SECTION I

Climate Change and Forests

Forests influence and are influenced by our climate.

AS WITH ALL SYSTEMS ON EARTH, CLIMATE AND FORESTS ARE INEXTRICABLY LINKED. ***Climate***—along with other factors, such as water, soil, and geology—dictates whether and how well plants grow. This connection is easy to see by comparing the slow growth of the boreal forests of Russia and Canada to the rapid growth of the tropical forests of Latin America and Africa. However, the ways in which trees influence climate may not be so easy to see. First, trees intercept and absorb a large amount of the energy emitted by the sun, which affects air and surface temperatures. Trees also influence the amount of water vapor in the ***atmosphere***: water absorbed by tree roots evaporates through leaf surfaces in a process called ***transpiration***. This, in turn, affects climate components of humidity and ***precipitation***. Similarly, trees influence the amount of ***carbon dioxide*** in the atmosphere by removing atmospheric carbon dioxide during ***photosynthesis*** and storing carbon molecules in trunks, branches, leaves, and roots. Large amounts of carbon are also stored in the forest soil as a result of falling leaf litter and root death. All trees photosynthesize and ***respire***, moving carbon dioxide out of the air and back again. Carbon dioxide and other ***greenhouse gases*** in the Earth's atmosphere help moderate the climate, making the planet habitable by trapping heat in the atmosphere. However, additional carbon dioxide added to the atmosphere from human activities, such as land-use changes and ***fossil fuel*** combustion, is a serious concern.

Scientists have been improving their understanding of Earth's climate through numerous studies over the past 200 years. Through many scientific experiments, scientists have collected, analyzed, and compared historical climate data to arrive at the conclusion that Earth's climate is changing. Since 1880, the average surface temperature on Earth has increased by more than 0.8 degrees Celsius (° C) or 1.4 degrees Fahrenheit (° F) (NRC, 2010), and the rate of warming has doubled since 1950 (IPCC, 2007). This average increase in surface temperature, called ***global warming***, results in changes to climate averages and also influences temperature and precipitation extremes. Collectively, these changes are known as ***climate change***. In the Southeast United States, average temperatures are projected to increase over the 21st century. Precipitation patterns are also projected to change within the region, with some areas receiving more rainfall and some receiving less (Ingram, Carter, & Dow, 2012).

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Words in boldface and italic are defined in the glossary.

People are approaching projected changes in the climate with a variety of adaptation and mitigation solutions.

Projected changes in climate can impact forests in several ways. For example, changes in temperature and precipitation can influence tree growth and survival. Over time, the range of some forest ***ecosystems*** may shift to new locations as ***species*** adjust to new climatic conditions. In addition, the frequency and severity of disturbances such as ***wildfires***, insects and diseases, and storms may change, which will influence ***forest health***. It is difficult to say exactly how climate may change forests because (1) the landscape of the Southeast is varied, with differing climates across coastal and mountain areas; (2) climate is a complex system with many different variables and interactions, some of which are not fully understood; and (3) over time people may change the inputs by planting different trees or changing ***greenhouse gas emissions***.

People are approaching projected changes in the climate with a variety of solutions that fall into two broad areas:

1. ***Adaptation*** is when natural or human systems adjust to a new or changing environment. While plant and animal populations have the ability to biologically adapt to new conditions over time, the rapid rates of change projected make successful adaptation more difficult. Adaptation to climate change by humans includes actions taken to avoid, benefit from, or deal with actual or expected climate change impacts. Adaptation can take place in advance (by planning before an expected impact occurs) or in response to changes that are already occurring.
2. ***Mitigation*** includes actions to reduce the human impact on the climate system. These actions may seek to decrease ***greenhouse gas emissions*** or to increase the amount of ***carbon dioxide*** being removed from the ***atmosphere***.

The activities in this section are designed to provide background and perspectives on the topic of climate change and introduce ways in which the U.S. Forest Service researchers are exploring how southeastern forests may be impacted by climate change.

ACTIVITY 1: Stepping through Climate Science introduces climate change by providing historical context of the major milestones in climate science or policy over the past two centuries. In this short introductory activity, students represent a piece of the climate timeline and walk the timeline together as a class. Students also begin to explore connections among climate, climate change, and forest ecosystems and discuss mitigation and adaptation strategies being implemented by the U.S. Forest Service to address climate change in national forests. This activity can be used to introduce any activities in the module, as it briefly covers concepts related to climate change and forests.

ACTIVITY 2: Clearing the Air provides a more detailed foundation in climate science and is particularly important if your students have not learned about climate change yet. The activity was designed to help students understand why people have different ideas and opinions about this issue, even though 97 percent of climatologists are in agreement that the climate is changing due mostly to human activities (Anderegg et al., 2010; Doran & Zimmerman, 2009). A slide presentation helps you address the following questions: Is climate changing and why? What may happen in the Southeast? Why don't some people agree on the issue? After this introduction, students evaluate climate change information and rewrite conclusions that are supported by science. Next, students brainstorm, negotiate, and critique local solutions through a role-play.

ACTIVITY 3: Atlas of Change explores the web-based U.S. Forest Service Climate Change Tree and Bird Atlases. Students learn about projected climate changes in their state and how suitable ***habitat*** for tree and bird species is projected to change by the end of the 21st century. This activity introduces climate ***modeling*** and focuses on technology tools as students learn to navigate the atlases online and to understand the link between climate and ***biodiversity***.

Potential Areas of Confusion

There are several topics in this section that may be sources of confusion for students based on their assumptions, prior experiences, or existing knowledge. You may be able to use questions to uncover this confusion and steer students toward the clarifications provided in the table.

Assumption or Confusion	More Adequate Conception
Weather anomalies can be used to prove or disprove climate change.	***Weather*** describes the atmospheric conditions at a specific place at a specific point in time. Weather is related to, but is not the same thing, as climate. Climate is the long-term average weather conditions in a particular location or region at a particular time of the year. Climate is typically measured in long increments of time, often at least 30 years. Therefore, evidence of climate change is best assessed through long-term alterations to temperature, precipitation, and other climate factors—not through single weather events, such as a heat wave or a blizzard.
Carbon dioxide makes up a small percentage of the total gases in our atmosphere. We are not adding enough carbon dioxide to change the climate system.	There are several atmospheric gases, and many do not trap heat. Greenhouse gases, such as carbon dioxide and methane, occur naturally in small amounts, but they are very efficient at absorbing heat energy. For this reason, a small change in carbon dioxide can have large impacts on the climate system. It may be helpful to give students another example of a small percentage that has a great effect, such as how salt makes up only 3.5 percent of seawater, but that is enough to make it undrinkable.
The carbon dioxide that humans add to the atmosphere through fossil fuel combustion increases the total amount of carbon on Earth.	Carbon naturally cycles through biological, physical, and geological systems over time. The amount of carbon on Earth is stable. However, human activities are transferring carbon that is stored in fossil fuels to the atmosphere at a faster rate than would occur naturally.
The hole in the ozone layer is a large contributor to global warming.	Both the ozone hole and global warming are influenced by human activities. However, the ozone hole and global warming are different issues. The ozone hole is a depletion of the atmosphere's ozone layer, which reduces the ability of the ozone layer to protect the Earth from the sun's ultraviolet radiation. The hole is caused by the release of CFCs, or chlorofluorocarbons. Unlike reflected radiation which is absorbed as heat, ultraviolet radiation is not a large contributing factor to the average increase in global surface temperature.
Aerosol spray cans are a large contributor to global warming.	Aerosol spray cans once contained CFC's as a propellant, but not since the 1980s when we became aware of the damage to the ozone layer.
If climate changes, forests can just move to the right spot.	While migration is a reasonable possibility for some species, others will be constrained by human-caused changes in the landscape that prevent plants and animals from extending their ranges. There are no guarantees that all of the organisms that make a functional forest (e.g., fungi, insects, microorganisms) will migrate together. In addition, seed dispersal varies by species and is fairly limited for most trees. Because trees grow slowly and may not reproduce for many years, they are less likely to be able to expand their ranges rapidly enough to escape negative impacts from climatic conditions. If climate changes occur quickly and variably, existing ecosystems will be less likely to adapt and some tree species may be lost. Even when successful migration occurs, it may be many decades before the forest achieves the same age and size distribution associated with a particular forest type.
Forests are not very sensitive to changes in climate.	Trees are able to tolerate wide ranges in temperature and precipitation, making them somewhat resilient to changes in climate that are projected for the Southeast. Increases in atmospheric carbon dioxide may even help trees grow faster, at least for a few years. The biggest problems may result if climate change alters the frequency or length of severe events. For example, recent droughts in Texas have killed large numbers of trees and made others susceptible to insect attack. Slight changes in temperature may alter when plants flower, when insects hatch, and when birds migrate. Changes in precipitation affect soil moisture levels and could affect amphibians as well as plants.

(Table rows 1 through 3 adapted from CIRES, 2012; Table rows 4-5 adapted from Leiserowitz, Smith, & Marlon, 2011)

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Climate and forests are interconnected systems.

Key Concepts in This Section

- Many lines of scientific evidence indicate the Earth's climate is changing and that these changes are caused by a combination of natural and human activities, particularly the combustion of fossil fuels.
- People have varying opinions and ideas about climate change, which may or may not be supported by scientific evidence.
- Communities around the world are working to minimize the effects of climate change by reducing atmospheric greenhouse gases and implementing strategies to help people and ecosystems adapt to changing climate conditions.
- Southeastern forests will probably be impacted by projected climate changes in several ways, including changes in tree growth and distribution.

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