deltaic Plain section. Increases in urban land use in the Mississippi Alluvial Valley are expected to range from 72 percent for forecasts of relatively low population and economic growth (Cornerstones C and D), to 112 percent for relatively high population and economic growth (Cornerstones A and B) through 2050. However, these rates of urbanization may have only a slight influence over water supply stress—model results indicate that index ratios would remain within 5 percent of current values (fig. 41).

Implications of projected population change—Population growth across the Mississippi Alluvial Valley is expected to vary considerably (fig. 15), with the largest increases likely to occur in the Deltaic Plain section where some parishes could grow by >750 persons per square mile by 2060. In contrast, population density over much of the Holocene Deposits section is expected to decrease (fig. 15).

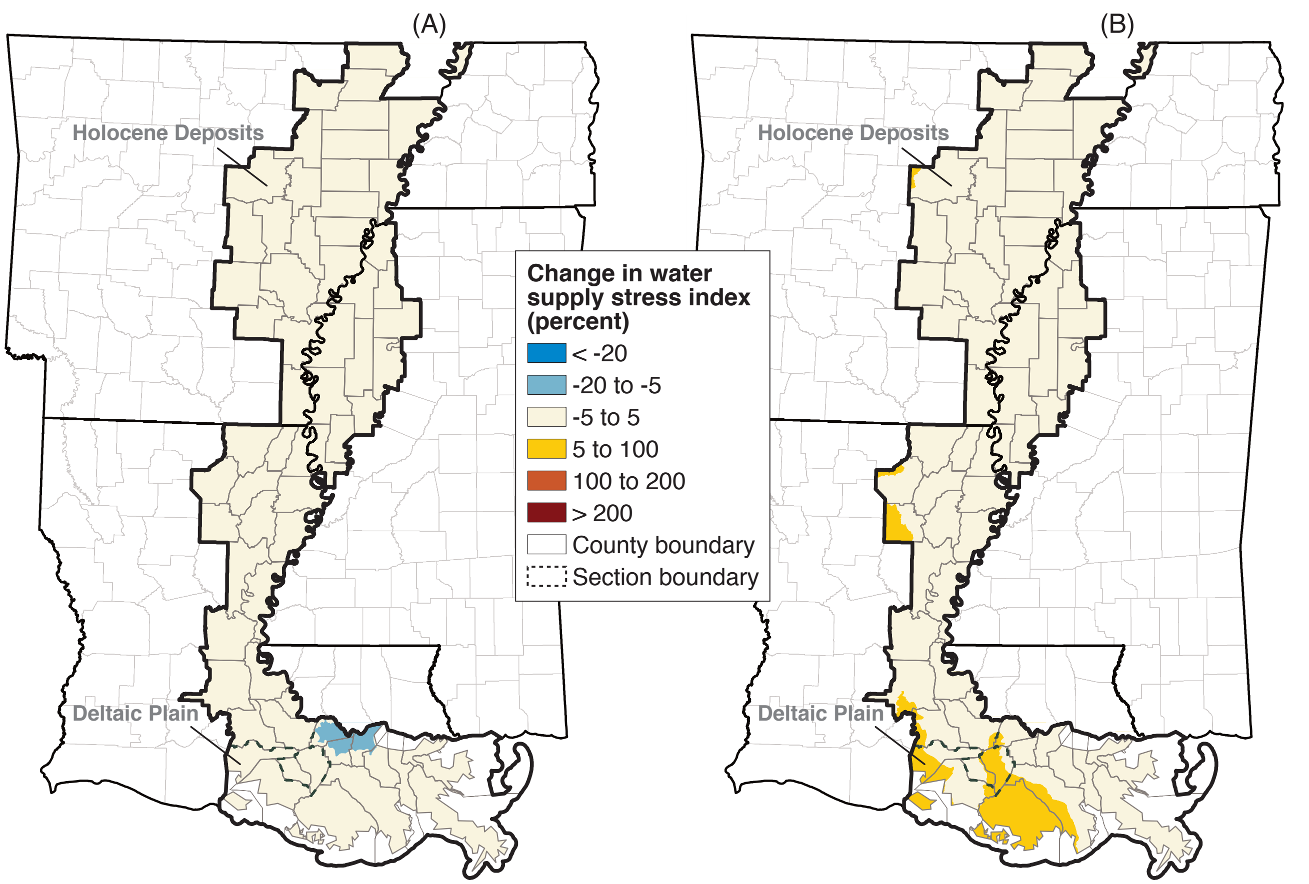

Figure 41—Forecasted change in water supply stress (water demand divided by water supply) in the U.S. Mississippi Alluvial Valley, 2050, that can be attributed to (A) land use change and (B) population change. (Source: Lockaby and others 2013)

The impacts of population growth in the Deltaic Plain section would be most severe in the lower Atchafalaya Basin and the Terrebonne Marsh, where the water supply stress index could rise by 10 to 100 percent by 2050 (fig. 41). Elsewhere in the Mississippi Alluvial Valley, population change would have minimal impacts on the water supply stress—ratios are expected to remain within 10 percent of current values (fig. 41).

Water Quality Forecasts

Although Lockaby and others (2013) primarily concentrated on water supply and demand for the Southern Forest Futures Project, they also identified likely sources of future water quality issues and described the key factors that are likely to drive water quality degradation in the South. The lower Mississippi Valley has been a focal point of water quality interests because extensive deforestation and large-scale hydrologic manipulations have shifted its landscape from a riverine forest system that enhances water quality to an agricultural system that serves as a substantial source of nonpoint source pollutants. Growth of the hypoxic zone in the Gulf of Mexico, which largely stems from increased nitrogen loads in the Mississippi River attributed to fertilizer runoff throughout its course (Rabalais and others 2002), has raised public awareness and prompted government efforts to mitigate degraded water quality in the lower Mississippi Valley (Jenkins and others 2010, Rabotyagov and others 2010).

Federal actions to curtail nonpoint source pollutants from agricultural fields in the lower Mississippi Valley are advancing along two fronts, both administered by agencies in the U.S. Department of Agriculture. First, the Mississippi River Healthy Basins Initiative, which is funded through the Natural Resources Conservation Service, provides incentives to landowners who apply agricultural best management practices that minimize nonpoint source pollutant loading (Kröger and others 2013). Second, conservation programs instituted through the Natural Resources Conservation Service and the Farm Service Agency have stimulated more than two decades of afforestation on economically marginal agricultural land (see the previous discussion on wildlife and forest communities). Although the original conservation programs were not explicitly designed to improve water quality, converting land from agriculture to forest reduces the amount of acreage under tillage, fertilization, and pest control; also, plantations that intercept agricultural runoff are effectively developing ecosystem services—such as sediment, nutrient, and pesticide retention—that benefit water quality (Dosskey and others 2012, Jenkins and others 2010).

As with water supply and demand (above), the population-growth and land-use changes forecasted for the Mississippi Alluvial Valley do not seem to be on a trajectory that would lead to increased degradation of water quality. This is particularly true for the Holocene Deposits section, where additional afforestation of agricultural land, minimal deforestation of existing forests to agricultural or urban uses, and increased application of best management practices should improve water quality functioning capacity and decrease loading of nonpoint source pollutants. The largest population increases and land use changes are projected to occur in the Deltaic Plain section where urban development could claim 11 to 25 percent of forest acreage by 2060 (table 9). Forest loss of this magnitude would likely escalate water quality issues in that section.

Historical alteration and degradation of the Mississippi River, its tributaries, and its floodplain have indelibly changed the hydrologic cycle and ecosystem service capacity of the lower Mississippi Valley. Despite substantial human disruptions to the natural hydrologic cycle, water resources have not been highly stressed. Nevertheless, forecasted climate change, land use change, and population growth through the next 50 years warrant further study to determine how these factors could impact the sustainability of water resources. Projections suggest that changing climate conditions could produce the greatest impacts. The dynamics of the hydrologic cycle are complex and the predicted changes in water supply stress vary substantially within the Mississippi Alluvial Valley, with demand-over-supply ratios ranging from reductions to increases at local levels. Future analyses scaled to the basin level would allow for more intensive assessment of potential threats to the sustainability of water resources in the Mississippi Alluvial Valley.

FOREST BIOMASS-BASED ENERGY

Interest in alternative energy sources has grown over the past decade in response to environmental concerns over fossil fuel combustion, national security issues implications of U.S. reliance on petroleum imports, and economic instability associated with volatile energy prices (Tripp and others 2009). Among the alternative energies, bioenergy has begun to assume an increasingly important role in national markets. In 2011, >26 percent of alternative transportation fuels consumed in the United States were biofuels, and >7 percent of renewable electricity produced in the United States was generated from biomass (U.S. Energy Information Administration 2013). Although the agricultural sector produces the largest proportion of feedstocks used for bioenergy production, some agricultural-based feedstocks have production cycles that require relatively high energy and fertilization inputs, yield relatively low reductions in greenhouse gas emissions, and raise concerns about water and food security (Adler and others 2007, Johnson and others 2007). Feedstocks harvested from managed forests or dedicated bioenergy plantations have the potential to replace agriculture-based bioenergy feedstocks, particularly those used in thermochemical processes (Johnson and others 2007).

The abundance of arable soils, a favorable growing season, an established agricultural infrastructure, and a developed transportation system favor development of a bioenergy economy in the lower Mississippi Valley (Tripp and others 2009). Alavalapati and others (2013) assessed the potential impact of forest-based bioenergy development to a suite of key issues for the Southern Forest Futures Project; these issues include forest products markets, technologies, policies, and sustainability. This report expands on background information relevant to the Mississippi Alluvial Valley and its associated sections, and synthesizes the applicable forecasts presented by Alavalapati and others (2013).

Current Status

With only 28 percent of its land base currently in forest cover, the Mississippi Alluvial Valley has fewer resources to support an industry based on forest-derived biomass than other areas in the South. Nevertheless, it does support five industrial facilities that generate electricity from hardwood processing waste derived from local forests (fig. 42), and these mills have a combined electricity generation capacity from woody biomass of >278 megawatts (U.S. Energy Information Administration 2013). Johnson and others (2010) reported that >1.2 million green tons of hardwood roundwood was harvested in the Mississippi Alluvial Valley in 2008. Although these mills routinely buy hardwood biomass from the subregion, their ratios of hardwood to softwood use vary, the percentage of hardwood processing waste used for energy is unknown, and their procurement zones are too extensive to determine how much energy was generated from feedstocks harvested exclusively from the Mississippi Alluvial Valley.

In addition to electricity generation by pulp mills, >30 hardwood sawmills and veneer mills currently operate in the Mississippi Alluvial Valley (Arkansas Forestry Commission 2013, Mississippi State University 2013). Many of these facilities burn wood processing waste as fuel for various onsite purposes. For example, some of the hardwood sawmills burn wood and bark waste to generate steam and heat for their lumber kilns. Because the amount of onsite use of waste materials for these purposes has not been quantified, the amount of hardwood biomass used to offset other energy sources is unknown for the Mississippi Alluvial Valley.

Two companies currently manufacture fuel pellets for the open market with oak and other wood waste material procured from hardwood processors that operate in the Mississippi Alluvial Valley (fig. 42). Fuel pellets produced by these manufacturers from sawdust, shavings, and other wastes are not for industrial use; rather, they are marketed to domestic buyers operating small-scale stoves and furnaces for residential heat (http://www.bayouwoodpellets.com, http://heatresource.com).

In addition to biomass feedstocks procured from managed forests, the agricultural landscape of the Mississippi Alluvial Valley offers an ideal setting for producing lignocellulosic feedstocks from dedicated energy crops (Tripp and others 2009). Efforts to develop short-rotation woody crop technology, primarily aimed at the culture of eastern cottonwood for pulp production, began in the Mississippi Alluvial Valley more than five decades ago (McKnight 1970). The economic viability of producing fiber in these plantations has oscillated over this time, and currently no industrial landowners are using this technology to produce a reliable source of pulp. However, research has begun on repurposing this plantation technology for energy feedstock production (Stanturf and others 2003, Stuhlinger and others 2010), and it remains the most viable and technologically advanced option currently available for short rotation management of a native tree species in the Mississippi Alluvial Valley.

Although cottonwood plantations have yet to emerge as a dedicated energy feedstock in the Mississippi Alluvial Valley, they have been in use for carbon sequestration on

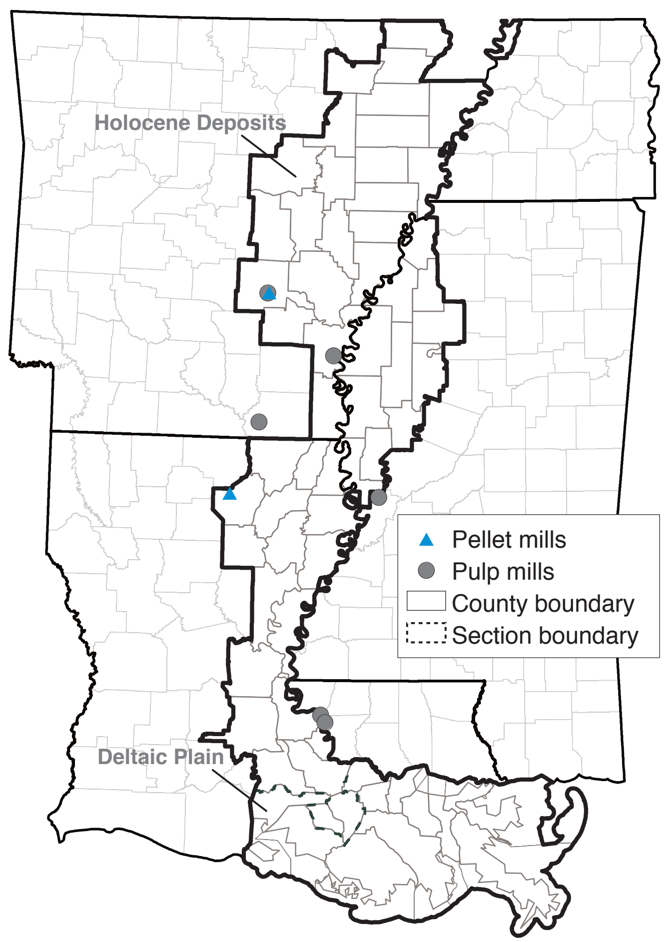

Figure 42—Location of forest products mills that use hardwood resources procured from the sections of the U.S. Mississippi Alluvial Valley.

economically marginal agricultural land over the last decade (Dey and others 2010, Gardiner and others 2004). These plantations have been modified for rapid sequestration of atmospheric carbon; in addition, they offer other economic and ecological benefits such as biomass or fiber production and quick development of forest structure for wildlife habitat. One company uses this technology to produce verifiable carbon offsets, which are marketed through their portfolio of >60,000 acres managed for forest restoration and carbon sequestration (GreenTrees 2013).

Forecasts

Alavalapati and others (2013) concluded that growth of the bioenergy industry in the Mississippi Alluvial Valley, as in the entire South, will be shaped by government policies, technological developments, sustainability constraints, and market trends. Because the interacting effects of these factors on future development of the bioenergy industry are largely unknown, the focus of their analysis was limited to the potential impact that forest-based bioenergy development could have on wood products markets and associated variables.

Forecasting was accomplished by parameterizing the Subregional Timber Supply model (Abt and others 2000) to determine how a range of energy wood consumption and supply scenarios would influence price, inventory, and removal responses (Alavalapati and others 2013). Consumption scenarios were defined based on the use of woody biomass for electricity generation, liquid fuels, and cellulosic bioproducts by the energy market:

1. No forest biomass-based energy market (woody biomass consumption remains at a level required by traditional forest industry)
2. Low biomass consumption
3. Medium biomass consumption
4. High biomass consumption.

By 2050, use of forest-based woody biomass to support a developing bioenergy industry in the South could raise harvesting levels by 54 to 113 percent over those recorded in 2007 by traditional forest products industries (Alavalapati and others 2013). Increased biomass harvesting, even under a future of low bioenergy consumption, would likely impact forest products markets across the South. Of greatest significance to the Mississippi Alluvial Valley, however, is how the forecasted increases in consumption would impact hardwood markets and hardwood resources.

Southwide, prices for hardwood sawtimber (table 22) appear to be relatively unresponsive to developments in bioenergy markets, and will likely decrease through 2050 even if bioenergy consumption reaches moderate to high levels.

In contrast to sawtimber, the development of forest biomass-based energy could exert a strong influence over other hardwood products, such as pulpwood, increasing prices by 100 to 200 percent with low consumption. Moderate to high consumption would elevate prices >200 percent. In addition to increasing prices, moderate to high consumption scenarios would be particularly detrimental to hardwood pulp manufacturing as >80 percent of hardwood biomass would be diverted to bioenergy (Alavalapati and others 2013).

Removals of all hardwoods are expected to increase by 20 and 100 percent through 2050 (table 22). Increased bioenergy consumption would not likely affect hardwood sawtimber removals (table 22), but would have an impact on removals of other hardwoods—by 2050, relatively high bioenergy consumption could increase removals by more than twice the 2007 level (table 22).

Although removals are expected to increase through 2050 for all hardwoods across the South, consumption attributed to future bioenergy markets is not anticipated to reduce inventories below 2007 levels (Alavalapati and others 2013). In fact, hardwood inventories for 2050 could increase by 20 to 100 percent irrespective of bioenergy consumption scenarios (table 22). These increases could be supported by afforestation of agricultural land, growth and improved management of current forests, and increased establishment of fast growing species (Alavalapati and others 2013). However, these southwide findings are not consistent with the projections for hardwood growing stock volumes in the Mississippi Alluvial Valley described at the beginning of this chapter—a 6.5- to 15-percent decrease even without added consumption for bioenergy production. Although downscaling the southwide projections to the Mississippi Alluvial Valley was beyond the scope of this report, removals for bioenergy would surely lead to further erosion of hardwood growing stock inventories unless prices increase beyond those predicted under Cornerstones A and C. If prices increase even higher, inventory decreases could be offset by a price-induced expansion in forest area.

Given the relatively low percentage of forest cover in the Mississippi Alluvial Valley, projections of decreasing hardwood growing stock volumes through 2060, and the established agricultural infrastructure, advancement of the bioenergy industry would likely depend on the development of biomass feedstocks production with short rotation woody crops. The Biomass Crop Assistance Program, created in the 2008 Farm Bill, provides incentives for landowners to partner with commercial biomass facilities that seek to secure procurement of feedstocks for energy production (http://www.fsa.usda.gov/FSA). However, this program and other relevant Federal policies have yet to motivate substantial bioenergy development in the Mississippi Alluvial Valley. Large-scale implementation of energy crop

Table 22—Changes in hardwood prices, inventory, and removals from 2007 to 2050 for consumption by forest industry; and for projections of low, moderate, and high consumption by the developing bioenergy industry

Consumption scenario	Direction and intensity of change[a]		
	Price	Inventory	Removals
	Current forest industry consumption		
Hardwood sawtimber	↓	↑	↑
Pulpwood and other hardwoods	↓	↑	↑
	Low bioenergy consumption		
Hardwood sawtimber	↓	↑	↑
Pulpwood and other hardwoods	↑	↑	↑
	Moderate bioenergy consumption		
Hardwood sawtimber	↓	↑	↑
Pulpwood and other hardwoods	↑	↑	↑
	High bioenergy consumption		
Hardwood sawtimber	↓	↑	↑
Pulpwood and other hardwoods	↑	↑	↑

[a] ↑ represents a directional increase and ↓ represents a directional decrease; orange represents a 0 to 20 percent change, green represents a 20 to 100 percent change, blue represents a 100 to 200 percent change, and black represents a change of >200 percent.

Source: Alavalapati and others (2013).

production by landowners will require demonstration of economic viability above what can be earned by producing row crops. Additionally, venture capitalists will not be likely to invest in bioprocessing facilities without the establishment of new State and local policies that favor bioenergy development (Tripp and others 2009).

Existing Federal policies will drive near-term expansion of the renewable energy market across the United States. The Mississippi Alluvial Valley has the opportunity for combined development of biomass-based energy and woody crop sequestration of greenhouse gas emissions, but future advancement in these areas hinges on the direction of forthcoming policy, the unknown impacts and timing of future technological breakthroughs, and the potential for emerging sustainability constraints on feedstocks production.

However, one certainty does exist—that the natural hardwood resource of the Mississippi Alluvial Valley would be shielded from potential harvesting demands if the bioenergy industry were based on feedstocks grown in short rotation woody crop systems.

OUTDOOR RECREATION

The bottomland forests of the lower Mississippi Valley offer unique aesthetic appeal, provide exceptionally rich habitats for native fish and wildlife populations, underpin a major North American migratory bird flyway, are situated in a favorable climate zone, and can be readily accessed by outdoors enthusiasts. Accordingly, these forests have traditionally been recognized as extraordinary destinations by those seeking outdoor recreation. The naturalist John James Audubon, President Theodore Roosevelt, and the author William Faulkner are among the historically and culturally significant figures who visited the lower Mississippi Valley for recreational pursuits and inspiration.

Although the extent of forests has greatly diminished over time, recreational use and values have become an important economy. The Southern Forest Futures Project addressed the current status and future projections for recreation in the South (Bowker and others 2013, Cordell and others 2013). The purpose of this section is to highlight the findings that are relevant to the Mississippi Alluvial Valley and provide synthesis of their implications to future availability and demand for recreational resources.

Current Status

Recreational resources—Forests account for about 28 percent of land use in the Mississippi Alluvial Valley, ranging from about 26 percent in the Holocene Deposits section to about 53 percent in the Deltaic Plain section (fig. 16). As with the rest of the South, privately owned tracts constitute the highest proportion of forest land in the Mississippi Alluvial Valley. Given this reality, recreational use of this resource is largely restricted to landowners and those who lease recreational rights from landowners. Nevertheless, Cordell and others (2013) reported that per capita availability of non-Federal forest area within a 75-mile radius of counties is >1.3 acres (fig. 43)—a level of availability that is consistent with the South as a whole. Availability in the Deltaic Plain section is somewhat lower than availability in the Holocene Deposits section (fig. 43).

Federal recreational resources in the Mississippi Alluvial Valley include >775,000 acres of land managed by the U.S. Fish and Wildlife Service, Forest Service, and Army Corps of Engineers. State-owned land contributes another 25,600 acres to the pool of recreational resources available to the public. Cordell and others (2013) estimated 0.07 to 1.5 acres of Federal- or State-owned lands per capita within a 75-mile driving radius for most counties (fig. 44)—a level of availability that is consistent with the South as a whole.

In addition to land-based recreational resources, the Mississippi Alluvial Valley offers a generous selection of water-based recreational resources, including the Gulf of Mexico, the Mississippi River, and numerous oxbow lakes, bayous, and permanently flooded swamps. The highest per capita availability of water area occurs in the Deltaic Plain section, particularly in Plaquemines Parish where

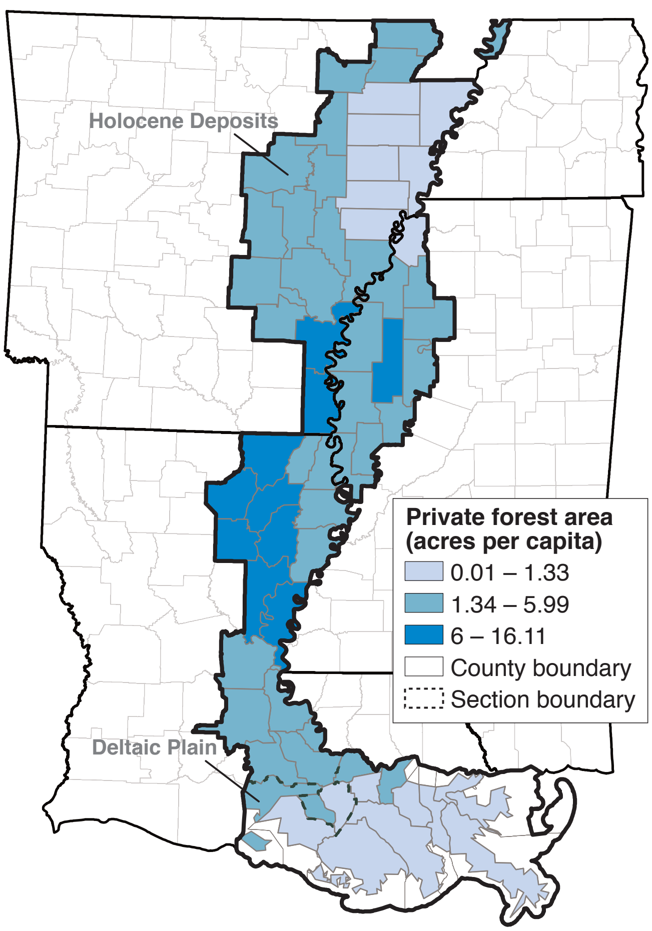

Figure 43—Occurrence of private forest area per capita within a 75-mile day trip for counties and parishes in the two sections of the U.S. Mississippi Alluvial Valley. (Source: Illustration modified from Cordell and others 2013)

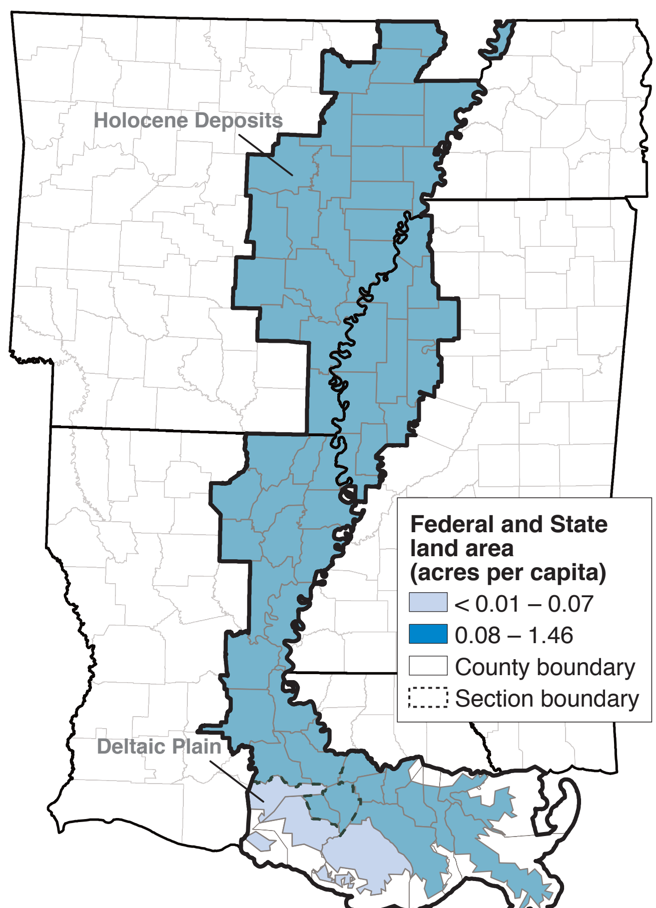

Figure 44—Occurrence of Federal and State land area per capita within a 75-mile day trip for counties and parishes in the two sections of the U.S. Mississippi Alluvial Valley. (Source: Illustration modified from Cordell and others 2013)

availability— >2.25 acres per capita—is higher than most areas in the South (fig. 45). Water availability is generally lowest in the northern half of the Holocene Deposits section, where it averages <0.4 acres per capita within a 75-mile radius of most counties (fig. 45).

Recreation participation—Nationally and across the South, the number of people participating in outdoor recreational activities and the number of days spent participating in outdoor recreational activities have increased rapidly over the past decade (Cordell and others 2013). In 2009, about 75 million southerners took to the outdoors for recreational pursuits for an annual average of 393 participation days (Cordell and others 2013). Participation statistics are not available for the Mississippi Alluvial Valley, but one can assume that trends probably track those of the South as a whole.

Cordell and others (2013) reported that the top five southern outdoor activities include visiting recreation and historic sites (78.9 percent population participation), viewing/photographing nature (73.2 percent population participation), hunting and fishing (38.8 percent population participation), backcountry activities (37.4 percent population participation), and motorized activities (37.1 percent population participation). For each of these groups, many of the specific activities popular in the Mississippi Alluvial Valley from 1999 to 2009—such as viewing or photographing natural scenery, viewing or photographing birds, big game hunting, warm water fishing, saltwater fishing, and waterskiing—have grown at a rate that exceeds the 20-percent growth rate for the South as a whole (Cordell and others 2013).

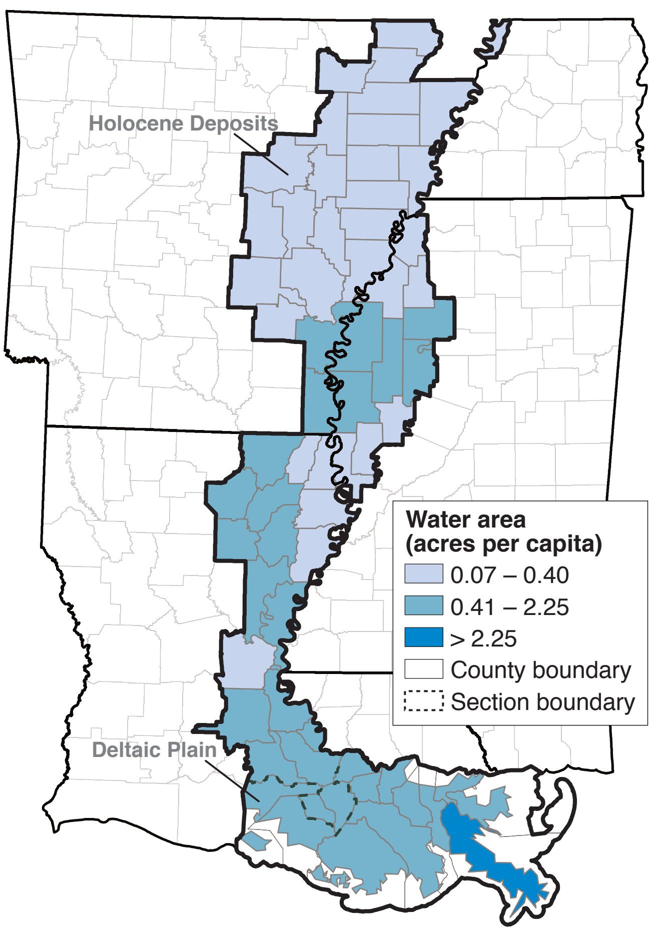

Figure 45—Occurrence of water area per capita within a 75-mile day trip for counties and parishes in the two sections of U.S. Mississippi Alluvial Valley. (Source: Illustration modified from Cordell and others 2013)

Forecasts

Resource availability—Predicted population growth and economic development would result in land use changes that would reduce the availability of private forested acreage in the Mississippi Alluvial Valley (chapter 3). Deforestation is projected to be greatest under the high economic and population growth and decreasing timber prices of Cornerstone B. Forest acreage could decrease by >8.6 percent for a total loss of 477,000 acres (table 7). Alternatively, land use change projected under Cornerstone C, low population and economic growth coupled with increasing timber prices, would result in a minimal 0.2-percent (12,000 acre) loss of forested acreage (table 7).

The Deltaic Plain section is projected to experience disproportionately greater losses in forest acreage than the Holocene Deposits section, primarily the result of increased urbanization. The high economic and population growth and decreasing timber prices of Cornerstone B could result in a 180,000-acre or 25-percent decrease in the Deltaic Plain section, and a 295,000-acre or 6-percent decrease in the Holocene Deposits section (tables 8 and 9). Alternatively, the low economic and population growth and increasing timber prices of Cornerstone C would result in an 80,000-acre or 11-percent loss in the Deltaic Plain section, and a 68,000-acre or 1.4-percent increase in the Holocene Deposits section (tables 8 and 9). Anticipated loss in forest acreage, along with expected population growth, through 2060 would greatly decrease forest availability and per capita forest availability throughout the Mississippi Alluvial Valley, but particularly in the Deltaic Plain section.

Although the extent of private forest lands in the Mississippi Alluvial Valley is expected to decrease with predicted economic development and population growth, the amount of public forest acreage is expected to remain relatively stable or slightly increase. Over the past two decades, Federal ownership of land has increased—as a result of foreclosures on agricultural property by the U.S. Department of Agriculture, expansions of the National Wildlife Refuge System, and mitigation of wetland loss by the U.S. Army Corps of Engineers—and will likely increase in the near future with the purchase of additional acreage in support of bottomland forest habitat restoration efforts. In 2004, the U.S. Fish and Wildlife Service established acquisition boundaries for two new wildlife refuges in the Mississippi portion of the Holocene Deposits section (www.fws.gov): the Holt Collier National Wildlife Refuge currently holds 2,068 acres but has an acquisition boundary of 18,000 acres, and the Theodore Roosevelt National Wildlife Refuge currently holds 817 acres within its 6,600-acre acquisition boundary. Forest restoration practices implemented within the established acquisition boundaries of these two refuges, as well as on future acquisitions elsewhere in the Mississippi Alluvial Valley, have the potential to mitigate a small portion of projected deforestation and increase the availability of public forests and recreational opportunities.

Recreation participation—Sizable increases in the number of people pursuing outdoor recreational activities and the number of days that participants engage in these activities are expected to mirror the 40 to 60 percent population increase projected for the South. Of 10 outdoor activities examined by Bowker and others (2013), day hiking, birding, and developed site use are expected to experience the largest increases in adult participation under all Cornerstone Futures. For these activities, per capita participation will likely increase because adult participation is projected to exceed population growth through 2060. Activities with participation rates that are sensitive to modeled trajectories of population growth and economic development include horseback riding on trails, recreational motorized water use, and recreational non-motorized water use. Overall participation in these outdoor pursuits is generally expected to increase, but per capita participation would vary by Cornerstone Future. Under the high population and economic growth of Cornerstones A and B, per capita participation would increase because participation rates, especially for horseback riding and motorized water use, are generally driven by household income (Bowker and others 2013). In contrast, under the low population and economic growth of Cornerstones C and D, per capita participation would decrease. Visiting primitive areas, recreational hunting, recreational fishing, and motorized off-road driving would increase in overall participation, but per capita participation would decrease regardless of Cornerstone Future (Bowker and others 2013). Factors leading to the likely decreases in per capita participation for these activities include the projected changes to demographics and reduced availability of forested acreage.

Population, economic, and land use changes in the Mississippi Alluvial Valley and surrounding areas are expected to influence availability of recreational resources and outdoor recreation participation through 2060. The largest reductions in per capita availability of recreational resources are expected in the Deltaic Plain section. These reductions are expected to advance under all Cornerstone Futures, but would be most severe under the high population and economic growth and decreasing timber prices of Cornerstone B. In contrast, the least amount of change is projected for the Holocene Deposits section, which would experience minimal reductions in per capita availability of recreational resources under Cornerstone C. The low population and economic growth, along with increasing timber prices, would lead to increased forest acreage on a landscape projected to experience a shrinking resident population.

CONCLUSIONS AND IMPLICATIONS

In 1928, the Forest Service and the Louisiana Division of Forestry commissioned G.H. Lentz and his assistant J.A. Putnam to undertake the first formal hardwood forest resource investigations in the State. Their investigations marked the first-known large-scale inventories of forest resources in the lower Mississippi Valley. Lentz and Putnam reported an increasing trend of farm abandonment and reversion of agricultural land back to forests. They predicted that the trend would be long term because "we already have more land under cultivation than can be worked at a profit." Following his early work on forest inventories, Putnam served as lead scientist for the Forest Service in what was to become the Center for Bottomland Hardwoods Research in Stoneville, MS. In 1968, amidst the most recent surge of deforestation in the lower Mississippi Valley, he annotated a copy of his original report with these words, "It could not be imagined how stupid we would be!" By his retirement in 1969, Putnam had witnessed a 50-percent reduction in forest area that moved agriculture into the dominant land use in the lower Mississippi Valley. Putnam's experience is a reminder that the findings presented in this report are based primarily on forecasts, and as such should be viewed with appropriate caution.

The Mississippi Alluvial Valley will likely be subject to a variety of forces that will change its landscapes and forests over the next 50 years. Wide-scale and recent forest restoration practices have abated the long-standing course of deforestation in the Holocene Deposits section. Existing Federal policies that support conservation initiatives on marginal agricultural lands will likely sustain this trend. Additionally, forest land use in the Holocene Deposits section could continue expanding, as a bioenergy industry based on biomass feedstocks produced in short rotation woody crop systems is poised to develop in this section. Future conversion of agricultural land to forest cover would catalyze development of many forest-based ecosystem services including water quality, wildlife habitat, recreational opportunities, and timber products.

Likewise, the future could also bring substantial threats to forests of the Holocene Deposits section. A warmer and dryer climate would increase wildfire potential, particularly in Arkansas. Nonnative plants will continue to invade and degrade forested ecosystems. Some noxious pests, particularly the emerald ash borer, appear to be unstoppable as they advance towards the forests of the Mississippi Alluvial Valley. Many nonnative plants and pests have the capacity to permanently change both the forest ecology and the economics of forestry. Several native forest communities are of particular concern in the Holocene Deposits section. High elevation alluvial sites are threatened by urban development, the pioneering eastern cottonwood and black willow forest types are threatened by river channel and floodplain engineering projects, and oak-dominated lowland forests are threatened by harvesting practices that alter species compositions.

The most significant changes to forests of the Mississippi Alluvial Valley are projected to occur in the Deltaic Plain section. Urban development spurred by rapid population growth would reduce forest land use to <50 percent of the total land base by 2020. As urban development proceeds, forest land use could drop to 39 percent of the total land base by 2060. Deforestation and urban growth advancing at this scale would precipitate a range of implications for forest-based industries, recreational area availability and use, ecosystem vulnerability to nonnative plants and pests, wildlife communities, and forest derived ecosystem services. Sustainability of coastal baldcypress-water tupelo swamps appears to be eminently jeopardized. Other loss and degradation of these forests would derive from the enduring impacts of altered hydrologic and sediment regimes, land subsidence, and sea-level rise. Increased water supply stress, reduced water quality functions, compromised storm and flood abatement, altered aquatic habitats, and declining forest-based economies are a few of the likely consequences that would ensue.

Irrespective of the shortcomings inherent to any forecasting exercise, the forests of the Mississippi Alluvial Valley in 2060 will most certainly be different from the forest of today. This report was developed to provide basic foresight into the current and approaching issues that will challenge future forest sustainability. This report will achieve its objective if it contributes to the development of informed management and policy approaches that address these challenges.

LITERATURE CITED

Abt, R.; Cubbage, F.; Pacheco, G. 2000. Southern forest resource assessment using the Subregional Timber Supply (SRTS) model. Forest Products Journal. 50: 25-33.

Adams, J.P.; Rousseau, R.J.; Leininger, T.D. 2012. Genetic control of growth traits and inheritance of resistance to bacterial leaf scorch in American sycamore. Silvae Genetica. 61: 4-5.

Adler, P.R.; Del Grosso, S.J.; Parton, W.J. 2007. Life-cycle assessment of net greenhouse-gas flux for bioenergy cropping systems. Ecological Applications. 17: 675-691.

Alavalapati, J.R.R.; Lal, P.; Susaeta, A. [and others]. 2013. Forest biomass-based energy. In: Wear, D.N.; Greis, J.G., eds. The Southern Forest Futures Project: technical report. Gen. Tech. Rep. SRS-178. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 213-260.

Ammon, V.; Nebeker, T.E.; Filer, T.H. [and others]. 1989. Oak decline. Technical Bulletin 161. Mississippi Agricultural & Forestry Experiment Station. 15 p.

Arkansas Forestry Commission. 2013. Portal page. http://forestry.arkansas.gov. [Date accessed: August 20, 2013].

Aslan, A.; Autin, W.J. 1998. Holocene flood-plain soil formation in the southern lower Mississippi Valley: implications for interpreting alluvial paleosols. Geological Society of America Bulletin. 110: 433-449.

Benson, J.F.; Chamberlain, M.J. 2007. Space use, survival, movements, and reproduction of reintroduced Louisiana black bears. Journal of Wildlife Management. 71: 2393-2403.

Bowker, J.M.; Askew, A.; Cordell, H.K.; Bergstrom, J.C. 2013. Outdoor recreation. In: Wear, D.N.; Greis, J.G., eds. The Southern Forest Futures Project: technical report. Gen. Tech. Rep. SRS-178. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 161-182.

Brown, C.A.; Montz, G.N. 1986. Baldcypress—the tree unique, the wood eternal. Baton Rouge, LA: Claitor's Publishing Division. 139 p.

Brown, W.T.; Jackson, W.C.; Keathley, G.L.; Moore, C.L. 1969. Soil survey Lake County, Tennessee. U.S. Department of Agriculture, Soil Conservation Service. 51 p.

Brown, D.A.; Nash, V.E.; Caldwell, A.G. [and others]. 1973. A monograph of the soils of the Southern Mississippi River Valley Alluvium. Southern Cooperative Series Bulletin 178. Arkansas Agricultural Experiment Station. 112 p.

Butler, B.J. 2010. Family forest owners of the Southern United States, 2006. [Unpublished data]. Newtown Square, PA: U.S. Department of Agriculture Forest Service, Northern Research Station.

Campbell, T.A.; Long, D.B. 2009. Feral swine damage and damage management in forested ecosystems. Forest Ecology and Management. 257: 2319-2326.

Canadian Food and Inspection Agency. 2013. Portal page. Available: http://www.inspection.gc.ca. [Date accessed: August 20, 2013].

Cappaert, D.; McCullough, D.G.; Poland, T.M.; Siegert, N.W. 2005. Emerald ash borer in North America: a research and regulatory challenge. American Entomologist. 51: 152-165.

Chambers, J.L.; Conner, W.H.; Day, J.W., Jr. [and others]. 2005. Conservation, protection and utilization of Louisiana's coastal wetland forests. Final Report. 102 p. On file with: Coastal Wetland Forest Conservation and Use Science Working Group, School of Renewable Natural Resources, 227 Renewable Natural Resources Building, Louisiana State University AgCenter, Baton Rouge, LA 70803.

Collinson, J.M. 2007. Video analysis of the escape flight of Pileated Woodpecker *Dryocopus pileatus*: does the Ivory-billed Woodpecker *Campephilus principalis* persist in continental North America? BMC Biology. 5: 8.

Conner, W.H.; Brody, M. 1989. Rising water levels and the future of southeastern Louisiana swamp forests. Estuaries. 12: 318-323.

Conner, W.H.; Day, J.W., Jr. 1988. Rising water levels in coastal Louisiana: implications for two coastal forested wetland areas in Louisiana. Journal of Coastal Research. 4: 589-596.

Conner, W.H.; Toliver, J.R. 1990. Long-term trends in the bald-cypress (*Taxodium distichum*) resource in Louisiana (U.S.A.). Forest Ecology and Management. 33/34: 543-557.

Cordell, H.K.; Betz, C.J.; Mou, S.H. 2013. Outdoor recreation in a shifting societal landscape. In: Wear, D.N.; Greis, J.G., eds. The Southern Forest Futures Project: technical report. Gen. Tech. Rep. SRS-178. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 123-160.

Davidson, J.M.; Wickland, A.C.; Patterson, H.A. [and others]. 2005. Transmission of *Phytophthora ramorum* in mixed-evergreen forest in California. Phytopathology. 95: 587-596.

Day, J.W., Jr.; Britsch, L.D.; Hawes, S.R. [and others]. 2000. Pattern and process of land loss in the Mississippi Delta: a spatial and temporal analysis of wetland habitat change. Estuaries. 23: 425-438.

Day, J.; Hunter, R.; Keim, R.F. [and others]. 2012. Ecological response of forested wetlands with and without large-scale Mississippi River input: implications for management. Ecological Engineering. 46: 57-67.

Delcourt, P.A.; Delcourt, H.R.; Brister, R.C.; Lackey, L.E. 1980. Quaternary vegetation history of the Mississippi Embayment. Quaternary Research. 13: 111-132.

Dey, D.C.; Gardiner, E.S.; Kabrick, J.M. [and others]. 2010. Innovations in afforestation of agricultural bottomlands to restore native forests in the eastern USA. Scandinavian Journal of Forest Research. 25 (Suppl 8): 31-42.

Dey, D.C.; Gardiner, E.S.; Schweitzer, C.J. [and others]. 2012. Underplanting to sustain future stocking of oak (*Quercus*) in temperate deciduous forests. New Forests. 43: 955-978.

Dosskey, M.G.; Bentrup, G.; Schoeneberger, M. 2012. A role for agroforestry in forest restoration in the Lower Mississippi Alluvial Valley. Journal of Forestry. 110(1): 48-55.

Doyle, T.W.; Krauss, K.W.; Conner, W.H.; From, A.S. 2010. Predicting the retreat and migration of tidal forests along the northern Gulf of Mexico under sea-level rise. Forest Ecology and Management. 259: 770-777.

Duan, J.J.; Bauer, L.S.; Abell, K.J.; van Driesche, R. 2012. Population responses of hymenopteran parasitoids to the emerald ash borer (Coleoptera: Buprestidae) in recently invaded areas in north central United States. BioControl. 57: 199-209.

Duerr, D.A.; Mistretta, P.A. 2013. Invasive pests—insects and diseases. In: Wear, D.N.; Greis, J.G., eds. The Southern Forest Futures Project: technical report. Gen. Tech. Rep. SRS-178. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 457-508.

Echt, C.S.; Demeer, D.; Gustafson, D. 2011. Patterns of differentiation among endangered pondberry populations. Conservation Genetics. 12: 1015-1026.

Eldredge, I.F. 1938. Forest resources of the North Arkansas Delta. Forest Survey Release No. 32. U.S. Department of Agriculture Forest Service, Southern Forest Experiment Station. 21 p.

Emerald Ash Borer Information Network. 2013. Emerald Ash Borer information network. Lansing, MI: Michigan State University. http://www.emeraldashborer.info. [Date accessed: March 13, 2013].

Faulkner, S.P.; Bhattarai, P.; Allen, Y. [and others]. 2009. Identifying baldcypress-water tupelo regeneration classes in forest wetlands of the Atchafalaya Basin, Louisiana. Wetlands. 29: 809-817.

Fenneman, N.M.; Johnson, D.W. 1946. Physical divisions of the coterminous U.S. Reston, VA: U.S. Geological Survey. 1:7,000,000.

Fitzpatrick, J.W.; Lammertink, M.; Luneau, M.D., Jr. [and others]. 2005. Ivory-billed woodpecker (*Campephilus principalis*) persists in continental North America. Science. 308: 1460-1462.

Fraedrich, S.W.; Harrington, T.C.; Rabaglia, R.J. 2007. Laurel wilt: a new and devastating disease of redbay caused by a fungal symbiont of the exotic redbay ambrosia beetle. Michigan Entomological Society. 52: 14-15.

Fraedrich, S.W.; Harrington, T.C.; Rabaglia, R.J. [and others]. 2008. A fungal symbiont of the redbay ambrosia beetle causes lethal wilt in redbay and other Lauraceae in the Southeastern United States. Plant Disease. 92: 215-224.

Fraedrich, S.W.; Harrington, T.C.; Bates, C.A. [and others]. 2011. Susceptibility to laurel wilt and disease incidence in two rare plant species, pondberry and pondspice. Plant Disease. 95: 1056-1062.

Frey, G.E.; Mercer, D.E.; Cubbage, F.W.; Abt, R.C. 2010. Economic potential of agroforestry and forestry in the Lower Mississippi Alluvial Valley with incentive programs and carbon payments. Southern Journal of Applied Forestry. 34: 176-185.

Frey, G.E.; Mercer, D.E.; Cubbage, F.W.; Abt, R.C. 2013. A real options model to assess the role of flexibility in forestry and agroforestry adoption and disadoption in the Lower Mississippi Alluvial Valley. Agricultural Economics. 44: 73-91.

Gardiner, E.S.; Oliver, J.M. 2005. Restoration of bottomland hardwood forests in the Lower Mississippi Alluvial Valley, U.S.A. In: Stanturf, J.A.; Madsen, P., eds. Restoration of boreal and temperate forests. Boca Raton, FL: CRC Press: 235-251.

Gardiner, E.S.; Stanturf, J.A.; Schweitzer, C.J. 2004. An afforestation system for restoring bottomland hardwood forests: biomass accumulation of Nuttall oak seedlings interplanted beneath eastern cottonwood. Restoration Ecology. 12: 525-532.

Goyer, R.A.; Lenhard, G.J.; Smith, J.D. 1990. Insect herbivores of a bald-cypress/tupelo ecosystem. Forest Ecology and Management. 33/34: 517-521.

Goyer, R.A.; McClain, M.; Effler, R.S.; Keim, R. [N.d.]. Patterns of baldcypress leafroller (BCLR) and forest tent caterpillar (FTC) defoliation in southeastern Louisiana swamps (1983-2006). http://www.fs.fed.us/r8/foresthealth/publications/. [Date accessed: August 20, 2013].

Gordon, D.R. 1998. Effects of invasive, non-indigenous plant species on ecosystem processes: lessons from Florida. Ecological Applications. 8: 975-989.

Grant, J.F.; Windham, M.T.; Haun, W.G. [and others]. 2011. Initial assessment of thousand cankers disease on black walnut, *Juglans nigr*a, in eastern Tennessee. Forests. 2: 741-748.

GreenTrees. 2013. Portal page. Available: http://www.green-trees.com. [Date accessed: August 20, 2013].

Grünwald, N.J.; Garbelotto, M.; Goss, E.M. [and others]. 2012. Emergence of the sudden oak death pathogen *Phytophthora ramorum*. Trends in Microbiology. 20: 131-138.

Haack, R.A.; Hérard, F.; Sun, J.; Turgeon, J.J. 2010. Managing invasive populations of Asian longhorned beetle and citrus longhorned beetle: a worldwide perspective. Annual Review of Entomology. 55: 521-546.

Hamel, P.B. 1995. Bachman's Warbler (*Vermivora bachmanii*). In: Poole, A.; Gill, F., eds. The Birds of North America, No. 150. Philadelphia, PA: The Academy of Natural Sciences; Washington, DC: The American Ornithologists' Union: 1-16.

Hawkins, T.S.; Schiff, N.M.; Gardiner, E.S. [and others]. 2007. Micropropagation of the endangered shrub pondberry (*Lindera melissifolia* [Walt.] Blue). HortScience. 42: 407-409.

Hodges, J.D. 1997. Development and ecology of bottomland hardwood sites. Forest Ecology and Management. 90: 117-125.

Hoeppner, S.S.; Shaffer, G.P.; Perkins, T.E. 2008. Through droughts and hurricanes: tree mortality, forest structure, and biomass production in a coastal swamp targeted for restoration in the Mississippi River Deltaic Plain. Forest Ecology and Management. 256: 937-948.

Hu, J.; Angeli, S.; Schuetz, S. [and others]. 2009. Ecology and management of exotic and endemic Asian longhorned beetle *Anoplophora glabripennis*. Agricultural and Forest Entomology. 11: 359-375.

Huggett, R.; Wear, D.N.; Li, R. [and others]. 2013. Forecasts of forest conditions. In: Wear, D.N.; Greis, J.G., eds. The Southern Forest Futures Project: technical report. Gen. Tech. Rep. SRS-178. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 73-101.

Hüberli, D.; Garbelotto, M. 2011. *Phytophthora ramorum* is a generalist plant pathogen with differences in virulence between isolates from infectious and dead-end hosts. Forest Pathology. 42: 8-13.

Hyberg, B.T.; Riley, P. 2009. Floodplain ecosystem restoration: commodity markets, environmental services, and the Farm Bill. Wetlands. 29: 527-534.

Intergovernmental Panel on Climate Change (IPCC). 2007. IPCC fourth assessment report: climate change 2007 (AR4). http://www.ipcc.ch/publications_and_data/publications_and_data_reports.htm. [Date accessed: August 23, 2013].

Jackson, J.A. 2002. Ivory-billed woodpecker (*Campephilus principalis*). In: Poole, A.; Gill, F., eds. The Birds of North America, No. 711. Philadelphia, PA: The Birds of North America. 28 p.

Jeffers, S.N.; Hwang, J.; Wamishe, Y.A.; Oak, S.W. 2010. Detection of *Phytophthora ramorum* at retail nurseries in the Southeastern United States. In: Frankel, S.J.; Kliejunas, J.T.; Palmieri, K.M., tech. coords. Proceedings of the Sudden Oak Death Fourth Science Symposium. Gen. Tech. Rep. PSW-GTR-229. Albany, CA: U.S. Department of Agriculture Forest Service, Pacific Southwest Research Station: 69-71.

Jenkins, W.A.; Murray, B.C.; Kramer, R.A.; Faulkner, S.P. 2010. Valuing ecosystem services from wetlands restoration in the Mississippi Alluvial Valley. Ecological Economics. 69: 1051-1061.

Johnson, J.M.-F.; Coleman, M.D.; Gesch, R. [and others]. 2007. Biomass-bioenergy crops in the United States: a changing paradigm. The Americas Journal of Plant Science and Biotechnology. 1: 1-28.

Johnson, T.G.; Steppleton, C.D.; Bentley, J.W. 2010. Southern pulpwood production, 2008. Resource Bulletin SRS-165. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 42 p.

Kelley, A. 1963. Levee building and the settlement of the Yazoo Basin. The Southern Quarterly. 1(July): 285-308.

Keim, R.F.; Chambers, J.L.; Hughes, M.S. [and others]. 2006. Long-term success of stump sprouts in high-graded baldcypress-water tupelo swamps in the Mississippi delta. Forest Ecology and Management. 234: 24-33.

Kesel, R.H. 2003. Human modifications to the sediment regime of the Lower Mississippi River flood plain. Geomorphology. 56: 325-334.

King, J.E. 1981. Late Quaternary vegetational history of Illinois. Ecological Monographs. 51: 43-62.

King, J.E.; Allen, W.H., Jr. 1977. A Holocene vegetation record from the Mississippi River Valley, southeastern Missouri. Quaternary Research. 8: 307-323.

King, S.L.; Twedt, D.J.; Wilson, R.R. 2006. The role of the Wetland Reserve Program in conservation efforts in the Mississippi River Alluvial Valley. Wildlife Society Bulletin. 34: 914-920.

Kluza, D.A.; Vieglais, D.A.; Andreasen, J.K.; Peterson, A.T. 2007. Sudden oak death: geographic risk estimates and predictions of origins. Plant Pathology. 56: 580-587.

Knight, K.S.; Brown, J.P.; Long, R.P. 2013. Factors affecting the survival of ash (*Fraxinus* spp.) trees infested by emerald ash borer (*Agrilus planipennis*). Biological Invasions. 15: 371-383.

Koch, F.H.; Smith, W.D. 2008a. Mapping sudden oak death risk nationally using host, climate and pathways data. In: Frankel, S.J.; Kliejunas, J.T.; Palmieri, K.M., tech. coords. Proceedings of the Sudden Oak Death Third Science Symposium. Gen. Tech. Rep. PSW-GTR-214. Albany, CA: U.S. Department of Agriculture Forest Service, Pacific Southwest Research Station: 279-287.

Koch, F.H.; Smith, W.D. 2008b. Spatio-temporal analysis of *Xyleborus glabratus* (Coleoptera: Circulionidae: Scolytinae) invasion in Eastern U.S. forests. Environmental Entomology. 37: 442-452.

Kolařík, M.; Freeland, E.; Utley, C.; Tisserat, N. 2011. *Geosmithia morbida* sp. nov., a new phytopathogenic species living in symbiosis with the walnut twig beetle (*Pityophthorus juglandis*) on Juglans in USA. Mycologia. 103: 325-332.

Kröger, R.; Littlejohn, K.A.; Pierce, S.C. [and others]. 2013. Evidence toward sediment accumulation characteristics of slotted inlet pipes as best management practices on agricultural landscapes. Ecological Engineering. 51: 249-255.

Kruse, J.J. 2000. *Archips goyerana*, n. sp. (Lepidoptera: Tortricidae) an important pest of baldcypress (Taxodiaceae) in Louisiana and Mississippi. Proceedings of the Entomological Society of Washington. 102: 741-746.

Leininger, T.D. 1998. Discovering the factors contributing to the decline and mortality of willow oak in the D'Arbonne National Wildlife Refuge, LA. In: Whiffen, H.J.-H.; Hubbard, W.C., eds. Proceedings of the 2nd Southern Forestry GIS Conference. Athens, GA: University of Georgia: 303-312.

Leininger, T.D.; Solomon, J.D.; Wilson, A.D.; Schiff, N.M. 1999. A guide to major insects, diseases, air pollution injury, and chemical injury of sycamore. Gen. Tech. Rep. SRS-28. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 44 p.

Lentz, G.H. 1928. Summary of first year's hardwood investigations in Louisiana. U.S. Department of Agriculture Library Book Number 1,387,639. On file with: U.S. Department of Agriculture Forest Service, Center for Bottomland Hardwoods Research, Stoneville, MS 38776-0227.

Liebhold, A.M.; Gottschalk, K.W.; Muzika, R.M. [and others]. 1995. Suitability of North American tree species to the gypsy moth: a summary of field and laboratory tests. Gen. Tech. Rep. NE-211. Radnor, PA: U.S. Department of Agriculture Forest Service, Northeastern Forest Experiment Station. 34 p.

Little, E.L., Jr. 1971. Atlas of United States trees. Conifers and important hardwoods. Misc. Publ. No. 1146. Washington, DC: U.S. Department of Agriculture Forest Service. 9 p. Vol. 1.

Little, E.L., Jr. 1977. Atlas of United States trees. Minor eastern hardwoods. Misc. Publ. No. 1342. Washington, DC: U.S. Department of Agriculture Forest Service. 17 p. Vol. 4.

Liu, Y.-Q.; Stanturf, J.; Goodrick, S. 2009. Trends in global wildfire potential in a changing climate. Forest Ecology and Management. 259: 685-697.

Lockaby, G.; Nagy, C.; Vose, J.M. [and others]. 2013. Forests and water. In: Wear, D.N.; Greis, J.G., eds. The Southern Forest Futures Project: technical report. Gen. Tech. Rep. SRS-178. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 309-339.

Louisiana Coastal Wetlands Conservation and Restoration Task Force and the Wetlands Conservation and Restoration Authority (LCWCRTF and WCRA). 1998. Coast 2050: toward a sustainable coastal Louisiana. Baton Rouge, LA: Louisiana Department of Natural Resources. 161 p.

Louisiana Department of Agriculture and Forestry. 2013. Portal page. Available: http://ldaf.state.la.us. [Date accessed: August 20, 2013].

Lyons, D.B.; Lavallée, R.; Kyei-Poku, G. [and others]. 2012. Towards the development of an autocontamination trap system to manage populations of emerald ash borer (Coleoptera: Buprestidae) with the native entomopathogenic fungus, *Beauveria bassiana*. Journal of Economic Entomology. 105: 1929-1939.

MacDonald, P.O.; Frayer, W.E.; Clauser, J.K. 1979. Documentation, chronology, and future projections of bottomland hardwood habitat loss in the Lower Mississippi Alluvial Plain. Washington, DC: U.S. Fish and Wildlife Service. 133 p. Vol. 1.

Massei, G.; Roy, S.; Bunting, R. 2011. Too many hogs? A review of methods to mitigate impact by wild boar and feral hogs. Human-Wildlife Interactions. 5: 79-99.

Mattoon, W.R. 1915. The Southern Cypress. Bulletin 272. Washington, DC: U.S. Department of Agriculture Forest Service. 74 p.

McCullough, D.G.; Mercader, R.J. 2012. Evaluation of potential strategies to slow ash mortality (SLAM) caused by emerald ash borer (*Agrilus planipennis*): SLAM in an urban forest. International Journal of Pest Management. 58: 9-23.

McKelvey, K.S.; Aubry, K.B.; Schwartz, M.K. 2008. Using anecdotal occurrence data for rare and elusive species: the illusion of reality and a call for evidentiary standards. BioScience. 58: 549-555.

McKnight, J.S. 1970. Planting cottonwood cuttings for timber production in the South. Res. Pap. SO-60. New Orleans: U.S. Department of Agriculture Forest Service, Southern Forest Experiment Station. 17 p.

McNab, W.H.; Cleland, D.T.; Freeouf, J.A. [and others], comps. 2005. Description of ecological subregions: sections of the conterminous United States. Washington, DC: U.S. Department of Agriculture, Forest Service. 80 p.

McNulty, S.; Myers, J.M.; Caldwell, P. [and others]. 2013. Climate change. In: Wear, D.N.; Greis, J.G., eds. The Southern Forest Futures Project: technical report. Gen. Tech. Rep. SRS-178. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 27-43.

Meadows, J.S.; Stanturf, J.A. 1997. Silvicultural systems for southern bottomland hardwood forests. Forest Ecology and Management. 90: 127-140.

Miller, J.H.; Chambliss, E.B.; Loewenstein, N.J. 2010. A field guide for the identification of invasive plants in southern forests. Gen. Tech. Rep. SRS-119. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 126 p.

Miller, J.H.; Lemke, D.; Coulston, J. 2013. The invasion of southern forests by nonnative plants: current and future occupation with impacts, management strategies, and mitigation approaches. In: Wear, D.N.; Greis, J.G., eds. The Southern Forest Futures Project: technical report. Gen. Tech. Rep. SRS-178. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 397-456.

Mississippi State University. 2013. Portal page. Available: http://www.cfr.msstate.edu. [Date accessed: August 20, 2013].

Morin, R.S.; Liebhold, A.M.; Luzader, E.R. [and others]. 2005. Mapping host-species abundance of three major exotic forest pests. Res. Pap. NE-726. Newtown Square, PA: U.S. Department of Agriculture Forest Service, Northeastern Research Station. 11 p.

Morris, R.C. 1977. Insect-caused degrade in hardwood lumber. Southern Lumberman. 234(2902): 19-20.

Morris, R.C.; Filer, T.H.; Solomon, J.D. [and others]. 1975. Insects and diseases of cottonwood. Gen. Tech. Rep. SO-8. New Orleans: U.S. Department of Agriculture Forest Service, Southern Forest Experiment Station. 37 p.

Moser, W.K.; Barnard, E.L.; Billings, R.F. [and others]. 2009. Impacts of nonnative invasive species on U.S. forests and recommendations for policy and management. Journal of Forestry. 107: 320-327.

Muller, R.A.; Grymes, III, J.M. 1998. Regional climates. In: Messina, M.G.; Conner, W.H., eds. Southern Forested Wetlands Ecology and Management. Boca Raton, FL: Lewis Publishers: 87-101.

North Carolina Forest Service. 2013. Portal page. Available: http://ncforestservice.gov. [Date accessed: August 20, 2013].

Oliver, C.D.; Burkhardt, E.C.; Skojac, D.A. 2005. The increasing scarcity of red oaks in Mississippi River floodplain forests: influence of the residual overstory. Forest Ecology and Management. 210: 393-414.

Oswalt, S.N. 2013. Forest resources of the lower Mississippi Alluvial Valley. Gen. Tech. Rep. SRS-GTR-177. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 29 p.

Peña, J.E.; Carrillo, D.; Duncan, R.E. [and others]. 2012. Susceptibility of *Persea* spp. and other Lauraceae to attack by redbay ambrosia beetle, *Xyleborus glabratus* (Coleoptera: Curculionidae: Scolytinae). Florida Entomologist. 95: 783-787.

Pimentel, D.; Zuniga, R.; Morrison, D. 2005. Update on the environmental and economic costs associated with alien-invasive species in the United States. Ecological Economics. 52: 273-288.

Putnam, J.A. 1929. Louisiana's hardwood industries and their possibilities. Louisiana. 1(7): 7-10, 22.

Putnam, J.A.; Bull, H. 1932. The trees of the bottomlands of the Mississippi River delta region. Occasional Paper No. 27. U.S. Department of Agriculture Forest Service, Southern Forest Experiment Station. 207 p.

Rabalais, N.N.; Turner, R.E.; Scavia, D. 2002. Beyond science into policy: Gulf of Mexico hypoxia and the Mississippi River. BioScience. 52: 129-142.

Rabotyagov, S.; Campbell, T.; Jha, M. [and others]. 2010. Least-cost control of agricultural nutrient contributions to the Gulf of Mexico hypoxic zone. Ecological Applications. 20: 1542-1555.

Rejmánek, M.; Smith, J.D.; Goyer, R.A. 1987. Population dynamics of the forest tent caterpillar (*Malacosoma disstria*) in a water tupelo (*Nyssa aquatica*) forests: a simulation model. Ecological Modelling. 39: 287-305.

Rudis, V.A. 2001. Composition, potential old growth, fragmentation, and ownership of Mississippi Alluvial Valley bottomland hardwoods: a regional assessment of historic change. In: Hamel, P.B.; Foti, T.L., tech. eds. Bottomland hardwoods of the Mississippi Alluvial Valley: characteristics and management of natural function, structure, and composition. Gen. Tech. Rep. SRS-42. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 28-48.

Saucier, R.T. 1974. Quaternary geology of the Lower Mississippi Valley. Research Series No. 6. Arkansas Archeological Survey. 26 p.

Saucier, R.T. 1994. Geomorphology and Quaternary geologic history of the Lower Mississippi Valley. Vicksburg, MS: U.S. Army Corps of Engineers, Waterways Experiment Station. 364 p. Vol. 1.

Schoenholtz, S.H.; James, J.P.; Kaminski, R.M. [and others]. 2001. Afforestation of bottomland hardwoods in the Lower Mississippi Alluvial Valley: status and trends. Wetlands. 21: 602-613.

Sharov, A.A.; Leonard, D.; Liebhold, A.M. [and others]. 2002. "SLOW the SPREAD" A national program to contain the gypsy moth. Journal of Forestry. 100: 30-35.

Siemann, E.; Carrillo, J.A.; Gabler, C.A. [and others]. 2009. Experimental test of the impacts of feral hogs on forest dynamics and processes in the Southeastern U.S. Forest Ecology and Management. 258: 546-553.

Smith, L.M.; Winkley, B.R. 1996. The response of the Lower Mississippi River to river engineering. Engineering Geology. 45: 433-455.

Solomon, J.D. 1995. Guide to insect borers of North American broadleaf trees and shrubs. Agric. Handb. 706. Washington, DC: U.S. Department of Agriculture Forest Service. 735 p.

Solomon, J.D.; Leininger, T.D.; Wilson, A.D. [and others]. 1993. Ash pests—a guide to major insects, diseases, air pollution injury, and chemical injury. Gen. Tech. Rep. SO-96. New Orleans: U.S. Department of Agriculture Forest Service, Southern Forest Experiment Station. 45 p.

Solomon, J.D.; McCracken, F.I.; Anderson, R.L. [and others]. 1997a. Oak pests—a guide to major insects, diseases, air pollution and chemical injury. Protection report R8-PR7. U.S. Department of Agriculture Forest Service, Southern Research Station. 69 p.

Solomon, J.D.; Wilson, A.D.; Leininger, T.D. [and others]. 1997b. Sugarberry dieback and mortality in southern Louisiana: cause, impact, and prognosis. Res. Pap. SRS-9. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 16 p.

Stanturf, J.; Gardiner, E.; Schoenholtz, S. 2003. Interplanting for bioenergy and riparian restoration in the southeastern USA. In: Nicholas, I.D., comp. Proceedings of the Conference on short rotation crops for bioenergy. Tauranga, New Zealand: International Energy Agency: 241-249.

Stanturf, J.A.; Goodrick, S.L. 2013. Fire. In: Wear, D.N.; Greis, J.G., eds. The Southern Forest Futures Project: technical report. Gen. Tech. Rep. SRS-178. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 509-542.

Stanturf, J.A.; Schoenholtz, S.H. 1998. Soils and landforms. In: Messina, M.G.; Conner, W.H., eds. Southern Forested Wetlands Ecology and Management. Boca Raton, FL: Lewis Publishers: 123-147.

Stanturf, J.A.; Schoenholtz, S.H.; Schweitzer, C.J.; Shepard, J.P. 2001. Achieving restoration success: myths in bottomland hardwood forests. Restoration Ecology. 9: 189-200.

Steyermark, J.A. 1949. *Lindera melissaefolia*. Rhodora. 51: 153-162.

Stover, W.S. 1942. Forest resources of the Delta section of Mississippi. Forest Survey Release No. 53. U.S. Department of Agriculture Forest Service. 28 p.

Stuhlinger, H.C.; Doruska, P.F.; Earl, J.A.; Pelkki, M.H. 2010. Growing cottonwoods for biomass: results of a ten-year irrigation study. In: Stanturf, J.A., ed. Proceedings of the 14th biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-121. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 175-179.

Sun, G.; McNulty, S.G.; Myers, J.M.; Cohen, E.C. 2008. Impacts of multiple stresses on water demand and supply across the Southeastern United States. Journal of American Water Resources Association. 44: 1441-1457.

The Gypsy Moth Slow the Spread Foundation. 2013. Portal page. Available: http://www.gmsts.org. [Date accessed: August 20, 2013].

Tingle, J.L.; Klimas, C.V.; Foti, T.L. 2001. Application of general land office survey notes to bottomland hardwood ecosystem management and restoration in the Lower Mississippi Valley—an example from Desha County, Arkansas. In: Hamel, P.B.; Foti, T.L., tech. eds. Bottomland hardwoods of the Mississippi Alluvial Valley: characteristics and management of natural function, structure, and composition. Gen. Tech. Rep. SRS-42. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 16-27.

Tobin, P.C.; Bai, B.B.; Eggen, D.A.; Leonard, D.S. 2012. The ecology, geopolitics, and economics of managing *Lymantria dispar* in the United States. International Journal of Pest Management. 58: 195-210.

Trahan, L.J. 2000. Soil survey of Plaquemines Parish, Louisiana. U.S. Department of Agriculture, Natural Resources Conservation Service. 141 p.

Trani Griep, M.; Collins, B. 2013. Wildlife and forest communities. In: Wear, D.N.; Greis, J.G., eds. The Southern Forest Futures Project: technical report. Gen. Tech. Rep. SRS-178. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 341-396.

Tripp, S.; Powell, R.; Nelson, P. 2009. Regional strategy for biobased products in the Mississippi Delta. Battelle Memorial Institute. 141 p.

U.S. Census Bureau. 2013. Portal page. Available: http://quickfacts.census.gov. [Date accessed: August 20, 2013].

U.S. Department of the Interior, Fish and Wildlife Service. 2009. Louisiana black bear recovery action plan. Available: http://ecos.fws.gov/speciesProfile/profile/speciesProfile.action?spcode=A08F. [Date accessed: August 20, 2013].

U.S. Department of Agriculture Animal and Plant Inspection Service (USDA and others). 2013. Portal page. Available: http://www.aphis.usda.gov. [Date accessed: August 20, 2013].

U.S. Department of Agriculture, Forest Service, Forest Health Protection. 2013. Portal page. Available: http://www.fs.fed.us/r8/foresthealth/laurelwilt. [Date accessed: August 20, 2013].

U.S. Energy Information Administration. 2013. Portal page. Available: http://www.eia.gov. [Date accessed: August 20, 2013].

Vilà, M.; Espinar, J.L.; Hejda, M. [and others]. 2011. Ecological impacts of nonnative plants: a meta-analysis of their effects on species, communities and ecosystems. Ecology Letters. 14: 702-708.

Wear, D.N. 2013. Forecasts of land uses. In: Wear, D.N.; Greis, J.G., eds. The Southern Forest Futures Project: technical report. Gen. Tech. Rep. SRS-178. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 45-71.

Wear, D.N.; Huggett, R.; Greis, J.G. 2013. Constructing alternative futures. In: Wear, D.N.; Greis, J.G., eds. The Southern Forest Futures Project: technical report. Gen. Tech. Rep. SRS-178. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 11-26.

Webster, C.R.; Jenkins, M.A.; Jose, S. 2006. Woody invaders and the challenges they pose to forest ecosystems in the Eastern United States. Journal of Forestry. 104: 366-374.

Winters, R.K. 1939a. Forest resources of the South Louisiana Delta. Forest Survey Release No. 42. New Orleans: U.S. Department of Agriculture Forest Service, Southern Forest Experiment Station. 20 p.

Winters, R.K. 1939b. Forest resources of the South Arkansas Delta. Forest Survey Release No. 46. New Orleans: U.S. Department of Agriculture Forest Service, Southern Forest Experiment Station. 24 p.

Winters, R.K.; Putnam, J.A.; Eldredge, I.F. 1938. Forest resources of the North-Louisiana Delta. Misc. Publ. No. 309. Washington, DC: U.S. Department of Agriculture. 49 p. + 1 color map.

Gardiner, E.S. 2014. Outlook for Mississippi Alluvial Valley forests: a subregional report from the Southern Forest Futures Project. Gen. Tech. Rep. SRS-201. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 83 p.

The Mississippi Alluvial Valley, which can be broadly subdivided into the Holocene Deposits section and the Deltaic Plain section, is a 24.9-million-acre area generally approximating the alluvial floodplain and delta of the lower Mississippi River. Its robust agricultural economy is maintained by a largely rural population, and recreational resources draw high visitation from nearby urban centers. The Mississippi Alluvial Valley forms a key corridor for migratory animals, and the Mississippi River has been developed as a vital conduit of commerce for much of North America. Although forest land use currently makes up only 28 percent of the Mississippi Alluvial Valley, bottomland hardwood forests and coastal swamps remain invaluable for producing forest products, sustaining biodiversity, providing recreational opportunities, and performing essential ecosystem services. Forecasts generated by the Southern Forest Futures Project provide science-based projections of how alternative futures of economic growth, population growth, climatic patterns, and a range of forest threats could drive potential trajectories of land use, forest conditions, water resources, recreational resources, and wildlife habitats across the Southern Region. This report identifies findings from the Southern Forest Futures Project that are relevant to the Mississippi Alluvial Valley, expands on the relevant findings through additional science synthesis and analysis, and outlines noteworthy implications of the alternative futures to forest-based resources and ecosystem services of the Mississippi Alluvial Valley.

Keywords: Bottomland hardwood forests, coastal swamps, forest threats, land use, Lower Mississippi Alluvial Valley, LMAV, Mississippi Alluvial Plain, Mississippi Delta, Southern Forest Futures Project.