Southeast

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Forests of the Southeastern United States are a complex mixture of private and public land, interspersed with rapidly urbanizing areas and agriculture. A long history of active forest management, often including intensive management such as forest plantations, fertilization, and prescribed fires, creates stand conditions and management regimes that differ from those in other areas of the United States. For example, relative to forests of the Western United States, smaller tracts of accessible forest land may be more amenable to management actions that can be used to mitigate carbon (C) emissions or help forests adapt to climate change. On the other hand, the large private ownership of relatively small forest land holdings makes it challenging to implement uniform or coordinated large-scale management activities.

Wildfires, hurricanes, drought, insect outbreaks, and pathogen outbreaks have been a driving force for millennia in southeastern forests. However, during the past two centuries, the type and magnitude of ecosystem stress and disturbance have changed and will likely continue to change as the climate warms (Dale et al. 2001). Wind and extreme precipitation events associated with hurricanes can have significant effects on southeastern forests. A single hurricane can reduce total forest C sequestration by 10 percent in the year in which it occurs (McNulty 2002), although not all forest species are equally susceptible to wind damage. Longleaf pine (*Pinus palustris* Mill.) shows less damage than does loblolly pine (*Pinus taeda* L.) when exposed to an equal level of wind stress (Johnsen et al. 2009), suggesting that the former species would be more resistant to an increase in windstorms. Extreme precipitation events that accompany hurricanes can cause extended submersion of low-lying forests, which can kill tree roots by causing anaerobic soil conditions (Whitlow and Harris 1979).

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Wildfires are a natural component of ecosystem maintenance and renewal in the southeast, which has more area burn annually, with wildfire and prescribed fire, than any other region of the United States (except Alaska in some years) (Andreu and Hermansen-Baez 2008). However, decades of fire exclusion coupled with increasing air temperatures have increased the potential for crown fire in some southeastern forests. Future fire potential is expected to increase from low to moderate in summer and autumn in eastern sections in the South, and from moderate to high in western portions of the South (Liu et al. 2010). As fire seasons lengthen in the future, the window for prescribed burning may decrease because of increased fuel flammability, thus potentially affecting the management of fuels and C dynamics; fuel treatments with prescribed fire emit 20 percent less carbon dioxide (CO_2) than wildfires, at least in the short term (Wiedinmyer and Hurteau 2010). Historically, longleaf pine was a dominant species across the region. It is well adapted to drought, with thick bark and fast seedling growth, allowing it to thrive in habitats subjected to periodic wildfire (Brockway et al. 1997). Most of the longleaf pine was cut during the 20th century and replanted with the faster growing loblolly pine, which is preferred by the timber industry but is less resistant to wildfire damage. Land managers are reassessing the preferential use of loblolly pine, because longleaf pine would be more resistant to the increased fire, drought, and wind expected with climate change.

Insect and pathogen outbreaks are increasing in southeastern forests (Pye et al. 2011). Higher temperature has caused a longer growing season of at least 2 weeks compared to historical lengths, allowing additional time for insects and pathogens to find trees that are more susceptible and to colonize trees to form new points of spread (Ayres and Lombardero 2000). In addition, timing of the predator-prey cycle may be changing. For example, when the growing season begins earlier, insects may be hatching and maturing before migratory insectivorous bird species return, allowing more insects to reach maturity, speed up the reproductive cycle, and locate susceptible host trees. Finally, higher temperature and subsequent soil drying increases stress in trees, reducing their physiological capacity to resist attack (McNulty et al. 1998a). If the trend of increasing frequency and severity of insect outbreaks continues, the productivity and large-scale structure of forest ecosystems will be altered significantly.

Some aspects of the exceptionally high biodiversity in the Southeast may be susceptible to climate change (Thompson et al. 2009), particularly species that are near the environmental limit of their range. Red spruce (*Picea rubens* Sarg.) and eastern hemlock (*Tsuga canadensis* [L.] Carrière) are well adapted to the cool climates of the last glacial age. However, during a period of postglacial warming, the extent and dominance of these two species have decreased greatly owing to stress complexes that include warmer temperature, air pollution, and insects (Elliott and Vose 2011, McNulty and Boggs 2010). With further warming, red spruce and eastern hemlock are projected to be extirpated from the Southern United States before the end of the 21st century (Prasad et al. 2007), and small remnant populations of balsam fir (*Abies balsamea* [L.] Mill.) will also be at risk. Birds and other terrestrial vertebrate species that depend on forests dominated by these trees for habitat and food must adapt, migrate, or face a similar fate.

Cold water fish species, which are generally confined to northern and mountainous areas of the Southeast where cooler water (and air) temperatures allow dissolved oxygen contents to remain at sufficient levels, will likely face increased stress from higher temperature at the southern limit of their range. In addition, rainfall intensity has been increasing for over a century (Karl et al. 1995), which can in turn increase soil erosion and stream turbidity (Trimble 2008). A combination of higher air temperature and lower water quality may significantly reduce trout abundance across the southeast during the coming decades (Flebbe et al. 2006).

The majority of the Nation's wood and fiber is produced in the southeast, but climate change could significantly alter productive capacity in the region (Wertin et al. 2010). Loblolly pine is the most important commercial species in the southeast, and although current air temperature is near optimal for growth across much of its range, as temperature

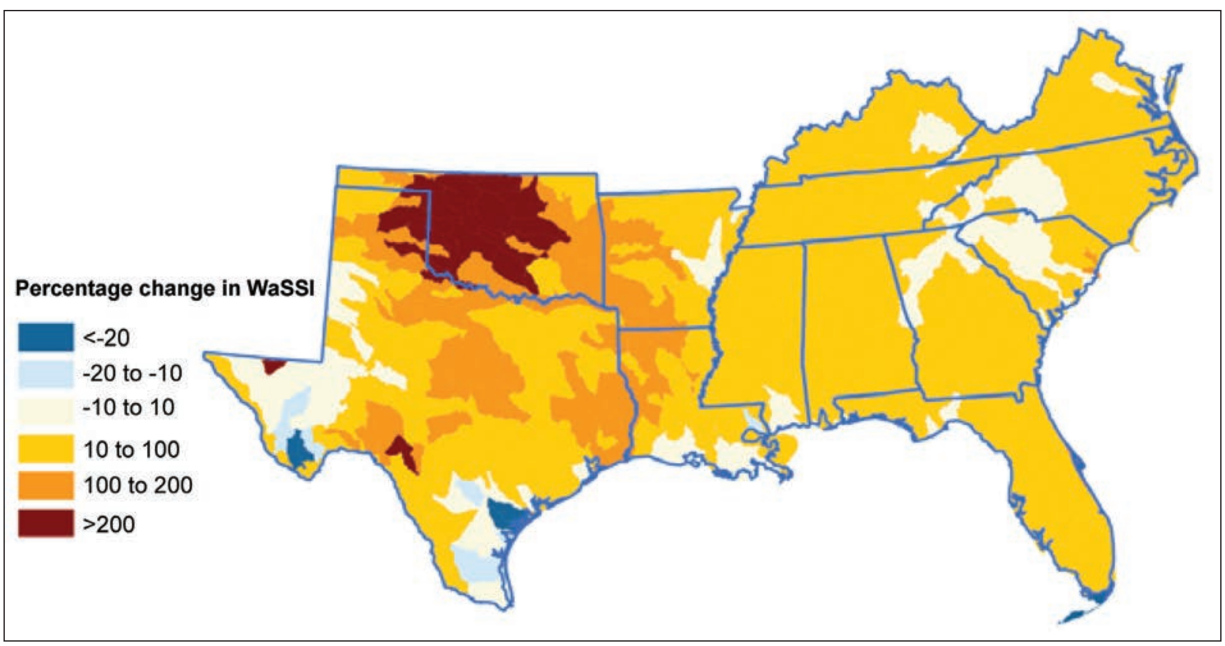

Figure A1-9—Percentage change in water supply stress owing to climate change, as defined by the water supply stress index (WaSSI) for 2050 using the CSIROMK2 B2 climate scenario. WaSSI is calculated by dividing water demand by supply, where higher values indicate higher stress on watersheds and water systems. From Lockaby et al. 2011.

continues to increase, conditions for pine growth may begin to deteriorate (McNulty et al. 1998b). Even if regional forest productivity remains high, the center of forest productivity could shift farther north into North Carolina and Virginia, causing significant economic and social effects in those areas gaining and losing timber industry jobs (Sohngen et al. 2001).

Carbon sequestration is an increasingly valued component of forest productivity. Globally, forests sequester up to 16 percent of all the CO_2 generated from the burning of fossil fuels, and in the United States, much of this storage occurs in Southeastern forests (Pan et al. 2011). In addition to potentially reducing forest productivity (and therefore C uptake), climate change could increase decomposition of soil organic matter and CO_2 release in the Southeast (Boddy 1993). When added to the potential for increased wildfires, the potential for ecosystem C sequestration may decrease in the future, and the ecosystem value of sequestered forest C may shift from the Southern to Northern United States (Hurteau et al. 2008).

Abundant, year-round rainfall has historically provided a sufficient supply of water for industrial, commercial, residential, agricultural, and hydro-electric use in the southeast, but several factors may contribute to a shift in water abundance. The population of the southeast is increasing and much of this increase is centered on metropolitan areas, whereas much of the water originates in forested headwaters, often long distances from urban areas. On an average annual basis, water supply is approximately 20 times higher than demand, although short-term (1 to 3 years) drought can significantly increase pressure on available water (Lockaby et al. 2011) (fig. A1-9). A combination of increased population, changing land use patterns, and shifts in rainfall patterns could further amplify water shortages, and even if precipitation rates remain unchanged, higher tree water use with higher air temperature, or shifting management regimes for new products such as biofuels, could contribute to water shortfalls (Lockaby et al. 2011, Sun et al. 2008). The seasonal timing of precipitation within the year could also affect water supply. If precipitation occurs in fewer, more intense events, then proportionally less water will be retained by forest ecosystems, and more will be lost as runoff, potentially causing flooding, soil erosion, and stream sedimentation (Trimble 2008).

The Southeast has diverse year-round recreational opportunities, some of which could be severely affected by climate change. Many Southeastern ski areas are marginally profitable, and increased winter warming may increase the proportion of rain to snow and prevent snow making (Millsaps and Groothuis 2003). Reduced quality or quantity of the ski season could force most of the marginal ski areas to permanently close. Similarly, cold water fisheries are a major recreational attraction, and revenues from lodging, food, and secondary activities are a major economic boost to local mountain economies. Therefore, extirpation of trout from these areas could significantly harm the recreation industry.

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