Project Learning Tree®

Climate Change and Southeastern Forests:

Secondary Environmental Education Module

Draft – February 2013

UF UNIVERSITY of FLORIDA
IFAS
School of Forest Resources and Conservation

PINEMAP

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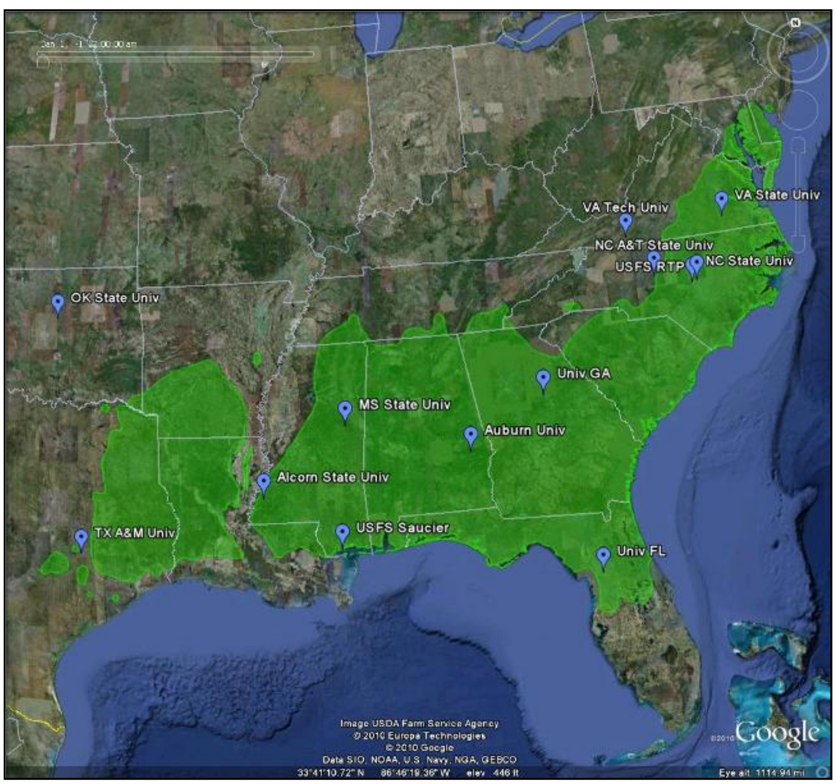
Background

About PINEMAP

PINEMAP is one of three Coordinated Agriculture Projects (CAP) awarded by the USDA National Institute of Food and Agriculture in 2011. The purpose of these CAPs is to encourage agriculture and forestry producers to increase carbon sequestration and adapt practices to reduce the impact of or to accommodate anticipated climate variation. This research will help develop new insights and solutions to the challenge of climate change. PINEMAP is funded for five years and focuses on planted pine forests in the Atlantic and Gulf coastal states that are managed by industrial and non-industrial private landowners. Loblolly pine (*Pinus taeda*) accounts for 80 percent of the planted forests in the South. PINEMAP integrates research, extension, and education to enable southern pine landowners manage forests to increase carbon sequestration; increase efficiency of nitrogen and other fertilizer inputs; and adapt forest management approaches to increase forest resilience and sustainability under variable climates.

One critical aspect of the CAPs is to share research findings with stakeholders, teachers, and the public. One way PINEMAP is accomplishing this goal is to work closely with Project Learning Tree to develop, test, and implement this secondary module. Forest researchers have helped develop and review these activities to reflect the concepts they are exploring, and although some examples relate to loblolly pine, the activities and concepts can be easily applied to forests across the continent.

Eleven land-grant universities, the US Forest Service, state climatologists, and Project Learning Tree are collaborating in PINEMAP activities.



PINEMAP FOCUSES ON THE NATIVE RANGE OF LOBLOLLY PINE (SHOWN IN GREEN) AND INCLUDES ELEVEN COLLABORATING INSTITUTIONS (NOTED IN BLUE).

About PLT

As in other PLT modules, this section will include an introduction to PLT, its mission, goals, organization, and materials and programs. In addition, it covers key concepts about quality environmental education and connections to standards.

More to come from PLT…

Why Climate Change and Southern Forests?

Climate change has been defined as the single biggest challenge that faces the planet today. It has also been called a huge hoax. Perhaps more than any other environmental issue, the topic of climate change challenges science teachers to faithfully convey the data, reveal the assumptions, engage critical-thinking skills, and help students understand why there are various opinions across the American public. In addition, the complexity and scale of climate change make it difficult for students to contemplate how they might make a difference. This module provides activities and resources to help educators meet these challenges.

In most other nations, elected officials, the business community, and citizens are already planning for climate change. They may be altering their dependence on fossil fuels, redirecting stormwater drainage patterns to accommodate sea level rise, or planting crops that tolerate warmer growing seasons. Many communities in the United States are also exploring ways to reduce carbon emissions or make transportation systems more effective, for example. We believe that students and their parents need current information, the background to make sense out of existing data, the willingness to listen to different points of view, and the skills to work together to help families, neighborhoods, communities, municipalities, states, and nations approach the challenges that climate change might bring.

While climate change is a global issue, and many excellent examples of change occur at the poles or mountaintops, climate change will be more meaningful to students if examples of change and its impacts are local. Because the impacts of climate change will be different throughout the world, we provide information on the southern United States and forest ecosystems to help make the materials relevant. Because weather patterns in the South are strongly affected by the Atlantic Ocean, the Gulf of Mexico, and El Niño and La Niña cycles, the actual impact of climate change is difficult for climatologists to discern. Until we have more data, better models, and greater understanding, we are limited to discussing projections and possibilities, not predictions or expectations.

Many other resources are available to teach students about climate change. Most of these materials are well suited to earth science courses. This module is for biology, agriculture, and environmental science teachers and focuses on the impacts of climate change on forest ecosystems and the role of forests in reducing atmospheric carbon dioxide. Learning about changes in temperature alone may not be meaningful to students, since we tolerate wide shifts in temperature daily and seasonally. However, the potential impacts to the ecosystems that students live near and depend upon could be significant, which should make the concepts presented in this module important to students and educators.

Southern pine forests provide critical economic and ecological services to US citizens. Southeastern forests contain one-third of the contiguous US forest carbon and form the backbone of an industry that supplies 16 percent of global industrial wood, 5.5 percent of the jobs, and 7.5 percent of the industrial economic activity of the region (Wear & Geis, 2002). It is a commodity that requires time to mature—in some cases 20 to 30 years before harvest. Seedlings that landowners plant this year will grow to be forests that are exposed to the climate of the future. This module helps students understand the challenges and opportunities land owners have as they plant and manage their forests.

And finally, students in our pilot tests and teachers responding to our needs assessment have made it clear they want to know what they can do to affect this issue. Many other resources provide excellent ideas about energy conservation and fossil fuel reduction, all of which is useful to mitigate climate change. Since this module focuses on forests, we provide information about life cycle assessment and the opportunities consumers have to use wood products to remove carbon from the atmosphere.

Purpose of This Module

This module is based on the interdisciplinary research that is undertaken in PINEMAP to help understand how to manage forests to mitigate climate change and adapt to potential changes in climate. It provides examples and supports basic concepts about the climate, carbon cycle, forest ecosystems, and genetics, as well as information about modeling and life cycle assessment to help students build a sufficiently complex mental model to see the connections between human, biological, and physical systems. It supports STEM education by linking closely with principles that underpin science and technology and enables students to improve their skills in science, technology, and mathematics.

The goals of this module are to:

1. Provide educators with the information and resources to teach about climate change and forests
2. Instill confidence in teachers to discuss climate change in their classroom
3. Develop student understanding of how forests impact climate and how climate change might impact forests in the southeastern US
4. Enable students to explain the impacts of projected climate changes in their region
5. Teach students how forests can be managed to address changing climate conditions and to reduce or prevent greenhouse gas emissions
6. Raise student awareness of how consumer choices can mitigate climate change
7. Teach students the skills needed to make informed decisions as consumers
8. Instill confidence and hope in students that individual and community actions can help address climate change
9. Develop students ability to use system-thinking skills to see connections between climate change, forests, and humans

The Development Process

Several sources of information informed the development of this module, and additional input from content reviews and pilot test educators improved it. We began with a review of the literature and the available activities in CLEANet and organizations working in climate change, such as GLOBE. We found insights from Sarah Wise (2010) and the National Center on Science Education very helpful in formulating our objectives. Using the framework of the PINEMAP project helped us develop the structure for the module, and tapping the expertise among the PINEMAP researchers enabled us to generate interesting, current, and meaningful activities. We conducted a needs assessment of science teachers in the Southeast and learned that those who responded were interested in using units of one to two weeks in length with activities that present and use data, provide opportunities for critical thinking, and explore ways students can become engaged in this issue (Monroe et al. in press). We developed an Advisory Committee of teachers, PLT coordinators, and educators from the Climate Literacy Network to review the activity concepts and drafts. Their insights were extraordinarily useful. We worked with the members of the NAAEE and EE-Capacity Climate Change Education Professional Learning Community and gained additional feedback on activity drafts. For two activities, we developed parallel versions and tested them with high school students enrolled in summer science camps at the University of Florida, Center for Precollegiate Education and Training to determine which version might be more effective. All of these resources helped us assemble a draft module which was reviewed by [insert #] education, forestry, and climate experts in spring 2013.

The revised module was used in a pilot test with *[insert #]* teachers in the southeast in fall 2013. Their experience with using the activities allowed us to provide clarifying explanations and examples. Their observations are sprinkled throughout the activities to help other teachers gain from these insights. From their experience we learned that *[insert info after pilot test]*.

The contributors, advisors, reviewers, and pilot testers are listed in the Acknowledgment section. They have all made important and often substantial contributions to the development and improvement of this material.

How to Use this Module

This module is designed for educators of students in grades 9-12, though many activities could be easily adapted for middle school or college students. Further, the module assumes that teachers of life science, biology, agriculture, and environmental science will use this material, as it applies the concept of climate change to forest ecosystems and management. We assume that earth science teachers will use educational resources that focus on atmospheric, hydrologic, and meteorological sciences and do not include that content here, expect for an introduction in Activity 2: Clearing the Air.

To help educators address the curriculum standards of their courses, we have correlated each activity to the Next Generation Science Standards (see Appendix G) and the PLT Conceptual Framework (see Appendix H). Of course each activity can be a launching pad for additional questions and extensions, but we have used the core components of each activity as the basis for these correlations. Other standards may also be achieved as teachers make adaptations to these materials.

The activities are organized by themes into five sections.

Section	Theme
1. Climate Change and Forests	Projected climate changes will likely affect forest ecosystems.
2. Forest Management and Adaptation	Forests can be managed to thrive in a changing climate.
3. Carbon Sequestration	Forests can be managed to reduce atmospheric greenhouse gases and to prevent greenhouse gas emissions.
4. Life Cycle Assessment	Consumer choices can play a role in reducing and preventing carbon emissions.
5. Solutions for Change	Working toward healthy, sustainable forests and communities

If teachers have limited time, addressing all the activities in one section may help supplement an important concept in the course curriculum, or selecting one activity from each section may provide a reasonable overview of the module concepts.

A variety of teaching strategies are presented in these activities to help educators engage students through multiple intelligences and learning styles. Suggested discussion questions help students process and generalize the exercise they just completed and apply the concept to novel circumstances. Videos on the website (http:/xxx) allow students to hear from PINEMAP researchers who are using these concepts, collecting data, and exploring forest management techniques. These may spark interesting discussions of career opportunities in science and forests.

Introductions to each section provide background information common to those activities. Based on the literature and the pilot test, we also provide a list of concepts that are likely to lead to confusion or misconceptions which may be useful as teachers embark in these areas.

Activity Design

Like other PLT activities, each provides a brief description and a box that contains activity specifics: objectives, assessment suggestions, related subjects, skills that are practiced, materials that are needed, estimated time, and other PLT activities that could be used it. Background information for the teacher is provided, a list of how to prepare for leading the activity, and step-by step suggestions for how to conduct the activity. Appropriate answers to discussion questions are provided in italics. Bold words are defined in the Glossary. Suggestions for ways to extend the activity are provided under the heading “Enrichment.” The list of resources includes web sites, readings, and reports for both teachers and students that relate to this topic. Student handouts are provided in a format that is easy to duplicate.

The web site that accompanies this module includes additional materials and information to make teaching these activities easier. Modifiable slide presentations are available so you can use your own photographs or remove slides. Additional handouts are available in color that you may wish to duplicate or project on the screen. Some activities have videos of researchers or forest landowners talking about their work. These can be used to supplement the activity and link to career possibilities.

Teaching about Climate Change

Public opinion polls suggest that the American population hold many different beliefs about climate change. These opinions shift slightly with media coverage of extreme weather events, international meetings on climate, and new research findings. Teachers should expect that students, parents, administrators, and co-workers hold similarly diverse perspectives. However, we do not believe these varying opinions should be framed in the classroom as a "scientific controversy" (McCaffrey, 2012). The science is clear, and in some areas unknown, but there are not competing scientific views on climate change. The controversies lie in how to apply these findings to our society, what policies to implement, and what investments to make. This module makes the assumption that the recent changes that scientists have observed in our global climate are influenced, in large part, by human activity. The consensus of scientific studies on climate supports this statement (IPCC, 2007).

We have designed activities that will increase student awareness and knowledge of the current research to better understand the relationship between climate, climate change, and forests; to project how forests might change over time; and to provide options for landowners to increase the ability of their forest to withstand climate-induced changes. We also provide an activity to help students understand why there are a variety of public opinions about climate change and how people can contribute to appropriate adaptations even if they disagree about the causes of climate change. Several activities allow students to collect and/or analyze data to better understand the process of science and the work of researchers. And since many students want to know what they can do to affect this issue, we introduce the concept of life cycle assessment and the role that wood products play in carbon sequestration.

We believe this module makes an important contribution to science education in the Southeast and look forward to hearing of your experiences with your students.

Sincerely,

Project Learning Tree and University of Florida

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Section 1: Climate Change and Forests
Projected climate changes will likely affect forest ecosystems.

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 boreal forests of Alaska and Canada to 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, called ***solar radiation***. This absorption does not contribute to overall warming, since excess energy is released when water, absorbed by tree roots, evaporates from leaf surfaces through ***transpiration***. Transpiration influences the amount of water vapor in the ***atmosphere***, which 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 soil. Both carbon dioxide and water vapor are ***greenhouse gases***, which trap heat in the atmosphere and affect the average temperature on Earth.

In numerous studies, scientists have collected, analyzed, and compared climate data to arrive at the conclusion that Earth's climate is changing. The average surface temperature on Earth has increased by more than 1.4° Fahrenheit over the past 100 years (NRC, 2010). This average increase in surface temperature is known as ***global warming*** and results in changes to climate averages as well as temperature and precipitation extremes. This is known as ***climate change***. In the southeastern 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).

These projected changes can impact forests in several ways. Some areas may experience longer growing seasons, which could increase tree growth and forest productivity. At the same time, longer growing seasons and warmer temperatures may increase the risk of ***wildfire*** and forest insect outbreaks. In addition, some areas may experience drought and extreme heat waves, which could stress trees and impact tree survival. It is difficult to say exactly how climate may change the forest because 1) the South is a varied place, with coastal and mountain areas that have very different climates, 2) climate is a complex system with many different variables and interactions, some of which we don't fully understand, 3) people can change the inputs by planting different trees or changing carbon 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, rapid rates of change make it less likely that they will be successful. Adaptation to climate change includes actions taken by humans 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 that reduce sources of ***greenhouse gases*** or increase the amount of ***carbon dioxide*** being removed from the ***atmosphere***. These actions seek to reduce the extent of future climatic changes that could be linked to greenhouse gases.

The activities in this section are designed to provide background on climate change and perspectives surrounding this topic, and to introduce the ways in which southern forests can be impacted by climate change, using USDA Forest Service research.

Activity 1, **The Changing Forest,** introduces students to how changes in climate affect southern forest ecosystems and forest management. This activity is a good introduction to the module; it highlights current monitoring and research activities of forest scientists reported in five 2-page articles from the USDA Forest Service's Southern Research Station magazine, *Compass*. Student groups read one of these articles, communicate the key points to their classmates, and then summarize ways that climate change might affect southern forests and the role of forest management and science in responding to those changes. The exercise may prompt questions which can be explored in other activities.

Activity 2, **Clearing the Air**, provides a 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. A slide presentation helps you address questions such as, is climate changing, why is climate changing, what will happen in the South, and why don't we all agree. After this introduction, students will evaluate climate change information and rewrite conclusions that are supported by science. Next, students will brainstorm, negotiate, and critique local solutions through a role play.

In Activity 3, **The Atlas of Change**, students explore the web-based USDA Forest Service's Climate Change Tree and Bird Atlases to learn about projected climate changes in their state and how suitable habitat for tree and bird species is projected to change within 100 years. This activity introduces modeling and focuses on technology as students learn to navigate the Atlases online and to understand the content provided in this tool.

Potential Areas of Confusion

Our pilot tests and the literature suggest there are several topics in this section that may be sources of confusion for students, based on their assumptions, prior experience, or knowledge. You may be able to use questions to uncover this confusion and steer students toward the following clarifications:

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 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, at the very 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 percent 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, occur naturally in small amounts, but they are very efficient at absorbing heat energy. This allows a small change in carbon dioxide to have large impacts on the climate system.
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. Human activities are transferring carbon that is stored in plants of fossil fuels to the atmosphere, at a faster rate than would naturally occur.
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 interstates, cities, farms, and changes in the landscape which prevent forests from growing to maturity. There are no guarantees that all of the organisms that make a functional forest (fungi, insects, etc.) will migrate together. More likely is that trees on the edge of their range will be stressed, and trees that do well in the new climate will thrive within the areas where they are currently growing.

(Table Rows 1-3 adapted from CIRES, 2012)

Key Concepts in This Section

The background information in these activities explains the key concepts that students should gain:

- Many lines of scientific evidence indicate the Earth's climate is changing and that this change is 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 are often partially supported by scientific evidence.
- People can reach incorrect conclusions because they have partial and missing knowledge, which is often the case when they focus on information that fits their existing understanding of the issue.
- Communities around the world are working to minimize the effects of climate change by reducing atmospheric greenhouse gases or by implementing strategies to help people 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, wildfire risk, and insect and disease outbreak.
- Scientists are currently working to understand how climate changes might affect forests.

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1: The Changing Forests

In small groups, students learn about research that is exploring climate change impacts on southeastern forests. This information will help forest managers monitor and respond to changes using new tools and management techniques.

Subjects
Agriculture Education, Biology, Environmental Issues / Ecology, Environmental Science, Forestry / Natural Resource Management, Integrated Science, Language Arts, Life Science, Integrated Science, Language Arts, Life Science

Skills
Leadership, communication, cooperative learning, critical analysis, making conclusions

Materials
Module: Student pages, USFS Compass articles
Other: None

Time Considerations
One to two 50-minute class periods

Objectives
Students will explain at least three ways that climate change could affect a forest ecosystem.
Students will explain at least two monitoring or management techniques for exploring climate change and forest health.
Students will communicate effectively in small group.
Students will teach information effectively to others in their group.

Assessment
Use students' answers on the worksheet to assess their understanding of the articles.

Ask students to write an essay describing three changes in southeastern forests that may be due to climate change, and at least two ways that forest managers can monitor and respond to these changes.

Background

Tree ***species*** grow and thrive within specific ranges of temperature, precipitation, sunlight, and humidity. Since these conditions vary by region and with changes in ***topography***, the structure and composition of forests also vary—creating diverse ***ecosystems*** around the world. In this way, forests are inseparably linked to Earth's ***climate***, and any long-term changes in average temperature and precipitation will likely influence ***forest health*** and survival. ***Climate change*** could influence tree growth and productivity, the frequency and severity of disturbances, and salinity levels in ***groundwater***.

- **Tree Growth and Productivity:** Warm and moist conditions are ideal for tree growth. However, if temperatures are too high or too low, or if temperatures fluctuate too quickly, some trees could become stressed and may eventually die. Similarly, trees can be affected if too much precipitation results in flooding or if too little precipitation causes drought. In particular, changing environmental conditions could affect species at the edge of their range, where they may already be stressed. These changes could cause some species of trees to die and allow for growth of other tree species that are better adapted for these different climate conditions. Forests may begin to migrate northward or to higher elevation as seeds are unable to germinate in warming conditions.
- **Frequency and Severity of Disturbances:** Forest health, structure, and composition are influenced by disturbances, such as ***wildfire***, insect and disease outbreaks, ***invasive species***, and storms. If these disturbances become more frequent and severe, entire forest ecosystems may change. Prolonged hot, dry ***weather*** can increase wildfire risk. Drought also creates ideal conditions for the southern pine beetle, and a population explosion of this organism can significantly impact forest health. Severe weather events, such as hurricanes in the Southeast, can cause trees that are already stressed from drought to be more susceptible to additional damage from high winds.
- **Saltwater Intrusion:** ***Sea level rise*** can affect coastal trees through ***saltwater intrusion***. As sea level rises, salt water mixes with fresh groundwater. This increased salinity may not be tolerated by some trees, which will not survive. These tree species may then be replaced with other species that are more tolerant to the new conditions—changing the forest ecosystem.

<u>Climate Change Adaptation and Mitigation</u>

Forest researchers are monitoring a variety of ecosystem components to better understand what is changing, whether changes can be explained by any predictable factor, and how forest managers can respond to change through ***adaptation*** and ***mitigation*** strategies.

Specific adaptation strategies include

- Instituting seed-bank programs for tree species that can tolerate salt, drought, and floods;
- Improving forest health and ***resilience*** by reducing forest stresses such as pollution, fragmentation (i.e., dividing up large continuous forests into smaller parcels), invasive species, insects, and diseases;
- Preparing to respond to forest declines by monitoring forest health and establishing criteria for prompt intervention; and
- Supporting and applying research that provides forest managers with strategies to adapt to predicted climate changes.

Specific mitigation strategies include

- Managing forests to maximize potential ***carbon sequestration***;
- Increasing forested land area through ***afforestation***;
- Reducing severe wildfire risk through use of ***prescribed fire*** and hazardous fuel reduction;
- Promoting the substitution of wood products (e.g. ***biomass*** energy, home construction, furniture, etc.) for ***fossil fuel*** intensive products; and
- Reducing greenhouse gas emissions through effective use of fertilizers and pesticides.

Getting Ready

This activity uses five short articles that appeared in the June 2011 issue of *Compass Magazine* published by the USDA Forest Service, Southern Research Station. The articles can be accessed on the USFS Southern Research Station website or on the module website [*insert module url*].

1. *Trees in Transition*, by Stephanie Worley Firley
   http://www.srs.fs.usda.gov/compasslive/compass18/treestransition.html
2. *Forest Ecosystem Stress in Real Time*, by Zoë Hoyle
   http://www.srs.fs.usda.gov/compasslive/compass18/stressrealtime.html
3. *More Fuel for Fire?,* by Susan Andrew
   http://www.srs.fs.usda.gov/compasslive/compass18/fuelfire.html
4. *CRAFTING Future Forests*, by Zoë Hoyle
   http://www.srs.fs.usda.gov/compasslive/compass18/futureforests.html
5. *Climate Change Invasions*, by Teresa Jackson
   http://www.srs.fs.usda.gov/compasslive/compass18/climateinvasions.html

Make copies of the "Changing Forest" student pages (each student will receive one student page to correspond with their *Compass* article).

Doing the Activity

1. If you have more than one class period for this exercise, students can read the article in their group. If you have only 50 minutes, ask students to read the article for homework and to be prepared to discuss the information when they come to class. You can assign the questions as homework as well, or save them for the first group activity.

2. If you have not already provided an introductory lesson on climate change, engage learners in a general discussion about climate change, making sure to discuss how climate is different from weather. Begin by asking learners to explain the difference and then invite questions and comments as you discuss background information related to climate change. (See Section 1 Overview.)

3. Next, engage students in a brief discussion about expected long-term changes to temperature and precipitation patterns, which in turn affect forest health and survival.

4. Ask students to brainstorm some ways that damage to the forests might be diminished or avoided as the climate changes. Offer other suggestions and ideas, and explain the difference between mitigation and adaptation.

5. Divide the class into five groups. Each group will read one of the five Compass articles. Give each student in the group a copy of the article and the associated "Changing Forest" student page. Alternatively, the articles can be read online.

6. Ask students to read the article and complete the "Changing Forest" student page as a group. Each student should become familiar enough with the information to be able to teach it to the students in the other groups. Give students at least 15 minutes to discuss and answer the questions based on the articles. Allow more time if necessary.

7. Ask students to count off in fives within their individual groups. Pair the same numbers together and reform the groups so that each group now has one person from each of the five articles.

8. In the new groups, ask one student in each group to be a timekeeper. Each student should take 3 minutes to explain his or her article to the other four. When the student is done, the others may ask questions.

9. When everyone understands all five articles (about 20 minutes), ask students to discuss the following questions:
   a. What common themes do the five readings have?
      - *Climate changes are causing changes in forest ecosystems*
      - *Climate changes are causing a variety of different forest stresses*
      - *New models are being developed to predict climate changes and the impacts of these changes*
   b. What are some indicators that changes are occurring?
      - *Warmer, drier conditions have occurred*
      - *Increased presence of invasive species*
   c. What are some impacts from climate change that southeastern forests might face in the future?
      - *Changes in the genetic makeup of forest tree species*
      - *Changes ranges of forest tree species*
      - *Increased drought*
      - *More frequent and more intense forest fires due to greater fuel loads*
      - *Stronger and more frequent tropical storms*
      - *Greater opportunities for invasive species, which could jeopardize the health of native forest species*
   d. What strategies could help reduce or promote adaptation to climate change impacts on forests?
      - *Prescribed burnings*
      - *Conserving genetic variation*
      - *Using models to predict changes*
      - *Using models to determine areas of forest stress*
   e. From the readings, what future career opportunities can you identify?
      - *Forest ecologist*
      - *Land manager*
      - *Research scientist*

10. Finally, use these open-ended questions to stimulate more discussion about climate change mitigation and adaptation:
   a. Considering the climate change research and solutions you discussed in your groups, did these articles mostly focus on adaptation or mitigation strategies?
      - *Most articles were related to adaptation.*
   b. How do you identify differences in mitigation and adaptation?
      - *Mitigation reduces the effects of future climate changes, while adaption helps humans and ecosystems adjust to new conditions brought on by climate changes.*
   c. What makes each set of strategies (mitigation and adaptation) important for forest ecosystem health?
      - *Mitigation strategies are important because they reduce the effects of further climate changes. Unfortunately, mitigation cannot reverse projected climate change. Therefore, adaption strategies are important to help forest ecosystems adjust to these likely changes.*

Enrichment

Watch the 12-minute video introduces climate change science, impacts on forest ecosystems, and how the USDA Forest Service is responding to climate change. Discuss with students the relationship between forest ecosystem and climate change and write down the impacts of climate change on forest ecosystem Available at http://www.fs.fed.us/video/climate/

Have a field trip to investigate how the climate change issues would affect schoolyard wildlife and how climate change would affect the wetland habitats or coastal forests nearby.

Resources

Climate Change Impacts and Adapting to Change
US EPA
www.epa.gov/climatechange/impacts-adaptation/index.html
This section of the US EPA climate change website provides information about the impacts of climate change and adaptation efforts by region and by sectors, such as forests, agriculture, and ecosystems.

The Forest Service and Climate Change Video
USDA Forest Service
www.fs.fed.us/video/climate
This 12-minute video introduces climate change science, impacts on forest ecosystems, and the Forest Service response to climate change.

Neil Sampson Says Climate Change Speeding Flux of Forest Ecosystems
EarthSky
http://earthsky.org/earth/climate-change-speeding-flux-of-forest-ecosystems
During this 90-second podcast, scientist Neil Sampson describes how forests may be affected by climate change.

State Climatologist Interview with NC People
State Climate Office of North Carolina
www.nc-climate.ncsu.edu/interviewNCpeople
During this 11-minute video, the North Carolina State Climatologist, Dr. Ryan Boyles, explains how climate change can impact southeastern forests.

Changing Forests: Trees in Transition

Name___________________________

1. In the introduction, it states that the only constant is change. If forests always change, what's the problem?

2. How might tree populations respond to changes in the climate?

3. What is the ForeCASTS project? How are ForeCASTS maps useful?

4. Why is it important to conserve genetic variation?

5. In general, how are tree ranges expected to change?

Changing Forests: Forest Ecosystem Stress in Real Time

Name___________________________

1. What is RAFES and what is it intended to do?

2. What is the problem with current ecosystem assessment, and why is the new approach more effective?

3. What important forest stressor is being researched for this project? Why is this stressor important?

4. How will forest managers be able to use the information in RAFES?

5. How do you think drought increases forests’ susceptibility to pests, disease, and wildfire?

Changing Forests: More Fuel for Fire?

Name___________________________

1. What is the KBDI? What does a high KBDI mean?

2. In which area is the increase in the length of fire season expected to be the greatest? What expected changes will cause longer fire seasons?

3. Describe the changes in fuel loads predictions. Which areas will have a decline? Which areas will have an increase?

4. What is a management option to mitigate climate change impacts?

Changing Forests: CRAFTING Future Forests

Name___________________________

1. What is the Forest Service National Roadmap for Responding to Climate Change?

2. Why is there a strong interest in restoring longleaf pine forests in the Southeast?

3. What challenges do forest restoration specialists face?

4. What is CRAFT? How does CRAFT help managers and stakeholders make decisions for the future?

Changing Forests: Climate Change Invasions

Name___________________________

1. How will invasive plant species likely be affected by climate change?

2. What types of tools are EFETAC researchers using to assess how climate change will affect the distribution of plant species?

3. What is required to understand how invasive species affect native habitats and species?

4. What is the goal of the EFETAC research?

Changing Forests: Trees in Transition

1. In the introduction, it states that the only constant is change. If forests always change, what's the problem?
   Forest species are able to tolerate small seasonal fluctuations in temperature and precipitation, in addition to small changes caused by disturbances such as storms and wildfire. In many areas today, typical temperature and precipitation patterns are changing rapidly. Many forest species may not have the ability to adjust to these climate changes.

2. How might tree populations respond to changes in the climate?
   Tree populations may adapt onsite to changing conditions, shift their ranges to new locations with more suitable conditions, or simply die out.

3. What is the ForeCASTS project? How are ForeCASTS maps useful?
   The ForeCASTS project allows researchers to predict future suitable habitat ranges for tree species both in the United States and around the world. Researchers are able to do this by using projections of future climate and fine scale ecoregions, or areas that share similar characteristics such as soil and topography. These maps can help target tree species by determining the areas in which climate change pressures are likely to be the most intense.

4. Why is it important to conserve genetic variation?
   Conserving genetic variation is important because genetic variation makes it possible for species to continue to evolve and adapt to change. This ability to change reduces the species' susceptibility to stressors such as insects, pathogens, and climate change.

5. In general, how are tree ranges expected to change?
   In general, the range for most tree species is expected to expand to the north and to drop off at its southern edges. The overall suitable habitat area is expected to decrease.

Changing Forests: Forest Ecosystem Stress in Real Time

1. What is RAFES and what is it intended to do?
   The RAFES (Remote Assessment of Forest Ecosystem Stress) network provides real time data on climate impacts in at-risk ecosystems. It is designed to give forest managers the time they need to respond to forest stress.

2. What is the problem with current ecosystem assessment, and why is the new approach more effective?
   Current ecosystem assessments often use too large a spatial scale, fail to directly measure climate impacts on tree stress, and don't allow time for managers to respond. RAFES uses a finer scale, monitors tree stress in real time, is cost effective, and can be deployed either across the landscape or simply in high-risk areas.

3. What important forest stressor is being researched for this project? Why is this stressor important?
   Water availability is the stressor being researched for this project. This stressor plays an important role in regulating forest stress and stream flow.

4. How will forest managers be able to use the information in RAFES?
   RAFES stations are equipped with sensors that detect soil water content and availability, soil temperature, woody fuel moisture and temperature, xylem sap flux density, precipitation, relative humidity, air temperature, and solar radiation. Data from these stations is transmitted hourly to NOAA's Geostationary Operational Environmental Satellite (GOES), from which it is downloaded and archived for analysis. This information can be accessed from anywhere via the Internet. Using a PC-based analytical tool, forest managers are able to monitor and assess the severity of climate-related stress.

5. How do you think drought increases forests' susceptibility to pests, disease, and wildfire?
   Student responses will vary.

Changing Forests: More Fuel for Fire?

1. What is the KBDI? What does a high KBDI mean?
   The KBDI, or Keetch-Byram Drought Index, estimates landscape fire potential. A high KBDI value indicates increased flammability of organic matter on the forest floor, creating wildfires that are more intense and spread faster.

2. In which area is the increase in the length of fire season expected to be the greatest? What expected changes will cause longer fire seasons?
   The increase in the length of fire season is expected to be the greatest in the Appalachian Mountain region, where the fire season is expected to increase from four to seven months by the end of this century. The longer fire season is caused by changes such as a delay in afternoon thunderstorms an increase in dryness in May and June.

3. Describe the changes in fuel loads predictions. Which areas will have a decline? Which areas will have an increase?
   In the South, reduced precipitation will cause an overall decline in fuel load because of reduced forest growth. However, due to differences in climate, there is a lot of variability in predicted fuel loads in different areas of the south. A decrease in precipitation in Tennessee and Kentucky may lead to a 20 percent reduction in fuel load. However, an increase in precipitation in coastal Virginia and the Carolinas may cause an increase in fuel loads.

4. What is a management option to mitigate climate change impacts?
   One management option to mitigate climate change impacts in prescribed burning. Prescribed burning reduces understory fuels and lowers the risk of wildfires.

Changing Forests: CRAFTING Future Forests

1. What is the Forest Service National Roadmap for Responding to Climate Change?
   The Forest Service National Roadmap for Responding to Climate Change is a framework that supports restoring forests to a healthy, functioning condition.

2. Why is there a strong interest in restoring longleaf pine forests in the Southeast?
   Longleaf pine forests are more resilient to insect attracts and hurricane winds than the loblolly forests that have replaced them in many areas in the Southeast.

3. What challenges do forest restoration specialists face?
   Population growth has increased in the south, and more people are building their homes near forests. Longleaf pine forests require frequent prescribed burning, which generates smoke that residents in nearby areas may not be willing to tolerate. Burning less frequently will eventually defeat the restoration.

4. What is CRAFT? How does CRAFT help managers and stakeholders make decisions for the future?
   CRAFT, or Comparative Risk Assessment Framework and Tools, is a new resource that scientists have developed to help natural resource managers and stakeholders make decisions about land management and find common ground.

Changing Forests: Climate Change Invasions

1. How will invasive plant species likely be affected by climate change?
   Studies have shown that climate change creates niches and opportunities that promote the invasion on nonnative species.

2. What types of tools are EFETAC researchers using to assess how climate change will affect the distribution of plant species?
   EFETAC researchers use a variety of modeling and simulation tools to make comparisons between habitats and geographical distributions of native and nonnative invasive plant species, which help them predict how climate change will affect the distribution of plant species. Additionally, researchers use Geographic Information System (GIS) remote sensing tools to visually map out results that are easy to understand.

3. What is required to understand how invasive species affect native habitats and species?
   To understand how invasive species affect native habitats and species, an understanding of plant biology and ecology is required. In particular, this includes an understanding of how species interact with each other and the environment. Biologists must look at how the life history and genetic traits of invasive plants affect the plant's ability to invade under current and projected future climate conditions.

4. What is the goal of the EFETAC research?
   The goal of EFETAC research is to preserve native biodiversity and to manage invasive species.

2: Clearing the Air

Students learn about the scientific evidence supporting climate change, use this information to evaluate and improve common conclusions that people draw about climate change, and participate in a role play to negotiate solutions. Through this activity, students explore the nature of science and better understand why there are various perspectives about climate change.

Subjects
Agriculture Education, Biology, Earth Science, Environmental Issues / Ecology, Environmental Science, Forestry / Natural Resource Management, Government / Politics, Integrated Science

Skills
Analyzing, Concluding, Discussing, Inferring, Decision Making

Materials
Module: Student pages, "2: Explaining the Evidence" and "2: Exploring Solutions" slide presentations available at [*insert url*]
Other: Flip chart paper, markers

Time Considerations
Two to three 50-minute class periods

Related Activities in Other PLT Guides
Climate Change and Forests (*Focus on Forests* module); Tough Choices (*Focus on Forests* module); The Global Climate (*PreK-8* Guide); Viewpoints on the Line (*PreK-8* Guide)

Objectives
Students will describe scientific evidence related to climate change.
Students will analyze conclusions about climate change and rewrite them to be scientifically accurate.
Students will explain how people can reach incorrect conclusions from partial information.
Students will be able to explain diverse perspectives on climate change.
Students will negotiate solutions that can help a community adapt to and mitigate climate change.

Assessment
Ask students to write a report that summarizes scientific evidence related to climate change, with at least three supporting references.

Have students analyze an editorial article on climate change. They should identify the article's claim, the strength and source of the supporting scientific evidence, and assumptions being made by the author.

Background

A variety of ideas, opinions, and beliefs surround the topic of ***climate change***. While some of these beliefs are supported by scientific evidence, others are not. Beliefs are ideas that we hold true and can be based on many things, such as past experiences, observations, faith, or beliefs of others. Scientific conclusions are beliefs that are based on scientific evidence. The scientific process involves testing hypotheses, collecting data through standardized measurements and observations, and stating assumptions that are used to link the interpretation of data to conclusions. Understanding scientific evidence and the reasons that people might hold ideas that conflict with the scientific consensus are key aspects of working together to move toward solutions for reducing and adapting to climate change.

Is Climate Change Changing?

Climate is the average weather conditions in a particular location or region at a particular time of the year. For example, it is generally hotter in the summer than the spring, and that is a function temperature extremes and average temperature, in both the day and the night. ***Weather***, as opposed to climate, describes the atmospheric conditions at a specific place at a specific point in time. Weather is what is happening outside right now.

> Slides 1-28 in the "2: Explaining the Evidence" presentation will help you provide students with a brief introduction to climate change, scientific evidence supporting human-induced climate change, and projected regional impacts. This background information follows the presentation and can be used along with the presenter notes found in the presentation file.

El Nino and La Nina oscillation cycles create variations that have important short-term influences on regional climates, especially in the Southeast—leading to warmer, cooler, wetter, or drier years. Climate also fluctuates over longer periods of time. Climate is measured in increments of at least 30 years, but when considering historical climate changes, we often look at much longer timeframes, in the range of hundreds to thousands of years. Evidence of **climate change** can be seen in long-term alterations to temperature, precipitation patterns, sea ice extent, sea level, and the frequency of extreme weather events. Data about these variables are collected through weather instruments and records, tree rings, ice cores, satellite images, sedimentary layers, and other observations.

Collectively, data from meteorological weather stations, at airports, on mountains, on ships in the ocean, and by satellites, indicate that over the past 100 years the average surface temperature on Earth has increased by more than 1.4° Fahrenheit (F) (NRC, 2012). Looking at global temperature from 1880 to today, studies show that most of the increase in average temperature has occurred since the 1970s (NASA GISS, 2012). In the Southeast, the average annual temperature did not change significantly over the last 100 years; however, similar to global averages, the annual average temperature has increased the most since 1970, by approximately 2°F (USGCRP, 2009). This average increase in global surface temperature is known as ***global warming*** and can create other changes in climatic conditions, such as rainfall.

While the total precipitation in the US has increased by about 5 percent in the past 50 years, this increase has not been consistently experienced by all locations in the country (NRC, 2012). Precipitation frequencies and distributions vary widely with short distances, so it is more helpful to look at regional changes in precipitation rather than global changes. In the Southeast, observed precipitation changes from 1901 to 2007 show that average fall precipitation increased by 30 percent since the early 1900s, and that summer and winter precipitation decreased by almost 10 percent in the eastern part of the region (USGCRP, 2009).

In addition to temperature and precipitation changes, climate research shows long-term changes to the extent of snow and ice cover. For example, measurements taken by the National Snow and Ice Data Center (2013) indicate that the monthly December arctic sea ice extent from 1979 to 2012 shows a decline of 3.5 percent per decade. In addition, the average arctic sea ice extent for December 2012 was the second lowest month in the satellite records ranging from 1979 to 2012. It is important to compare the same months across years, as comparing the ice extent in December to the ice extent in July would represent a change in season rather than a change in climate.

Increases in global surface temperature are reflected in our oceans. Like any body of liquid, a warmer ocean expands as the molecules move at greater speeds, and bigger oceans lap higher along shorelines. This expansion of warm water has contributed to global sea level rise, which is estimated to be about 8 inches higher than it was in 1870 (NRC, 2012). Sea levels are also affected to some degree by melting glaciers and polar ice. Sea levels are measured with tide gauges and satellite images.

Finally, climate change can also be seen through long-terms alterations to the frequency and intensity of weather events, such as extreme heat and cold periods, droughts, floods, winter storms, thunderstorms and tornados, and hurricanes. Similar to precipitation, trends in extreme weather events are best identified regionally and must consider the range of weather patterns that typically affect the area. In the southeastern region, the trends in weather events vary. The frequency of flood events has been increasing since the late 1800s, and particularly within the last two decades. This may be due to increases in impermeable surfaces in cities across the region. At the same time, decadal frequencies of hurricane landfalls in the region have slightly decreased in the past 100 years. The frequencies of extreme maximum temperatures and extreme minimum temperatures have been decreasing across much of the region since the early 20th century. However, the frequency of minimum temperatures above 75°F has been increasing across the majority of the Southeast (Ingram, Carter, & Dow, 2012).

Why is Climate Changing?

Changes in climate are driven by many factors. These factors include ***solar radiation***, ocean composition, ***greenhouse effect***, ***albedo*** effect, continental land arrangement, volcanic eruptions, ***fossil fuel*** combustion, and land-use change. Historically, the Earth has experienced 100,000 year cycles of ice ages and warmer periods, mostly due to changes in solar radiation. While natural forces explain historical climate shifts, those same factors do not account for the changes that are now being observed. Recent ***models*** of climate change suggest that both natural and human-induced changes are responsible for recent increases in global temperature. Both the US Climate Change Science Program (2006) and the Intergovernmental Panel on Climate Change (2007) agree that human activities, particularly increases in ***greenhouse gases***, are influencing the climate system.

The levels of greenhouse gases, such as ***carbon dioxide*** (CO_2), methane (CH_4), ozone (O_3), and nitrous oxide (N_2O), affect Earth's energy balance though the greenhouse effect—a natural process where greenhouse gases absorb and trap heat radiating off the Earth's surface. Measurements from ice core samples representing the past several thousand years indicate that until the late 1800s, CO_2 levels in the Earth's ***atmosphere*** had been fairly stable at about 280 parts per million (ppm). In 2010, CO_2 levels reached 392 ppm, which is a 40 percent increase than preindustrial levels (USGCRP, 2009). Researchers have noted that the rise in greenhouse gases coincides with rises in average global temperatures.

What Will Happen in the Future?

Because the global climate is a complex system and because there are many possible changes to the factors that increase greenhouse gases and temperature, firm predictions about the impacts of climate change are not possible. Climatologists use climate models to make projections, however, and some have more support and certainty than others. ***Projections*** describe how future climate is expected to respond to various scenarios of the factors that might affect climate change, such as population growth, greenhouse gas ***emissions***, and land development patterns.

The impact of a few degrees in temperature increase is likely to have a variety of effects around the planet. While the polar regions are currently experiencing warmer winters, less sea ice, and glacial retreat, the equatorial regions will likely experience less temperature change. More heat in the atmosphere will mean more ***evaporation*** from the planet's surface, which can reduce soil moisture and increase drought in some places and increase rainfall and extreme storm events in others. Changing temperature and precipitation may change ocean and atmospheric currents, creating new weather patterns, with potentially welcomed, disastrous, or unanticipated effects. Changes in temperature and precipitation on the land are likely to bring about changes in the frequency and intensity of storms, including hurricanes and tornadoes, ***wildfires***, and pest and disease outbreaks. Plants and animals that currently live at the edge of their range may find the changing environment no longer meets their needs. Some populations may be able to migrate or shift; others may become smaller.

Through the 21st century, the southeastern region is expected to see increases in temperature, both increases and decreases in precipitation, and increases in the frequencies of major hurricanes. In particular, coastal communities in the region are threatened by ***sea level rise*** and ***saltwater intrusion***. Warmer temperatures can lead to more invasive exotic organisms, greater risk of wildfire, and losses in forest productivity. At the same time, increased levels of atmospheric carbon dioxide may benefit trees through increasing ***photosynthesis***, if other factors do not limit tree growth. The immediate impacts on forest ecosystems and agriculture are of great concern to many decision makers, researchers, resource managers, and farmers. The long term impacts will affect us all through availability and price.

Why Doesn't Everyone Agree?

> Slides 29 - 32 in the "2: Explaining the Evidence" presentation enable you to explain areas of and causes for this disagreement. The "Analyzing Perspectives" student pages give students an opportunity to work with these ideas.

The certainty with which climate scientists think about global warming raises an important question: why do people disagree about this issue? Of course the issue of climate change is complex and multifaceted, which makes it a difficult topic to explain and understand. Some people simply don't have the information to enable them to agree; they are appropriately confused and have a lot of questions. Some people have never had an earth science class and don't have a background to understand some climate concepts. Without understandable explanations, it is easier to stick with what we have experienced in our lifetime—the relatively stable climate.

Others might understand the information and even acknowledge that changes are likely, but because they do not like the possible solutions or social changes, they find it easier to downplay the problem. Any industry that produces or relies on fossil fuel could be affected by changes in carbon emission policy. They might have strong reasons to convince people that global warming is not due to human actions. In addition, it is easy to convince people that individuals shouldn't change anything because individuals won't reap any benefit of their changes. If changes happen, their impact may be in the future and more readily seen in places where climate changes are more extreme—likely not the southeastern US.

Even still, the strongly held and very diverse opinions across America make the topic of climate change a very different issue than other environmental challenges. At the root of these various perspectives is a simple fact of human information processing: we more readily perceive and accept information that matches what we already know. Teachers demonstrate this every day by reminding students of previous lessons and experiences. Given a great deal of information, we are likely to pass over that which doesn't fit our mental model and focus on the bits that reinforce our ideas. Thus, it is hard to begin to change someone's mind because they don't even see the same information!

This selective perception makes it possible for people to have partial information about climate change. By having only part of the story, people may arrive at conclusions that are only true some of the time and are not supported by some evidence. The homework exercise helps students recognize some of these challenges.

If people don't have the time to learn about climate change, they are likely to accept the ideas of the political leaders and influential people they trust. Those leaders may only see some of the information, may have reasons to not want to see societal change, or may have beliefs about religion or science that conflict with the conclusions of climate scientists. All of these factors contribute to a variety of opinions about the causes of climate change. Yale and George Mason Universities have conducted opinion polls with the general public over several years and have identified six different categories of beliefs. Although the percentage of the population in each category changes slightly with the news reports, there are people who are alarmed and concerned about the problem, people who are confused or not interested in learning more, and people who doubt or are convinced that we should not make any changes to accommodate any natural shifts in temperature. Your students' parents probably fall into all six categories. The student exercises in this activity and the other activities in this module are designed to help you provide science-based information, allow students to understand these concepts and debate the interpretations, and engage them in thinking carefully and completely about the issue.

Exploring Solutions

The information about climate change is important and interesting, but students will likely want to know that there are people, communities, organizations, and nations who are currently doing something about the problem. Rather than being fearful of the future, students can adopt a problem solving approach to climate change. Community and business leaders first consider what is likely to happen in the future. If the potential changes could be bad and the risk of doing nothing is high, they are motivated to do something to reduce that risk. If the changes will happen to other people (living far away or in the future), the discussion may turn on what is our obligation to them? If we accept the concept of sustainability, we believe we should give others the same opportunities and resources that we have enjoyed.

> The "2: Exploring Solutions" presentation could be shown on the same day if the first portion goes quickly, or could be saved for a second period. After explaining mitigation and adaptation, several examples of real communities taking action are provided. The role play activity in Part B allows students to identify with community members with different ideas about climate change and discuss potential solutions they could take.

Most climate change ***mitigation*** strategies involve reducing emissions or increasing sequestration of greenhouse gases, and mostly methane and carbon dioxide. By understanding the sources of these gases in the atmosphere, people can think about how to move these compounds somewhere else, or not produce them in the first place. Increasing energy efficiency to reduce combustion of fossil fuels and reducing our reliance on products or systems that currently depend on fossil fuels will be helpful. Some communities, such as Aspen, Colorado, are already taking action to help people reduce energy consumption with improvements in public transportation and building efficiency. In addition, churches and businesses are participating in programs like the 10% challenge to encourage their members to conserve resources, reuse products, and reduce their use of energy.

Producing energy without fossil fuels, with ***renewable resources***, will help reduce atmospheric carbon. A great deal of information is available about ***biomass***, nuclear, solar, and wind power, and some communities have already explored and implemented these technologies. For example, communities in Kansas are powered by wind energy and communities in Vermont are powered by wood.

In addition to reducing the amount of carbon released into the atmosphere, actions that can increase forest cover can help sequester carbon. Reforestation and afforestation projects, managing forests to optimize carbon sequestration while meeting other management goals, and avoiding large wildfires through appropriate vegetation management could all be solutions. Technologies that capture and store carbon are also being developed, which could allow us to continue to burn some plentiful fossil fuels.. But in the end, it may be important for students to consider what is enough? What amount of resource use allows us to be content? What contributes to happiness? And how many of us can the Earth support?

Any of these solutions can be steeped in nuance that will make them appropriate in some places and not in others. The simple strategy of eating less meat is a good example. Cows from feedlots in Kansas are fed corn grown with fertilizers made from fossil fuels. The meat is shipped by trucks and trains across the continent. The system depends on petroleum. Deer and cows that eat twigs and grass produce meat that does not contribute as much to atmospheric carbon, but the expense of this meat may mean that people will choose to eat less of it. Students will be able to explore the pros and cons of ***product life cycles*** in Section 4 of this module.

In addition to considering how to reduce atmospheric carbon, communities around the world are planning and implementing climate change ***adaptation*** strategies. This process involves understanding projected climate impacts, assessing human and natural systems that are at risk of negative impacts, and determining ways to lessen those impacts. Adaptation projects may take the form of new infrastructure, health programs, disaster preparedness, and agricultural and forestry practices.

Getting Ready

Download the "2: Explaining the Evidence" and "2: Exploring Solutions" slide presentations from [*insert url*]. Review the presentation, background information, and presentation notes to decide how much you wish to present.

Make copies of student pages, after determining which options you will use for Part A.

Doing the Activity

Part A

1. Begin by explaining to students that people have different levels of knowledge and different viewpoints on climate change. Some information that we hear or read is based on scientific evidence, while other information is based on opinions or beliefs, which may or may not be supported by scientific evidence. Since we are in a science class, our focus will be to learn how most scientists understand climate change. We will also discuss the range of opinions held by the public because this will help us consider potential actions that communities might be able to agree on implementing.

2. Distribute the "Fact or Fiction" student page and ask students to read the statements and judge which statements they think are supported or unsupported by scientific evidence.

3. Once students have completed the worksheet, ask them what they thought about the statements. Was it easy or hard to decide the answers? Have they heard some of these statements about climate change either from the news, friends, family, or in class?

4. Provide an overview climate change science and multiple perspectives, either with the "2: Explaining the Evidence" slide presentation or another resource.

5. Depending on your available time, student ability, and preference, choose one of two options:
   <u>Option 1: Group Work</u>
   a. Organize the students into groups of four, and give each group one of the "Analyzing Perspectives" student page (one per student).
   b. Explain that each group has been given a different short paragraph about climate change to read. As a group they should use the questions on the "Analyzing Perspectives" student page to assess the paragraph and the conclusion.
   c. When the groups are finishing up, make sure to visit each group and ask them to explain their thinking about the conclusion and how they rephrased the conclusion to better represent what the scientific

community thinks about climate change. Help the groups as needed to arrive at science-based conclusion.

d. Ask students to count off in fours within their individual groups. Pair the same numbers together and reform the groups so that each group now has one person from each of the four paragraphs. In the new groups, ask each student to spend one minute describing the initial conclusion, why someone might arrive at that conclusion, and how they rewrote the statement to be more accurate.

Option 2: Individual Homework

a. Give each student at least one of the "Analyzing Perspectives" student pages. For homework, students should read the paragraph(s) and answer the questions to assess the information and conclusion.
b. When students return to class, have volunteers share how they rewrote their conclusion to be more accurate. Make sure to cover each student page you distributed.

6. In a class discussion, review some of the common pitfalls of the conclusions the students assessed.
   a. If these conclusions don't represent the scientific consensus about climate change, why do some people believe them?
      - *People may have partial and missing knowledge about the issue. It is easy to focus on one piece of evidence and miss others. People hear, remember, and understand information that makes sense to them.*
   b. Besides scientific knowledge, what other things do you think influence the way people feel about climate change?
      - *People filter information through their view of the world, values, and beliefs (political, religious, and cultural).*

Part B

1. Explain that despite their different perspectives, it is still important for people to work together in a community. Today, students will have the opportunity to practice talking to people with different perspectives.

2. Use the "2: Exploring Solutions" slide presentation to share information about the ways communities and nations are changing behaviors and adapting to climate change. This information can also be shared from your experience.

3. Create groups of at least four students. Ten role cards representing a range of views about climate change are provided, so you can select the most relevant roles for your local context and for the number of students in your class. The ten roles have been separated into 4 groups; select at least one role from each group to ensure a diversity of perspectives is represented in each student group.

4. Explain the process of the role play based on the "Facilitator Instructions" student page and ask for volunteers or assign students in each group to be the facilitator, recorder, and timekeeper. Give the facilitator the "Facilitator Instructions" student page. Give the recorder the "Group Notes" student page, flip chart paper, and markers.

5. Distribute one role from the "Climate Change Role Cards" and one copy of the "Role Play Guide" to each student. Explain to students that the ideas for actions they develop and support during the exercise should be consistent with their assigned role.

6. Rotate among groups to assist the group facilitator and to ensure students are on task.

7. Once all the groups are finished, ask each group to present their plan to the class and explain how they made their final decision.

8. Lead a class discussion about the experience of the role play, the advantages and disadvantages of working with people with different perspectives, and how the students think communities might talk about climate change.

9. Ask students to look again at the statements about climate change that they examined at the beginning of the lesson and confirm what statements are supported by evidence. Review the answers with students, and make sure to clarify any remaining questions or misunderstandings.

Enrichment

Have students create a few questions that they could use to interview at least three adults (e.g., family, neighbors) to learn more about their knowledge and views on climate change. Students should summarize what they learned in a short paper.

Resources

Climate Change: Evidence, Impacts, and Choices: Answers to Common Questions about the Science of Climate Change
National Research Council, 2012
http://nas-sites.org/americasclimatechoices/files/2012/06/19014_cvtx_R1.pdf
This booklet summarizes the current state of knowledge about climate change, explains some impacts expected in this century and beyond, and examines how science can help inform choices about managing and reducing the risks posed by climate change.

Climate Literacy Guidelines: The Essential Principles of Climate Science
US Global Change Research Program, 2009
www.globalchange.gov/resources/educators/climate-literacy
This guide presents information for individuals and communities who want to learn about climate, impacts of climate change, and approaches to mitigation and adaptation.

Misconceptions about Science
University of California Museum of Paleontology
http://undsci.berkeley.edu/teaching/misconceptions.php
This portion of the Understanding Science website is dedicated to addressing misconceptions of the scientific process and includes a list of scientific terms that students might misunderstand.

Skeptical Science: Getting Skeptical about Global Warming Skepticism
John Cook, Global Change Institute at the University of Queensland
www.skepticalscience.com
This website reviews scientific, peer-reviewed literature to help explain climate change and to address common misconceptions about climate change.

Southeast Region Technical Report to the National Climate Assessment
Keith Ingram, Kirstin Dow, and Lynne Carter; 2012
http://downloads.usgcrp.gov/NCA/Activities/NCA_SE_Technical_Report_FINAL_7-23-12.pdf
This report summarizes the scientific literature that addresses climate impacts on the southeastern United States with a focus on literature published since 2004. Includes a chapter that specifically examines climate change and forests.

Teaching Controversy
Mark McCaffrey, 2012. The Earth Scientist 28(3): 25-29.
http://www.nestanet.org/cms/sites/default/files/journal/Fall12.pdf
The author discusses why teachers should not present climate change as a "theory" open for debate, but instead should focus on helping students understand climate change and the supporting scientific research. This article is part of a special issue on climate change education from the journal of the National Earth Science Teachers Association.

Yale Project on Climate Change Communication
Yale University
http://environment.yale.edu/climate
This website provides several reports, videos, and other resources that help explain research related to public knowledge and perceptions of climate change.

Your Warming World Interactive Map
New Scientist
http://warmingworld.newscientistapps.com
This interactive map allows users to click on any location on the planet and see a graph that shows differences in surface temperatures from 1880 to the present, relative to average temperatures for the three decades from 1951 to 1980.

**Several additional climate change information and education resources are found in the Appendix, along with formal and informal curricula.

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Fact or Fiction

Name: ___________________

Please circle whether you think each of the following statements is or is not supported by scientific evidence. You can also circle that you do not know.

1. **The Earth's climate is already changing.**

   Supported by science | Not supported by science | I don't know

2. **Climate change will affect regions of the Earth differently, with some areas becoming wetter and others becoming drier.**

   Supported by science | Not supported by science | I don't know

3. **The impacts of climate change will not really impact people or the systems we depend upon (such as food, water, places to live, etc.)**

   Supported by science | Not supported by science | I don't know

4. **Sea level rise is caused by the polar ice caps melting.**

   Supported by science | Not supported by science | I don't know

5. **Burning fossil fuels is the only cause of climate change.**

   Supported by science | Not supported by science | I don't know

6. **The annual melting of arctic sea ice or glaciers is evidence of climate change.**

   Supported by science | Not supported by science | I don't know

7. **The greenhouse effect is a natural process that supports life on Earth.**

   Supported by science | Not supported by science | I don't know

8. **Most scientists disagree about the causes of climate change.**

   Supported by science | Not supported by science | I don't know

Analyzing Perspectives – Natural Causes of Climate Change

Name__________________________

Imagine your friend Emily tells you she has been learning about the causes of climate change from reading and listening to news reports, searching the internet, and talking with friends. All the information she has learned is **accurate and science-based**. However, the conclusion Emily makes using this information is **NOT** supported by science. Here's what Emily said:

> Climate has changed in the past, and those changes were caused by several factors or natural forces. Natural factors include variations in the Earth's orbit around the Sun, volcanic eruptions, solar flares, greenhouse gas concentrations, and other factors. In particular, concentrations of greenhouse gases, like carbon dioxide, have naturally fluctuated over time. The amount of carbon dioxide emitted from the human activities is a tiny fraction of the total carbon cycling through the atmosphere, land, and oceans. Natural carbon dioxide emissions are 766 billion tons per year; human carbon dioxide emissions are only 20 billion tons per year. This current fluctuation in climate is similar to historic climate changes because human activities have not added that much carbon dioxide to the atmosphere. Therefore, climate change is a natural process that human activity is not impacting.

1. What were your initial thoughts as you read the paragraph?

2. What assumptions does Emily make to arrive at her conclusion?

3. What science-based information is relevant, but missing, from what Emily learned?

4. What would you say to Emily? REWRITE the conclusion to be more accurate, based on the additional information that challenges the conclusion.

Analyzing Perspectives – Human Causes of Climate Change

Name___________________________

Imagine your friend Jamie tells you he has been learning about the causes of climate change from reading and listening to news reports, searching the internet, and talking with friends. All the information he has learned is **accurate and science-based**. However, the conclusion Jamie makes using this information is **NOT** supported by science. Here's what Jamie said:

> Many factors affect the global climate of the Earth. The key factor to consider regarding climate change is carbon dioxide. By burning fossil fuels, such as oil, natural gas, and coal, we have increased the amount of carbon dioxide in the atmosphere and disrupted the carbon cycle. The level of atmospheric carbon dioxide is higher now than it has been in over 800,000 years. This increased amount of carbon traps more of the radiation reflected off the Earth's surface, which amplifies the greenhouse effect. In addition, land-use changes have altered vegetation patterns around the globe. Deforestation has resulted in fewer trees to remove and store, or sequester, carbon through photosynthesis. These land-use changes have also disrupted the carbon cycle. The impact of human activities on the carbon cycle is so large that it completely overshadows any natural causes of climate change. While natural factors have played a role in the past, current and projected climate changes are only the result of human activities.

1. What were your initial thoughts as you read the paragraph?

2. What assumptions does Jamie make to arrive at her conclusion?

3. What science-based information is relevant, but missing, from what Jamie learned?

4. What would you say to Jamie? REWRITE the conclusion to be more accurate, based on the additional information that challenges the conclusion.

Analyzing Perspectives – The Greenhouse Effect

Name___________________________

Imagine your friend Micah tells you he has been learning about the greenhouse effect from reading and listening to news reports, searching the internet, and talking with friends. All the information he has learned is **accurate and science-based**. However, the conclusion Micah makes using this information is **NOT** supported by science. Here's what Micah said:

> Several gases contribute to the greenhouse effect, including carbon dioxide (CO_2), methane (CH_4), ozone (O_3), and nitrous oxide (N_2O). These gases absorb heat radiating off of the earth and trap that heat within the atmosphere.. Greenhouse gas emissions have increased since the Industrial Revolution, which has amplified the greenhouse effect. Scientists have noted that this rise in greenhouse gases coincides with rises in overall global temperature. According to existing climate models, global temperatures are expected to rise anywhere between 2 and 11.5 degrees Fahrenheit by the year 2100. Results of global temperature changes of this magnitude include: sea level rise, increase in ocean water acidity, decrease in snowfall and permafrost, and changes in precipitation. The greenhouse effect is a negative and harmful process because it is warming the planet and creating climate change.

1. What were your initial thoughts as you read the paragraph?

2. What assumptions does Micah make to arrive at her conclusion?

3. What science-based information is relevant, but missing, from what Micah learned?

4. What would you say to Micah? REWRITE the conclusion to be more accurate, based on the additional information that challenges the conclusion.

Analyzing Perspectives – Effects of Climate Change

Name__________________________

Imagine your friend Jayden tells you she has been learning about the effects of climate change from reading and listening to news reports, searching the internet, and talking with friends. All the information she has learned is **accurate and science-based**. However, the conclusion Jayden makes using this information is **NOT** supported by science. Here's what Jayden said:

> After analyzing climate observations, measurements, and data collected around the world, most climate scientists agree that the average surface temperature of the Earth is increasing. This is known as global warming. Most scientists also agree that human activities, which are increasing atmospheric levels of greenhouse gases, are partially responsible for this warming. As a result, the entire planet is and will continue to warm in the years to come. This warming will affect weather patterns around the world, changing climate averages and changing extremes in temperature and precipitation. The greenhouse gases that are causing global warming are found in the atmosphere, and the atmosphere surrounds the entire globe equally. Therefore, the everywhere on Earth will be hotter and drier.

1. What were your initial thoughts as you read the paragraph?

2. What assumptions does Jayden make to arrive at her conclusion?

3. What science-based information is relevant, but missing, from what Jayden learned?

4. What would you say to Jayden? REWRITE the conclusion to be more accurate, based on the additional information that challenges the conclusion.

Climate Change Role Cards

Group 1	**Casey** You are very concerned about climate change; you believe it is happening and that it is caused mostly by human actions. In particular, you know that burning coal, natural gas, and oil for energy production is increasing the amount of carbon dioxide in our atmosphere, which is causing climate change. You believe that people need to take immediate and substantial action to reduce atmospheric carbon dioxide and to adapt to projected changes in temperature, precipitation, and weather events. This is not a political issue to you but a matter of the maintaining life on Earth. You heard about a tree planting campaign and you are interested in starting something similar in your town.
	Morgan As a religious youth leader in your community, you have strong faith and believe that God created the world and will take care of the Earth. At the same time, you believe that humans have the responsibility for their actions. You believe that climate change is happening and it is mostly due to human actions. And, you are greatly concerned about the impacts of climate change in your community, such as extreme weather and its effects on both people's health and the surrounding forests and wildlife. You have spent much time thinking about climate change and it is a big concern for you. You wish to work with people together for future generations.
	Kendall You work for a local environmental organization called Carbon Sink. You are very concerned about climate change; you believe it is happening and that it is caused mostly by human actions. In particular, you know that burning coal, natural gas, and oil for energy production is increasing the amount of carbon dioxide in our atmosphere, which is causing climate change. You believe that people need to take immediate and substantial action to reduce atmospheric carbon dioxide and to adapt to projected changes in temperature, precipitation, and weather events. This is not a political issue to you but a matter of the maintaining life on Earth. You heard about a tree planting campaign and you are interested in starting something similar in your local community.
Group 2	**Justice** You work for a small grocery store in your town. You believe that climate is changing due to a combination of natural causes and human activities. Humans are playing a large role in increasing and accelerating natural climate change. You think that practical solutions are needed at the local, regional, national, and global level. However, you are concerned that people might not be willing to make large behavior changes for a benefit that will not happen in the near future. You think that climate change solutions need to have more immediate benefits as well so that people will be more likely to adopt them. For example, reducing fossil fuel use saves people money, reduces air pollution, and helps reduce atmosphere carbon dioxide.
	Quinn You believe that climate is changing due to a combination of natural causes and human activities. Humans are playing a large role in increasing and accelerating natural climate change. You think that practical solutions are needed at the local, regional, national, and global level. However, you are concerned that people might not be willing to make large behavior changes for a benefit that will not happen in the near future. You think that climate change solutions need to have more immediate benefits as well so that people will be more likely to adopt them. For example, reducing fossil fuel use saves people money, reduces air pollution, and helps mitigate climate change.

Climate Change Role Cards (cont.)

Group 3	**Kris** You believe that climate change is happening, but the climate has been changing for a long time and humans have nothing to do with it. Therefore, there is no way for people to affect climate change because they have no control over the climate. This theory about human-influenced climate change is all part of the political agenda and scientists are supporting it to fund their research. We really shouldn't be spending so much effort researching causes and solutions for climate change. We should focus on people's ability to adapt to this new climate; for example, by changing food production strategies or by improving community preparedness and disaster response.
	Harper You have strong faith and believe that God created a perfect world and there is nothing humans can do to affect it. In your mind, climate has been changing for a long time and humans have nothing to do with it. Therefore, there is no way for people to affect climate change. This theory about human-influenced climate change is part of the political agenda and scientists are supporting it to fund their research. We really shouldn't be spending so much effort researching causes and solutions for climate change. We should focus on people's ability to adapt to this new climate; for example, by changing food production strategies or by improving community preparedness and disaster response.
Group 4	**Taylor** You believe that the science on climate change is not at all clear. The news reports are contradictory. For example, when there is a heat wave, the headlines read "Global Warming Effects Being Felt in the South!" But when we have a colder winter than usual, the headlines changes to "Snow in the South? Who Said the Climate is Changing?" There are scientists on both sides of the issue making different conclusions about whether it is happening, the causes, and the effects. Once the science has been settled, and the news media are consistent, you will be receptive to either side. You are just not sure that we should be taking action on climate change when there is so much that is still being debated.
	Jordan You work for an international company and have traveled to different countries. You believe that the science on climate change is not at all clear. The news reports are contradictory. For example, when there is a heat wave, the headlines read "Global Warming Effects Being Felt in the South!" But when we have a colder winter than usual, the headlines changes to "Snow in the South? Who Said the Climate is Changing?" There are scientists on both sides of the issue making different conclusions about whether it is happening, the causes, and the effects. You are just not sure that we should be taking action on climate change when there is so much that is still being debated.
	Sam You believe that climate change is happening but you are not sure whether it is due to natural or human causes. You are also unsure whether or not a change to the climate is a bad thing. You do not spend much time thinking about climate change and it is not a big concern for you. However, you are greatly concerned about other environmental issues, such as air pollution in your city and its effects on both people's health and the surrounding forests and wildlife. Also, you think natural resource conservation is a good idea to ensure both healthy environments and productive economies for future generations.

Role Play Guide

Before the Role Play

Read the scenario and your role card. Fill out the "My Role" Box to prepare your introduction when the role play begins.

Scenario

You are a resident in the medium-sized town of Centerville. Due to your knowledge, leadership, and social standing, the mayor of Centerville has appointed you to the Climate Change Adaptation and Mitigation Council. The mayor is concerned about the potential impacts of climate change and recognizes that there are a variety of beliefs and perceptions across the community. While you may not agree about climate change issues, you are all interested in community well-being, environmental health, and a thriving local economy.

Your task is to work together to determine a solution to help the community address climate change in some way. First, you will brainstorm at least four potential action ideas. Then your group will select the best idea based on a set of criteria and develop that idea into a more detailed action plan to present to the mayor.

My Role

Name:

Your ideas and opinions about climate change:

One initial idea for an action you are willing to support:

During the Role Play

You will evaluate the suggested actions by using the following criteria.

Criteria for Selecting an Action[1]

<u>Greenhouse Gas Emissions Reduction Benefit</u>

Does the proposed action reduce greenhouse gases? In what way—by sequestering atmospheric carbon dioxide or by reducing emissions?

<u>Technical Feasibility</u>

Does technology already exist to implement the proposed action? How easy is this action going to be to implement?

<u>Cost Efficient</u>

How expensive will this action be? Will it result in long-term savings? How will the project be funded?

<u>Trade-offs</u>

How will citizens feel about this action? Who benefits from this action? In what ways? Who might be negatively impacted from this action? In what ways?

[1]Evaluation criteria adapted from American Public Transportation Association, 2011.

Group Notes

Criteria Table

Criteria Actions	GHG Emissions Reduction Benefit	Technical Feasibility	Cost Efficient	Trade-offs	Additional Comments
Action 1:					
Action 2:					
Action 3:					
Action 4:					
Action 5:					
Action 6:					

Facilitator Instructions

As the group's facilitator, you will guide the group the process of getting to know each other, brainstorming action ideas, evaluating action ideas, and selecting one idea that everyone agrees upon.

Before the Role Play

1. Give your group 2-3 minutes to read the scenario and their role card.

During the Role Play

1. Remind your group that it is important to be respectful to other group members and to allow others to speak without interruption.

2. Ask each group member to spend 1-2 minutes introducing him/herself and to share one action they are willing to support. The recorder should take notes, either on the Group Notes pages or on large paper.

3. After all group members have spoken, explain that the group will now spend about 15 minutes considering the suggested actions by using a set of criteria and questions. Use the criteria to guide a discussion about each proposed action. Ensure that all group members have a chance to speak. You should have at least four actions to discuss, and the recorder should take notes for the group.

4. After discussing all the options, spend 10 minutes discussing the following questions. Work together to narrow down the suggestions to one action you all find agreeable.
   a. Are there some actions that most of you can agree upon?
   b. For those you disagree upon, what is it about the action that is causing disagreement? Can some aspect of the action be modified or improved to make it more agreeable?
   c. Which action is most suitable for the community?

5. Develop a detailed outline that describes your selected action. Create a poster to show the key points of your plan to use during your group presentations. You should provide enough explanation that the mayor will understand
   a. What the action is and how it relates to climate change,
   b. Who it will affect in the community, and
   c. How and where it will be implemented.

3: Atlas of Change

Students will use two online resources, the Climate Change Tree and Bird Atlases from the United States Forest Service, to explore the effects of climate change on the future distributions of suitable habitats for forest types, tree species, and bird species in southeastern United States.

Subjects
Agriculture Education, Biology, Environmental Issues / Ecology, Environmental Science, Forestry / Natural Resource Management, Integrated Science, Language Arts, Life Science

Skills
Comparing and contrasting, determining causes and effects, interpreting, predicting

Materials from Module
Module: Student pages, "3: Understanding Models" slide presentation available at [*insert url*]
Other: Computers with Internet connection, poster materials

Time considerations
Two to three 50-minute periods

Related Activities in other PLT Guides
Climate Change and Forests (*Focus on Forests* module)

Objectives
Students will explain how modeling is used to project potential climate changes.
Students will describe the effects of climate change on forest ecosystems and bird populations.
Students will apply importance values of forest health to climate change data.
Students will communicate to others the potential future distributions of forest types, tree species, and bird species.

Assessment
Have students write a summary of their poster presentation, which can be assessed for understanding of potential climate change effects on future distributions of forests, trees, and bird species.

Background

Projected changes in ***climate***, such as temperature and precipitation, are likely to affect forests in the United States. Because ***climate change*** is gradual, and because moisture availability has a strong influence on what plants are able to grow, various factors can be assembled in a computer ***model*** to help suggest what might happen in the future. Models combine data from many variables and use mathematical equations to approximate processes and systems over time.

<u>Climate Change Tree Atlas</u>

Researchers with the United States Forest Service (USFS) are using models to examine the extent of potential climate change effects on forest ***ecosystems***. Forest Service scientists have combined Forest Inventory Analysis records for nearly 3 million trees and data on 38 environmental variables (e.g., average annual precipitation, mean July temperature, elevation) in the Climate Change Tree Atlas to predict whether or not a particular tree ***species*** or forest type will have suitable ***habitat*** in any given area by the end of the 21st century (Iverson, Prasad, Matthews, & Peters, 2008). The Atlas includes information on 134 species of trees in the eastern United States, which are grouped into ten forest type categories and are displayed on maps that can be accessed on the Atlas website. The forest type indicated on the maps is the dominant forest type found in a given location. There may be other non-dominant forest types present in the area but they are not displayed on the map. The seven forest types found in the Southeast are described in the "Southeastern Forest Types" student page. Each forest type and its ***biodiversity*** depend on the environmental characteristics of that area. As climate changes, the locations of suitable habitat for these forest types will also change.

<u>Climate Change Bird Atlas</u>

The animals that live in these forests will also be affected by climate changes. Many bird species, for example, are closely linked to particular stages of forest development or forest types because of their food and nesting requirements. Much like the forest ecosystems, the habitats of these bird species depend on the environmental characteristics. Depending on how climate change modifies their habitat, these bird species might flourish or might decrease in population. Thus, scientists developed the Climate Change Bird Atlas to correlate 147 bird species with tree species and to track their relative habitat gain or loss (Matthews, Iverson, Prasad, & Peters, 2011). This atlas combines bird population data (from the Breeding Bird Survey) with 11 environmental variables and tree species potential change data to generate models of current and future suitable habitat.

<u>Global Climate Models and Emission Scenarios</u>

Both atlases rely on a wealth of data that scientists have been collecting for many years. Collecting and assembling existing environmental data is challenging but possible, since those factors are observable and measurable in nature. Scientists took records of rainfall, for example, and averaged them over a region to be able to include existing precipitation data. Similarly, scientists sampled tree and bird species in forest plots and bird survey routes across the region, identifying and measuring the relative abundance of the species. Using these combined data, scientists can develop models of current habitat for tree and bird species.

To estimate how changes in future climate conditions may affect these species, however, scientists first have to model what those changes might be, which is also a challenge. The atlases use three climate models to project changes to the climate:

1. Parallel Climate Model (PCM)
2. Hadley CM3 Model (Hadley)
3. Geophysical Fluid Dynamics Laboratory (GFDL) Model

These climate models combine atmospheric, ocean, sea-ice, and land-surface variables to represent historical climate variability and then project future climate changes due to human-induced greenhouse gas ***emissions***.

The three climate models represent the range of climate predictions, with PCM having the mildest degree of change and Hadley having the biggest degree of change.

Greenhouse gas emissions are important components of our changing climate. However, because future emission levels depend on national policy and decisions that people will make, it is hard to predict emission levels. To show the range of possibilities, the atlases apply two emission scenarios to each model:

1. High emission scenario, where few conservation efforts are taken to reduce atmospheric carbon dioxide
2. Low emission scenario, where significant efforts are taken to reduce atmospheric carbon dioxide

Generally, the Hadley-High model shows the worst-case scenario (greatest effects from climate change, with highest emissions) and the PCM-Low is considered to show the best-case scenario (least effects from climate change, with lowest emissions). These two models can be used to understand the full range of possible outcomes. In addition, the atlases include results from both emission scenarios using an average from all three models. Based on which models are used as inputs, results for forest types, tree species, and bird species ranges will be impacted accordingly.

Getting Ready

Download the slide presentation "3: Understanding Models" from [*insert url*] and review it to determine how much you wish to present to students.

Watch the "An Introduction to Climate Change Atlas: How Does it Work?" video (4 minutes, 19 seconds at www.nrs.fs.fed.us/atlas, see link in right column under Atlas Tutorial Videos), and go through both student pages to familiarize yourself with the atlases and the activity.

Make copies of the student pages, one for each student. Alternatively, provide students with the link (*insert url*) to open the "Atlas Guide" student page from their computer station, enabling students to utilize active hyperlinks and to type directly into the document.

Doing the Activity

1. Remind your students of the variables that affect climate and the ways those variables are changing.

2. Ask students how soon these changes might affect forest ecosystems in your state. Discuss and record their ideas about the ecological impacts of climate change so you can revisit them at the end of the activity.

3. Introduce models and how models are used to simulate processes and systems over time. You may wish to use the slide presentation, "3: Understanding Models" to do so. Introduce the US Forest Service Bird and Tree Atlas as an online program that uses models to project changes to forest types, tree species, and bird species. The slide presentation is designed to help you make this introduction.

4. As a class, watch the "An Introduction to Climate Change Atlas: How Does it Work?" video (see Getting Ready).

5. After the video, answer any student questions and revisit sections of the video where students felt confused.

6. Explain to the students that they will explore both climate change atlases to consider current and potential future distributions of tree and bird species in the southeastern United States. They will use their information to create a poster of how one type of forest might change over the next century.

7. Distribute one copy of the "Atlas Guide" student page to each student (or provide link to access student page online). Based on computer availability and student ability, decide whether students will work individually or small groups (2-3 students) and whether the Atlas Guide will be completed in class or as homework. Organize students accordingly, review instructions, and ask students to complete the worksheet.

8. After students have completed both parts of the Atlas Guide, explain that they will work in groups to create posters that communicate what they have learned about projected changes to climate and suitable habitat for tree and bird species in their state. Divide the class into five groups. Student groups can use any relevant responses from their completed Atlas Guide, but they will likely need to revisit the Atlases and explore more about their specific topic to complete the poster. Each poster should contain important text, graphics, and pictures. Posters can be created on poster boards, sheets of bulletin board paper, or flip chart paper. You can also create posters using presentation software and have them printed. This format is typically used for poster presentations at professional conferences and meetings (see Resources section for more information).

Posters should contain the following information:

Group 1: Projected Changes in Temperature and Precipitation

- Using the Hadley High and PCM Low models, describe and compare how temperature and precipitation could change in your state.

Group 2: Current Forest Types

- Describe each forest type found in your state. Make sure to include common tree species, important forest uses and benefits, and general locations.

Group 3: Projected Changes to Forest Types

- Using the Hadley High and PCM Low models, describe and compare how suitable habitats for forest types in your state are projected to change. You don't have to repeat what Groups 1 and 2 are doing.

Group 4: Tree Species

- Describe the tree species you identified as winners/losers in your state. Include information about their natural history that might provide clues about why they will thrive or suffer in the future climate scenarios.

Group 5: Bird Species

- Describe the bird species you identified as winners/losers in your state. Do these birds require forested habitat for nesting or feeding? (Hint: look at the Life History tab for each bird species description from Cornell (available through the external links on the individual bird species page, or directly at www.allaboutbirds.org.) How do you think these species might be affected by changes to their habitats? You might want to consult with Group 4.

9. Ask students to put up their posters around the room. Give students time to read each of the other groups' posters.

10. Have a class discussion about the different forest types in your state and how they may be affected by climate change.

a. Was there a trend in how the different forest types might change?
b. Which forest types seemed to be affected the most in these models?
c. Are bird species likely to be affected by changes to forested ecosystems? How?
d. How could these changes affect people?
e. What do you think the state's forests will look like in 100 years?
   - *The models in the atlas are based on the year 2100. However, a change in suitable habitat does not mean that already established trees will immediately die. Due to the long lifespan of trees,*

these changes will be gradual and it is not possible to estimate the exact timeframe for when they will occur.

f. How did the different models influence the results about projected change? Why is this important to understand?
g. If you were a reporter writing a news story about the projections given in the Atlas, which model(s) would you discuss in your story? How could your choice affect public understanding about climate change impacts?

11. Ask students to consider their initial ideas about the ecological impacts of climate change. Would they change their answer, given what they learned by using the atlases?

Enrichment

Have students identify two tree species found in their neighborhood and then use the Tree Atlas to explore both species and the potential effects of climate change on their suitable habitat. Could the neighborhood do anything to help these trees continue to thrive?

Organize a poster presentation for others to see the students' posters. The posters could be displayed at a science night or at some other community event. Ask students to attend and stand by their posters to explain the information and answer questions.

Resources

All About Birds
The Cornell Lab of Ornithology
www.allaboutbirds.org
This comprehensive website about birds and bird watching contains lots of information to aid in bird identification.

Creating Effective Poster Presentations
North Carolina State University
www.ncsu.edu/project/posters
This website shows how to create professional poster presentation using different software programs and provides examples of effective posters.

Global Dynamical Climate Models, What They Are and What They Are Not (Part1)
NOAA Geophysical Fluid Dynamics Laboratory
www.gfdl.noaa.gov/e-media-produced-by-gfdl-ccvp#cm101
This 10-minute video provides an introduction to global climate models, explaining in simple terms how the models work to predict climate changes in the future.

How Do Climate Models Work?
Koshland Science Museum Website
https://koshland-science-museum.org/explore-the-science/earth-lab/modeling
This easy-to-understand slideshow uses simple graphics and text to address four main topics: how climate models work, how climate models are tested, what has caused global climate change, and what are the future impacts of climate change.

Southern Forests for the Future
World Resources Institute Website
www.seesouthernforests.org

This website contains maps, photos, case studies, and other information to highlight key features and trends for southern forests.

References

Iverson, L. R., Prasad, A. M., Matthews, S. N., & Peters, M.P. (2008). Estimating potential habitat for 134 eastern US tree species under six climate scenarios. *Forest Ecology and Management, 254,* 390–406. Retrieved from www.treesearch.fs.fed.us/pubs/13412

Matthews S.N., Iverson L.R., Prasad, A.M,. & Peters, M.P. (2011). Potential habitat changes of 147 North American bird species to redistribution of vegetation and climate following predicted climate change. *Ecography, 260*, 1460–1472. Retrieved from http://www.treesearch.fs.fed.us/pubs/39841

Atlas Guide

Name(s):

This guide will provide instructions for using the Climate Change Tree Atlas and Bird Atlas. Follow the steps and answer the questions on this worksheet.

Things to Know Before You Get Started

As you navigate the website, look for this green help button. You can click this button to get more information about specific areas of the website.

The Atlas uses three global climate models to show the range of projected changes in the year 2100, and for each model, you can view projections under two carbon emission scenarios. In addition, the Atlas includes results for both emission scenarios using an average from all three models.

<u>Global Climate Models</u>

1. Parallel Climate Model (PCM)
2. Geophysical Fluid Dynamics Laboratory (GFDL) model
3. Hadley CM3 model (Hadley)

<u>Emission Scenarios</u>

1. High emission scenario (where little conservation efforts are taken to reduce atmospheric CO_2)
2. Low emission scenario (where significant efforts are taken to reduce atmospheric CO_2)

In total, you can view projected changes in eight combinations of models and scenarios:

1. Hadley-High
2. Hadley-Low
3. PCM-High
4. PCM-Low
5. GFDL-High
6. GFDL-Low
7. Avg. of 3-High
8. Avg. of 3-Low

Generally, the Hadley High model shows the worst-case scenario (greatest effects from climate change, with highest emissions) and the PCM-Low is considered to show the best-case scenario (least effects from climate change, with lowest emissions). We will explore and compare these two models to assess the full range of possible projected changes.

Part 1—Tree Atlas

- Open the Climate Change Tree Atlas on your web browser: www.nrs.fs.fed.us/atlas/tree.

First, we'll look at projected temperature and precipitation changes in your state and see how the assumptions in the different models and scenarios change these projections.

- Click the ***Summary of Predictors*** button on the right side of the screen under *134 Species Combined/Compared.*

- Click ***Maps of actual predictors used in the model*** under *Predictor Values*.

- By default, this page will load maps under the Average Temperature tab in the Climate category. The map on the left shows Average Annual Temperature under current climate conditions and the map on the right shows projected Average Annual Temperature under the Hadley-High model.

1. Read the map legends and compare the two maps. According to the Hadley High Scenario for the end of this century, how is the average temperature in your state expected to change compare to Current conditions?

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- By hovering over the **Climate Scenario Menu** button, you should see that, in addition to the Current map, there are eight different maps to view for average temperature. Each map is created using a different combination of global climate models and emission scenarios.

- By clicking on the **Climate Scenario Menu** button, you can select one of the models for one map and compare it to another model in the other map. In the map on the left, choose PCM-Low. Keep the map on the right set for Hadley-High.

2. Describe the difference between the average temperature maps for the PCM-Low and Hadley-High scenarios.

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- Now click the ***Precipitation*** tab. *Note: Each time you click a new tab, the maps will reset to Current and Hadley-High.*

3. Read the map legends and compare the two maps. According to the Hadley High Scenario for the end of this century, how is the precipitation in your state expected to change compare to Current conditions?

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- By clicking on the ***Climate Scenario Menu*** button in the map on the left, choose PCM-Low. Keep the map on the right set for Hadley-High.

4. Describe the difference between the precipitation maps for the PCM-Low and Hadley-High scenarios.

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- Next, compare the Current map with maps based on the Average of three High scenarios and the Average of three Low scenarios for average temperature and precipitation.

5. Summarize the differences that could occur in the southern region in terms of changes in temperature and precipitation. Are there any places under either average model where are temperature and precipitation projected to remain the same?

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Next we'll look at potential changes forest types in the eastern United States under different climate scenarios.

- Look just below the brown menu bar at the top of the page and click ***Tree Atlas*** in the *You are here* line.

- Click on the ***Combined Species Output*** button on the right of the screen under *134 Species Combined/Compared.*

- Click the ***Modeled Future Habitats*** tab, and then click ***Potential Changes by Forest Types****.* Just as before, you can compare two maps and change the models that were used to make the maps.

- The Current Forest Inventory and Analysis (FIA) map on the left side identifies the forest types found in your state, using the data collected on forest inventory plots by the US Forest Service. The forest type shown in a particular map location is dominant forest type found there. In any given location, there may be other non-dominant forest types present that are not represented on the map.

6. Read the legend for the Current FIA map. Describe the forest types found in your state (general locations and abundance).
Hint: Click the green help button at the top of the page to see the full titles for forest types and the list of the major tree species in each.

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- Use the ***Climate Scenario Menu*** button to compare how suitable habitat for the forest types in your state will change under the different models and scenarios. Make sure to look at the Hadley-High and PCM-Low scenarios. You can also click the ***View Summary of Changes*** button to compare several scenarios at once.

7. Looking at the Hadley-High and PCM-Low scenarios, how might the suitable habitat for forest types be affected by climate change in your state?

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Next we'll look at potential changes for individual tree species in the eastern United States under different climate scenarios.

- Look just below the brown menu bar at the top of the page and click ***Combined Species Outputs*** in the *You are here* line.

- Click the ***Modeled Future Habitats*** tab.

- Click ***Potential Species Winners and Losers by State*** and click on your state in the map.

- After clicking on your state, you will be directed to a sortable table of species and their relative abundance of a species (called Importance Value).

- The top row of the table contains abbreviations for each column in the table. Hover your mouse over each abbreviation to see the full title for each column. In columns 6-10, you'll see the titles for different climate models and emission scenarios.

- By clicking each model, you can determine which species would lose the most and least potential suitable habitat under that particular model. You can sort the list from high to low numbers, or low to high numbers, by clicking the small orange arrow.
  Hint: A species with a negative number is projected to lose suitable habitat; a species with a positive number is projected to gain suitable habitat. The species with a zero either do not grow in your state or are not projected to change in the future.

8. For each model, name the top three species that would gain suitable habitat in your state. Fill in your answers in the table below.

	Hadley-High	PCM-Low	Average of 3 Models-High	Average of 3 Models -Low
1 (highest score)				
2				
3				

From your table, which species are most commonly shown as gaining suitable habitat?

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9. For each model, name the top three species that would lose suitable habitat in your state. Fill in your answers in the table below.

	Hadley-High	PCM-Low	Average of 3 Models-High	Average of 3 Models -Low
1 (lowest score)				
2				
3				

From your table, which species are most commonly shown as losing suitable habitat?

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Part 2—Bird Atlas

Next we'll look at potential changes for bird species in the eastern United States under different climate scenarios.

- Click the back arrow to return to the **Species Winners and Losers by State** page, then click ***Climate Change Atlas*** in the *You are here* line to return to the main Climate Change Atlas web page.
- Click ***Bird Atlas*** under ***Browse the Atlases*** in the pale yellow box on the right side of the page. The first page shows a sortable list of all the bird species included in the atlas.
- Click ***Combined Species Outputs***.
- Click ***Modeled Future Habitats***.
- Click ***Potential Changes by State,*** and then click on your state in the map.
- Click on ***Winners and Losers at a Glance*** and maximize the table that appears in a new window. This table contains values for the current and modeled future relative abundance (incidence value) of different bird species in your state.

10. Which three bird species are currently most abundant in your state?
Hint: Look in the Current Modeled column (labeled CUPRD), where the bird species are sorted in descending order by abundance value.

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- The columns to the right of the Current Modeled contain data for the eight climate scenarios. The values in those cells represent the difference from the modeled scenario and the current model.

11. For the models below, name the top three species that would gain the most suitable habitat in your state. The top ten species that gain abundance are highlighted in green. Fill in your answers in the table below.

	Hadley-High (HadHi_D)	PCM-Low (PCMlo_D)	Average of 3 Models-High (GCM3Hi_D)	Average of 3 Models –Low (GCM3lo_D)
1 (highest score)				
2				
3				

From your table, which species are most commonly shown as gaining suitable habitat?

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12. For each model, name the top three species that would lose the most suitable habitat in your state. The bottom species to have a loss in abundance are highlighted in pink. Fill in your answers in the table below.

	Hadley-High (HadHi_D)	PCM-Low (PCMlo_D)	Average of 3 Models-High (GCM3Hi_D)	Average of 3 Models –Low (GCM3lo_D)
1 (lowest score)				
2				
3				

From your table, which species are most commonly shown as losing suitable habitat?

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Next, we'll look more closely at the bird species projected to gain or lose potential habitat in your state.

- Close the window with the winners and losers at a glance.
- Return to the main ***Bird Atlas*** page using the You Are Here line under the brown menu bar.
- Sort the table of bird species by clicking on the ***Common Name*** header.
- Choose one of the species projected to gain potential habitat in your state, and click on that bird's common name in the list.

- The links provided under ***External Species Links*** will allow you to hear the calls of the individual bird species, see video of the birds in their natural habitat, and provide more information.

13. Using the links under External Species Links, complete the following table:

Common name:
Scientific name:
Habitat description:
What do these birds eat?
Where do these birds nest?

- Return to the main ***Bird Atlas*** page using the You Are Here line under the brown menu bar.

14. Now choose one of the species projected to lose potential habitat in your state, click on that bird's common name in the list, and use the ***External Species Links*** to complete the following table:

Common name:
Scientific name:
Habitat description:
What do these birds eat?
Where do these birds nest?

Southeastern Forest Types

The list below describes the seven forest types found in the southeastern United States and contains the species included in each forest type, as categorized by the USDA Forest Service.

Loblolly/Shortleaf Pine forests include sand pine, shortleaf pine, spruce pine, Table Mountain pine, pitch pine, pond pine, loblolly pine, Virginia pine, and sweetgum.

Loblolly pine

Pitch Pine Cone and Foliage

Shortleaf Pine and Cone

Longleaf/Slash Pine forests are dominated by two pine species native to the Southeast—slash pine and longleaf pine.

Longleaf Pine Forest

Slash pine needles and cone

Oak/Gum/Cypress forests include Atlantic white-cedar, bald cypress, red maple, water hickory, water locust, sweetgum, water tupelo, Ogeechee tupelo, swamp tupelo, overcup oak, swamp chestnut oak, nuttal oak, willow oak, and American elm.

Overcup Oak

Pond Cypress

Sweetgum Foliage

Oak/Pine forests include eastern redcedar, shortleaf pine, longleaf pine, eastern white pine, loblolly pine, Virginia pine, scarlet oak, southern red oak, water oak, northern red oak, post oak, black oak, and bluejack oak.

Water Oak

Oak/Hickory forests include bitternut hickory, shellbark hickory, shagbark hickory, black hickory, common persimmon, black walnut, sweetgum, yellow-poplar, white oak, swamp white oak, scarlet oak, northern pin oak, southern red oak, cherrybark oak, shingle oak, overcup oak, bur oak, blackjack oak, swamp chestnut oak, chinkapin oak, nuttall oak, willow oak, chestnut oak, northern red oak, Shumard oak, post oak, black oak, black locust, and sassafras.

Bitternut Hickory

Elm/Ash/Cottonwood forests include red maple, river birch, pecan, sugarberry, hackberry, white ash, black ash, green ash, sycamore, water elm, eastern cottonwood, peachleaf willow, black willow, winged elm, American elm, cedar elm, slippery elm, and rock elm.

Eastern Cottonwood

Maple/Beech/Birch forests include black maple, striped maple, red maple, sugar maple, mountain maple, yellow birch, sweet birch, gray birch, blue ash, waterlocust, honeylocust, black walnut, black cherry, black locust, and American basswood.

Sweet Birch

Honeylocust

Section 2: Forest Management and Adaptation
Forests can be managed to thrive in a changing climate.

Forests cover about 60 percent of the land area in the southeastern United States. Several species of pine trees dominate these forests, growing in both tree ***plantations*** and natural forests on private and public lands. Based on landowner management objectives, pine forests can be managed to provide multiple benefits, including timber products, ***non-timber forest products***, wildlife ***habitat***, water quality protection, soil stabilization, recreation, aesthetics, and land stewardship. Private landowners own 86 percent of southern forests, one-third of which are owned by companies (Butler & Wear, 2011). Privately-owned pine forests typically grow trees for timber production, creating wood products such as paper, lumber, ***biomass*** for energy, and more. As a region, the South produces more wood than any other single nation, accounting for 58 percent of the total U.S. wood production and almost 16 percent of the world's production.

Many of these private forests are intensively managed to produce profits from pines. Forest managers working with forest industry select seedlings of superior genetic stock, apply fertilizer once or twice during the forest cycle to supplement the soil nutrients, and watch carefully for evidence of insects and disease. Depending upon the tree and the location, trees can be ***harvested*** for pulp and paper in as little as 15 years.

Non-industrial private forest landowners may also grow trees for profit, though they usually invest fewer resources in their trees and it takes longer for them to reach a marketable size. If the price of wood is low, these landowners might keep growing trees in the hope that the price will go up next year.

Climate variability and uncertainty, of course, also play a role in ***forest management***. How the forest is managed may increase its health and ***resilience*** to a changing climate, enabling the trees to withstand less rain, hotter summers, shorter winters, or more insect pests. Since trees grow for many years, forest landowners do not have the option of changing the crop they plant and since forests cover many acres they do not irrigate them. Forest landowners must adapt to the ***weather*** and ***climate*** for the duration of their forest. They have several strategies they use to do so.

Activity 4, **Managing Forests for Change**, invites students to develop a concept map of a southern forest, recalling the factors that affect tree growth. Videos of forest landowners or supplemental scenario cards provide information about the priorities and opportunities three landowners have to manage their forests. Students will be given management solution cards and climate scenarios for their forest. They will modify their concept map to explain how those management strategies affect tree growth, how climate change may affect tree growth, and how management options may help the forest thrive. Their concept maps should be useful tools for showing relationships between forests, climate change impacts, and strategies people can use to manage forests. Students may wish to return to these maps during the summary activities in Section 5.

Activity 5, **Mapping Seed Sources**, introduces students to ongoing research into the genetics of loblolly pine. Because of variation between the eastern and western populations of native pines, some families grow faster than others and some resist drought better. Students will be asked to graph survival and height data from six different families in three sites to determine which traits are associated with which population. Of course if a combination of these ideal traits were to be found in the same tree, the seedlings would be well-suited for producing growth despite a future climate of less rainfall.

Both activities help convey opportunities we have to adapt to climate change and continue to produce wood products from forests in the South.

Potential Areas of Confusion

Our pilot tests and the literature suggest there are several topics in this section that may be sources of confusion for students, based on their assumptions, prior experience, or knowledge. You may be able to use questions to uncover this confusion and steer students toward the following clarifications:

Assumption or Confusion	More Adequate Conception
Nature knows best. Leaving forests alone is the best way to manage them.	There are many advantages to wild, natural forests. If landowners wish to maximize certain components of their forest, such as recreational trails or timber, the forest can better meet those objectives with management. Dead trees next to parking lots could be removed for safety and seedlings with superior genes can be planted. In the face of climate change, natural evolution may not be able to accommodate the potential changes.
Foresters know best. Trained professionals can determine how to make any property profitable.	Professional foresters and researchers have many solutions to increasing the growth of trees and making forests more profitable. In some areas, such as where soil nutrients are depleted, management may help, but still not overcome severe problems. As climate varies, however, changes such as insect pests, exotic diseases, hurricanes, drought, and flood will make it challenging for the best foresters to predict the best management plan. Helping the forest resist problems and flourish despite the changes may be the best solution.
Forests are here for everyone.	The forested landscape provides many ecosystem services that everyone benefits from, such as improved air quality, groundwater recharge, and biodiversity. Many forests in the Southeast are privately owned, however, and those landowners determine how to manage their forest. They may want a patch of wild nature for their family or steady income from harvesting timber. The United States does not have a legal mechanism for managing private property unless the landowners have entered their property in a land trust or conservation easement.
Genetically modified organisms are evil.	Farmers have been selecting the best plants and domestic animals for breeding for eons. Forest geneticists also select traits, fertilize cones with selected pollen, and save the seedlings with the best form and fastest growth. All of the crops that provide food for millions of people have been grown from selected seeds. Changing the genetic structure of an organism with genes from other species is a different issue.

Key Concepts in This Section

The background information in these two activities explains the key concepts that students should gain:

- Southern pine forests are very productive and privately owned by the forest industry and individuals.
- Forest management strategies are used to increase tree growth and enhance forest health.
- In an uncertain climate future, thinned forests should be more resilient.
- Genes naturally found in trees that tolerate drought and grow quickly are being used by forest researchers to develop improved seedlings.

References

Butler, B. J., & Wear, D. N. (2011). Chapter 6: Forest ownership dynamics of southern forests. In D. Wear & J. Greis (Eds.), *Southern forest futures project*. Asheville, NC: USDA Forest Service. Retrieved from http://www.srs.fs.usda.gov/futures/reports/draft/Frame.htm

4: Managing Forests for Change

This activity allows students to explore the connections between forests, climate change impacts, and management strategies for creating resilient forests. Students diagram these connections through concept mapping.

Subjects
Agriculture Education, Biology, Environmental Issues / Ecology, Environmental Science, Forestry / Natural Resource Management, Integrated Science, Life Science

Skills
Identifying Relationships and Patterns, Determining Cause and Effects; Predicting

Materials
Module: Student pages, videos and “4: Building a Systems Map” slide presentation available at [*insert url*]
Other: Scissors, tape

Time Considerations
Two 50-minute periods

Related Activities in Other PLT Guides
Who Owns America’s Forests? (*Focus on Forests* module);Climate Change and Forests (*Focus on Forests* module); Every Tree for Itself(*PreK-8* Guide)

Objectives
Students will describe forest ownership and management objectives in the southeastern U.S.
Students will describe how forests are managed to meet environmental and economic objectives.
Students will identify natural events that impact forest health and productivity and how these might change, given climate projections.
Students will explain how forest management decisions can impact forest health and productivity.
Students will visually organize the relationships between changes in climate, changes in forests, and management decisions in a concept map.

Assessment
Use the student answers for the “Forest Profile” student page to assess understanding of forest management.

Use student presentations and concept maps to assess understand of the relationships between changes in climate, changes in forests, and management decisions.

Background

Good ***forest management*** practices are important for ensuring the health and stability of forests. To achieve their objectives, ***foresters*** develop management plans detailing the practices and activities they will apply to the forested land. These activities may include replanting practices, selection of ***species***, tree ***harvesting*** and ***thinning*** schedules, fertilizer applications, steps to enhance wildlife ***habitat*** or ***biodiversity***, actions to protect water quality, and ***vegetation*** management to reduce ***wildfire*** risk.

When thinking about the forest as a system, it is easy to see why management activities could be needed to maximize the landowner's objectives. This activity begins with students generating a concept map of the forest system. The slide presentation "4: Building a Systems Map" is provided to help you teach this important skill.

In many areas of the South, it is increasingly important for forest managers to consider ***climate change*** when choosing management strategies, as variations in climate will be affecting pine forest productivity and ***forest health*** during the lifetime of trees that are already in the ground and the ones being planted today. The importance of these activities can be seen in the forest system concept map, too. Although temperature changes in the Southeast are not expected to be as large as in the North, much of the region may experience a rise in average temperature, which can alter the growing season length, fire patterns, and ***species*** migration. Precipitation patterns will also change. Climate ***models*** suggest that some areas will receive less rain and others will receive more. Much of the additional precipitation may not fall during the growing season, however, or may arrive in storm events. When rain comes during large storms, much of the water runs into surface drainage areas rather than filtering into the ground. Impacts on southern pine forests will vary. For those places that experience warm and moist conditions, they could have longer growing seasons, which could allow tree productivity to increase. Alternatively, prolonged droughts could stress trees, decrease productivity, and impact tree survival. For a good introduction to visualizations of climate models, see the Activity 3: Atlas of Change.

Additional factors influenced by climate will also impact southern pine forests, such as soil moisture, wildfire, insects, and diseases. Changes in precipitation and temperature influence ***evaporation*** and ***groundwater*** levels, both of which affect the amount of water stored in soils and trees. Longer fire seasons and hot, dry conditions could increase the frequency and severity of wildfires. If changing climate conditions create a higher frequency of severe hurricanes across the region, that allow forest insects, such as southern pine beetles, to expand their range. These insects can be very destructive, especially when trees are stressed by drought and extreme ***weather*** events. ***Invasive species*** from tropical areas are also likely to increase their range. Climate conditions, tree growth, and forest stressors are interrelated. For example, reduced summer precipitation and increased temperature during the growing season will result in increased moisture stress, as less water is available for the trees. This in turn could reduce growth rates, change wood quality, and increase the risk of disturbance by fire, insects, and disease.

As climate conditions change, there are many ways to approach forest management, but no one strategy will work for every forest. In general, it will be important to create resilient forests—those that can resist and recover from disturbance—that are better able to adapt to change. Given enough time and ***genetic diversity***, species can biologically adapt and thus survive changes in environmental conditions. However, rapid changes in the environment make it less likely that plant and animal populations will be able to change with new conditions. ***Adaptation*** to climate change includes actions taken by humans to avoid, benefit from, or deal with actual or expected climate change impacts. These include some management options that may enhance the ability of forests to adapt to climate change such as:

- **Thin crowded forests:** As stands develop and become increasingly crowded, competition becomes intense. Individual trees can become stressed as they compete for resources such as light, water, and nutrients. Stressed trees are more susceptible to disease and insect attack. In addition, overcrowded stands are more susceptible to mortality from wildfire. Removing selected trees from the forest reduces the stress on other trees, enhances growth of the remaining trees, and decreases the risk of wildfire, insect attack, and disease.

- **Promote genetic diversity:** Forests with high levels of genetic diversity (different species or different families of a single species) are better able to withstand environmental changes than forests with low genetic diversity. Species and families differ in their ability to grow under different climate conditions. For example, longleaf, sand, and shortleaf pines are more drought tolerant than loblolly and slash pines. See Activity 5: Mapping Seed Sources for more information on genetic diversity within a species.
- **Maintain a diversity of age-classes:** Forest vulnerability to different hazards or stresses vary by age. For example, older stands are more vulnerable to insect attack than young stands. Maintaining a diversity of age classes across the landscape decreases the vulnerability of an area to a single stress or hazard.
- **Prescribed fire:** Many southeastern ***ecosystems*** are adapted to the periodic, low-intensity fires that have always occurred naturally. Without periodic fire in the ecosystem, the forest ***understory*** can become filled with dense vegetation, fallen trees and limbs, and fast-growing trees. Over time, the absence of fire changes the make-up of an ecosystem and creates hazardous fuel loads, so that when a fire does occur, it is more intense and damaging. To reduce wildfire risk and to maintain or restore fire-dependent ecosystems, trained professionals plan and set ***prescribed fires*** in natural areas under appropriate weather and safety conditions.
- **Creating and maintaining markets for wood:** Part of the challenge of managing forests is finding markets for the wood. For example, despite the importance of thinning crowded forests (explained above), many pine ***plantations*** (and natural forests) all over the South are not being thinned because there is not a readily available market for small saplings and brush. Where ***biomass*** energy facilities are available, forest landowners may be able to take advantage of this market.

Getting Ready

Make copies of student pages (one per student). Download the slide presentation "4: Building a Systems Map" from [*insert url*] and review it to determine how much you wish to present to students.

Cut concept map pieces on the "Visualizing the Connections" student page.

Doing the Activity

Part 1: Visualizing the forest connections

1. First, students will work as a class to develop a concept map of a managed forest. If students are not familiar with creating concept maps, review an example or use the slide presentation "4: Building a Systems Map." Important concepts should be in boxes or circles, and lines or arrows are used to show how these items are connected in cause and effect relationships. If a change in one box directly causes a change in the other, then an arrow is added to represent that relationship. The type of change is characterized by adding a + or - sign to the arrow. See the presentation for details.

2. Pass out the "Visualizing the Connections" student page (one per student). If you have not pre-cut the concept map pieces, instruct students to do so now.

3. To ensure that students do not get bogged down in connections which are not emphasized in this activity, have the class construct the map together on a class board or using the slide presentation. Following the numbered order of the cards, call on students to add the next card and arrows, or introduce the card in order and ask for a volunteer to determine where the arrows go. Students should follow along on their handout, taping cards in place and drawing arrows. A completed concept map is on page xx. It may be helpful to talk through the relationships by saying, "When tree density is increased, competition is increased, which reduces tree growth. If tree density is reduced, competition is less severe, trees obtain more nutrients, and grow more."

Part 2: Making management decisions

1. During the second part of the exercise, students will use their basic map to decide how to manage their forest in a future with changing climatic conditions. Divide the class into three equal groups and assign each group a forest case. Each case has a corresponding video available online at [*insert url*] where a southern landowner or manager briefly describes the forest and how it is managed to meet their objectives. If the video is not available, distribute the Forest Scenario description to each group.
   a. Private industrial landowner managing loblolly pines for timber production
   b. Private family landowner in central Georgia managing mixed pine
   c. Public land agency restoring longleaf pine ecosystem

4. Ask students to watch the video describing the options and limitations that go along with their assigned forest (or read their scenario) and complete the "Forest Profile" student page.

5. Next, distribute all four management solutions cards and two of the climate change scenarios to each group. Give the groups 15 minutes to discuss the following questions:
   a. What do you think will happen to this forest if nothing is done? Why?
   b. How do the management strategies change the forest concept map?
   c. How might this forest be affected by climate change, and what management strategies might become important?
   d. What would you do if you were in charge of managing this forest and knew the climate might be changing?

6. For each climate change scenario, ask each group to adapt their concept map to illustrate the connections between projected climate changes, forest growth, and forest management. They will need to add new cards based on their scenarios and management strategies.

7. Ask each group to present their scenarios, their predictions for how their forest would be affected by change, and the management strategies they chose to address the changes. The slide presentation includes some sample results for these scenarios.

8. After all groups have presented, discuss the following questions as a class:
   a. What are some general trends for how climate change might affect forests?
   b. Which management practices could help landowners increase forest resilience?

Enrichment

After working through the various scenarios in this exercise, instructors may want to make a more thorough concept map using information from the background section or from other exercises in this module. While doing this can be a useful exercise, there is a strong possibility that the final product will be a very complicated map, containing many variables and a tangle of connections. While such a map may not help students see the behavior of a system, it will help students to understand that there are truly a multitude of connections in the forest ecosystem. In light of such connections, it is not surprising how even seemingly insignificant management decisions can have broad effects that ripple through the system.

Have students visit your state's forest agency website, where they can explore management programs for state.

Resources

America's Longleaf
America's Longleaf Restoration Initiative
http://americaslongleaf.org
This website describes an initiative to restore and conserve longleaf pine ecosystems. Also includes lots of publications, photos, and maps that provide information on longleaf pine ecosystems.

Forest Encyclopedia Network
USDA Forest Service Southern Research Station and Southern Regional Extension Forestry Office
www.forestryencyclopedia.net
This website has several encyclopedias that provide scientific knowledge and tools related to forest ecosystems and management.

My Land Plan: Resource for Woodland Owners
American Forest Foundation
http://mylandplan.org
This website serves as a resource for individual woodland owners to aid in the management of their land. The site offers a Land Plan tool that includes a mapping feature and customized information for each piece of woodland.

North Carolina's Emerging Forest Threats: Management Options for Healthy Forests
Lisa Jennings, USDA Forest Service, 2012
www.sgcp.ncsu.edu:8090/documents/NCFS_brochure_8x11.pdf
This pamphlet uses information summarized from over 300 peer-reviewed science papers found in the USDA Forest Service's TACCIMO tool to describe threats to North Carolina's forests and natural resources and management options to address those threats. *(Change to Southern Region Emerging Forest Threats when available)*

Southern Forest Futures Project
USDA Forest Service
www.srs.fs.usda.gov/futures
This website provides summary reports, a webinar, and other resources related to a multi-year research effort that forecasts changes in southern forests between 2010 and 2060.

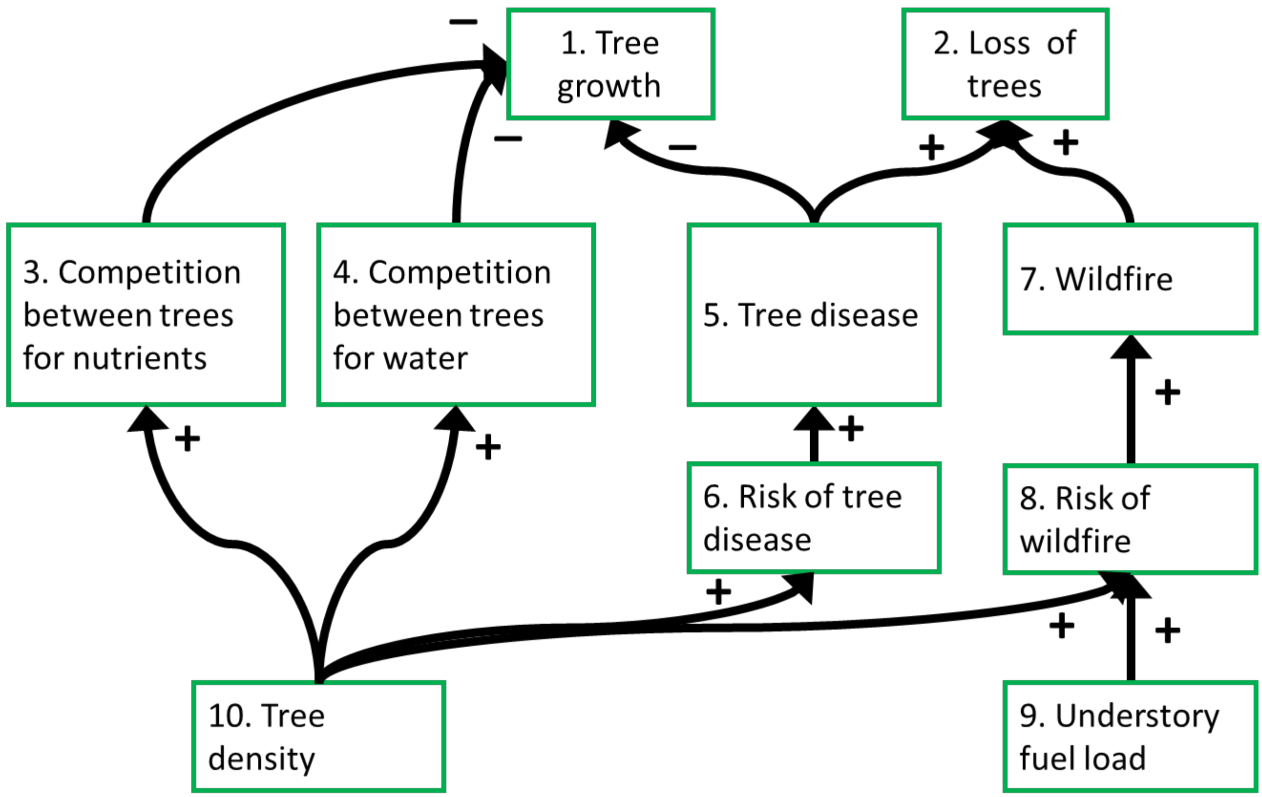
Systems Thinking Essay
The Center for Ecoliteracy.
www.ecoliteracy.org/essays/systems-thinking
The short essay describes how ecological understanding requires shifting to a new way of thinking.

Systems Thinking in Action
Pegasus in Communications
www.pegasuscom.com
This website provides tools, resources, and information about systems thinking and organizational learning. Information about some of the basic concepts and tools used by these approaches can be found under the "Learn More" tab on the website homepage.

PINEMAP fact sheets on management when available

Basic Map Completed:

At the end of the first step of the exercise, the class should produce a concept map like the one below. Note that this map does not show all of the connections or variables involved in managing a forest. Students may suggest other connections that make sense. In that case, explain to the students that this map is intended to emphasize specific connections that are particularly important when attempting to address the management challenges covered in this exercise.



Visualizing the Connections

Cut out the cards below and use them to construct a concept map of a managed forest. Use the clues provided on the cards to help you figure out where the cards should go and how they should be connected. Note that the map of the managed forest that you are about to construct will not depict all possible connections. Specific connections are chosen to emphasize relationships that play particularly important roles in the context of this exercise. As you improve your understanding of forest management, you may be able to identify other connections not included here.

Map area

1. Tree growth

2. Loss of trees

Basic map cards

3. Competition between trees for nutrients (One arrow out)

4. Competition between trees for water (One arrow out)

5. Tree Disease (Two arrows out)

6. Risk of disease, (One arrow out)

7. Wildfire (One arrow out)

8. Risk of wildfire (One arrow out)

9. Fuel load (One arrow out)

10. Tree density (Four arrows out)

Change and management cards

Temperature

Fungi

Precipitation

Groundwater

Length of growing season

Temperature

Thinning

Prescribed fire

Genetic diversity

Applied fertilizer

Forest Scenario 1: Private Industrial Landowner

Here at Stand 153 in Rayonier's southeastern Mississippi district, rows of loblolly pine stretch as far as the eye can see. On the 989 acre property, all the trees are the same age and were planted in 2001 just after we harvested 25 year old loblolly pines. Those trees were 75 feet tall and about 20 inches in diameter at breast height. These trees were processed at a lumber mill and made into boards to be used in furniture, buildings, or other wooden products. Although we are most interested in growing trees quickly that have strong, flexible cellulose fibers, we also know that our property provides important ecosystem services to the region. The rain that falls on this land seeps into the underground aquifer and recharges the groundwater that the people in the region drink. We protect water quality through using Silviculture Best Management Practices (BMPs). Deer, turkeys, and bear wander these woods eating berries, nuts, and young sprouts. We lease the opportunity to hunt on these lands to people in local communities each year.

Although these trees are all the same species, they are not genetically identical. Every other row comes from a different family, which provides genetic diversity in this forest. They all don't grow at the same rate because they all have a slightly different genetic makeup. That also means they may not all be as susceptible to drought or pine beetle invasions. This is one way we help plan for future uncertainties.

We planted this stands with 622 seedlings to an acre, which means each tree has a 7 x 10 foot spacing around it. That works for young trees and means they put more energy in to growing tall instead of growing branches. But when the trees are about 6 inches in diameter and 40 feet tall, they start competing with each other for nutrients and water. We thinned this stand in 2008 by taking out every 5^{th} row. By thinning the forest we help the remaining trees grow quickly. We took the trees we thinned to our mill where they were chipped and ground to purify the cellulose. We use cellulose to make rayon fabric and food additives, such as the thickeners used in low fat ice cream and salad dressing. Our cellulose is also used to make the hard plastic used in football helmets and toothbrush handles and the flexible cellophane used in envelope windows and tape..

We also apply fertilizer to this stand two times while these trees are growing – usually once when the trees are planted and once around age 15. The fertilizer we use provides more nitrogen to the trees, which is what this soil lacks because it is so sandy. The fertilizer is made from petroleum and is probably going to get more expensive as our oil reserves decrease. We do not apply more than we need, but some of the nitrogen probably ends up in the nearby streams. We monitor those streams to make sure we are not polluting them.

THIS DENSE PINE FOREST WILL BE THINNED WHEN THE TREES GROW LARGER AND BEGIN COMPETING FOR NUTRIENTS, SUNLIGHT, AND WATER. PHOTO BY LARRY KORHNAK.

Forest Scenario 2: Private Family Landowner

I'm Mr. Earl Barrs, and my wife and I own 1,500 acres of forest in central Georgia, called Gully Branch Tree Farm. Our land is home to several different ecosystem types including loblolly pine plantations and natural loblolly and short leaf pine stands, as well as stands of upland and bottomland hardwoods. We have ponds that provide habitat for catfish, bream, largemouth bass, and grass carp, and our forests are home to many bird species.

Gully Branch has uneven-aged forest stands, with some that contain ten years old trees and some that are over one hundred years old. The stands are selectively harvested when the trees reach merchantable age and are sold to pulp and lumber mills. We sustainably manage our forests for timber production, while enhancing wildlife habitat and water quality and reducing soil erosion. We have been using prescribed fire as a management tool in some locations of the forest to reduce understory vegetation and to increase wildlife habitat. We hope to expand our prescribed burning program in the future. In addition, we enjoy opening our land to students, teachers, community members, and others to teach people about well-managed working forests.

Since I planted these trees at 400 per acre, they will continue to grow better if I thin the stand. These trees were thinned 5 years ago. I was able to sell the trees I cut down to a woody biomass facility, so I pretty much broke even–it cost about as much to cut the trees as I made by selling them. The other advantage to thinning a forest is that it helps prevent a pine beetle problem. Pine beetles are always around. When it doesn't rain and the trees are stressed, the beetles have an easier time infesting a tree. If they can overwhelm a tree's defensive system, they can lay eggs. If enough beetles are successful at reproducing, and if the young beetles can find more stressed trees nearby, you could have an epidemic beetle outbreak in your forest. By thinning the trees, I'm hoping that each tree is strong enough to resist the beetles.

When I replant this stand I'm planning to plant fewer seedlings. I'll space them further apart so they compete less in the first few years. Maybe they'll grow more branches, and maybe I won't have to thin. I've been lucky because it rained last summer and the trees grew about ½ inch last year, which is typical for loblolly pines. But when it doesn't rain enough, the forest suffers. I can't irrigate, of course, that's impractical in a forest. So about all I can do is thin the forest and hope the remaining trees get enough rain to grow.

MR. BARRS SHARING INFORMATION ABOUT GULLY BRANCH TREE FARM WITH A TOUR GROUP. PHOTO BY LESLIE BOBY.

Forest Scenario 3: Public Land Agency

Welcome to the Blackwater River State Forest, located in northwest Florida. We are proud of our rolling hills, hiking and horse trails, lakes and rivers, and endangered species. All of these can be found on the 209,571 acres managed by the Florida Forest Service. This state forest, along with nearby forests in Conecuh National Forest and Eglin Air Force Base, makeup the largest contiguous longleaf pine forest in the world. Longleaf pine forests once dominated the Southeast, and many land management agencies are working to restore this ecosystem across the region.

The forest is home to over 2,500 species of plants and 300 bird species, including red-cockaded woodpeckers—an endangered species. They live in old longleaf pine trees, so it is our job to keep the longleaf forest healthy. Since longleaf pine is adapted to fire, we use fire to manage the forest. Actually, we try to mimic the types of fires that would have been frequently started by lightning, during our numerous thunderstorms in the summer. Because we are in control of these fires, and we start them under specified weather conditions, we call them prescribed fires. Fire helps keep weedy vegetation out of the forest and maintains the biodiversity that you see here.

By using prescribed fire regularly, we also reduce the risk of wildfire, which our neighboring towns and villages appreciate. They get smoke from our fires every now and then, but we do everything possible to lessen the impact on residents through proper planning and smoke management. Of course, burning depends on the weather. We can’t burn if it rains too much, but a drought would make burning dangerous. Ideal conditions for burning include recent rains so that the leaf litter is almost damp. A slight breeze (but not gusty winds) and low humidity also help. This combination allows a fire to catch but not take off. Also, it helps the smoke to rise and dissipate, and not settle in the low spots. Finally, we need a southerly wind to keep smoke off the interstate. In the years when we don’t get these conditions, we have to burn less often.

We mostly manage for ecosystem restoration. Since much of the land was previously planted in slash pine, we are harvesting those areas following Silviculture Best Management Practices (BMPs)to restore the longleaf pine ecosystems. Through multiple-use management, the Florida Forest Service manages for plants and animals that are endangered, threatened, or species of special concern; timber production and harvesting; watershed protection; wildlife habitat; and recreation.

LONGLEAF PINE ECOSYSTEMS ARE MANAGED WITH PRESCRIBED FIRE. PHOTO BY LARRY KORHNAK.

Forest Profile

As you watch the video or read the forest scenario, complete the chart below.

Names:

Ownership	
Location	
Size	
Forest Types, Species, Age Classes	
Management Objectives	
Management Strategies	
Other	

Management Strategy Cards

Thinning helps reduce competition between trees and promotes growth of the remaining trees. Thinning can increase the amount of water that each tree obtains and reducing stand density can reduce the risk of insects, disease, wildfires. In a changing climate, reduced stand density can facilitate the growth of remaining trees.
Prescribed fire is an important tool to reduce fuels and the risk of wildfire, reduce invasive plants and insects, and maintain native forest ecosystem health. However, changes in temperature, precipitation, and storm events could reduce opportunities to use prescribed fire safely. Wildfire risk will increase with elevated summer temperatures and reduced rainfall during the growing season. Heavy equipment like mulchers may be needed in high risk areas if prescribed fire cannot be used.
Increasing diversity within a species by selecting genetic traits for a future climate and within a forest by planting several species will help forest owners prepare for uncertainty. Multi-aged forests of multiple species will be at less risk than monocultures of one genotype and one age. Species with larger ranges, and therefore with the genetic potential to tolerate a wider variety of conditions, would offer less risk than species with narrowly defined ranges.
Fertilizing a forest stand could encourage more rapid tree growth where nutrients such as nitrogen are limiting, taking advantage of the increased carbon dioxide in the atmosphere. Some areas may experience increased depositions of nitrogen, however, and fertilized trees could develop smaller root areas and become more susceptible to drought stress.

Climate Scenario Cards

1. Warmer winter temperatures have caused an increase in tree fungi that cause disease.
2. Reduced summer rainfall has left less groundwater available for the trees.
3. Less rain fell but the understory grew thick and tall.
4. Increased temperatures have resulted in a longer growing season with high precipitation.
5. Increased storms have increased the likelihood of damaging damaged trees that will attract pests
6. Rapid changes to climate patterns have caused increased uncertainty regarding the amount of precipitation from year to year.

5: Mapping Seed Sources

Students use growth data from loblolly pine forests to identify genetically different populations and project where trees with certain characteristics are likely to thrive in changing climatic conditions.

Subjects
Agriculture Education, Biology, Biotechnology, Environmental Issues / Ecology, Environmental Science, Forestry / Natural Resource Management, Integrated Science, Life Science

Skills
Identifying Relationships and Patterns, Determining Cause and Effects, Data Analysis, Interpreting

Materials
Module: Student pages
Other: Graph paper or access to Excel

Time Considerations
Part A: One 50-minute class period

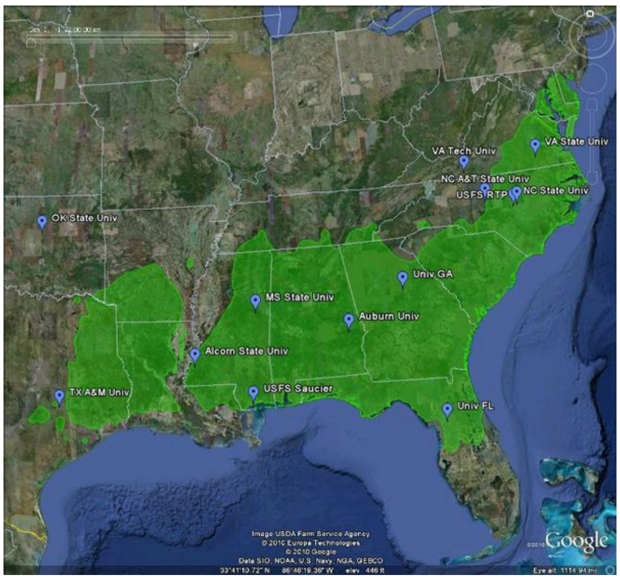
Related Activities in Other PLT Guides
Climate Change and Forests (*Focus on Forests* module)

Objectives
Students will be able to state why variations in growth can be seen across the range of loblolly pine.
Students will be able to identify where key traits originate, given population and climate data.
Students will be able to predict which characteristics will produce more wood under future climate conditions of less rainfall and warmer temperatures.

Assessment
Ask students to submit their responses on the worksheet and assess for accuracy of the identification of population source of each family and the response to the scenario.

Background

How a tree grows is a function of the environment and its genetic makeup. Some of the traits controlled by ***genes*** are growth potential, ability to tolerate drought, and disease resistance. Whether a tree gets full sun or too much shade, a lot of rainfall or drought, or exposed to a horde of tree-eating insects is a function of the environment. The genes involved in predicting traits such as tree growth number in the 100's to 1000's, and are not a single gene on one ***chromosome***, as is the gene controlling flower color in Mendel's peas. Because many genes are involved, it is more difficult to identify which genes control such traits. One way to do this is to test many different families of trees with the best average growth under different environmental conditions. When some of the important genes are identified, researchers use the suite of genes that occur in wild trees and breed them with trees from other populations to create new seedlings with the desired characteristics.



Loblolly pine is a tree native to the Southeast U.S. It grows from coastal Virginia, south to northern Florida and west to eastern Texas, in two populations, separated by the Mississippi river valley. The genetic makeup of these two populations is significantly different, though there is some blending at the edges of the river valley where pollen from the west manages to fertilize cones on the western edge of the eastern zone. This genetic difference occurred during the recent Ice Age when glaciers covered northern North America and pushed native plants and animals south. Some loblolly pines survived by moving into Florida and the Caribbean Islands. Other trees from the same ***species*** migrated into Mexico and Central America. While the trees were in these two areas, the genetic make-up of these two populations diverged. Individuals most suited to each ***climate*** reproduced more often and those with a less appropriate set of ***alleles*** reproduced less or died. As the glaciers receded, loblolly trees slowly returned to the current range in the southeastern US, with the western population moving up from Mexico and the eastern population from the Caribbean and south Florida.

In the western population, the trees tolerate drought and ***fusiform rust*** significantly better than those in the East. Compared with the western population, the eastern trees grow taller and faster with adequate rain. Forest researchers are looking for genes across both populations and testing which trees will tolerate the conditions that a future climate will bring to the region. They are also breeding trees with these superior characteristics to develop lines that will tolerate drought and still grow quickly. Since these traits are controlled by many different genes, the offspring from one parent from the western population and one from the eastern population will yield offspring that exhibit all possible ***phenotypes***. For example, some will be drought susceptible and fast growing, others more drought tolerant and fast growing. Researchers cross ideal parents and select the best offspring as seed sources for future generations.

In this activity, students will use tree height data from six families planted at three test locations across the entire range. By relating tree size and survival with average rainfall, they will be able to discover patterns of drought tolerance and growth and identify two distinct populations.

Getting Ready

Review the activity and the worksheet.

Make copies of the student handouts and worksheet for each student.

Set up Excel in the computer lab, or obtain graph paper for students.

Doing the Activity

1. Remind students that they have studied how genetic variation and natural selection affect populations of plants and animals. Ask them to recall some traits that are controlled by one gene with several alleles (*eye color in people and flower color in sweet peas*). Explain that other traits, such as body type or height in humans, are governed by a host of genes as well as environmental conditions. But even when the environment is controlled and people eat exactly the same thing, some people will grow differently than other people because of their genetic make-up. Trees are like that too.

2. Remind the students that the yield of wood from an acre of land is related to both the number of trees that survive to harvest and the size of the trees. For example, 200 tons of wood from one acre can come from 500 trees that are 90 feet tall or 800 trees that are 80 feet tall, even if they are all the same age and diameter.

3. Ask students what they already know about the traits that might be important in trees that are grown for paper and lumber, such as loblolly pine. This tree is grown in plantations across its range, from Virginia to Texas, and is also found in wild, natural forests. You might find these discussion questions helpful:
   a. What traits are important?
      - *Fast growth, straight growth, few branches, survival under stressful conditions, quick response to fertilizer, resistance to fire and disease.*

   b. How could people obtain these traits for their trees?
      - *If forest managers save the seeds from trees that have an excellent form, they can grow seedlings in a nursery and make those particular traits available to more forest landowners.*

4. Use the information in the Background to explain to students that there is genetic variation across the population of loblolly pine–some trees have the potential to grow quickly while other trees tolerate drought better. These differences are due to natural selection. For example, trees with greater drought tolerance will survive better in more droughty regions, which means they will reproduce more. In this way nature selects for trees adapted to thrive with less rainfall. Researchers study how well trees grow in many different areas of the South and look for the trees with the best traits. Forest researchers spend a lot of time in the woods measuring trees, too. They apply different types and rates of fertilizer and see which trees grow more quickly than others. Since they return to the same trees each year, they establish permanent plots in the forest, similar to those students used in Activity 7, Counting Carbon. Since the plots are of a known size, the researchers can measure this sample of trees and then estimate the growth of similar trees in a larger area. Because of these differences, trees from west of the Mississippi tolerate drought better than trees east of the river.

5. Ask students to work in groups or individually, based on how well your students can accomplish these tasks. As you distribute the student page, explain that the first column identifies the family – each family has the same genetic makeup. The remaining two columns provide the average survival as a percent of the original number of trees planted and the average height of surviving trees after ten years of growth in the field. Each row provides these data for each family. Researchers collect data just like these and then look for patterns and relationships to understand more about the trees and conditions in which they grow best. However, one key piece of information is missing from their data set—information about which population is the original source of the family genotypes (eastern or western). That is what students will be able to predict after graphing these data and looking at patterns.

6. Ask students to make three column graphs, one for each site, with the families on the X axis and percent survival and height on the Y axis. It may help to keep survival and height in two different colors. Ask them to look at the patterns and determine which families are responding similarly to rainfall and are probably

related. Which families came from the western population and which from the east? Completed graphs are on page 7.

Students should notice that at the site with an average of 50 inches of rainfall per year that all families have high survival and that families A, C and E are slightly taller than families B, D, and F. At the drier site with an average of 40 inches of rainfall per year the survival of families A, C, and E is poor while families B, D, and F do much better. The trees in families B, D, and E are slightly taller compared with A, C, and E during drought conditions.

7. Ask students the following questions:
   a. Why do you think all families have high survival and the best growth at an average of 50 inches per year of rainfall?
   b. Which families are likely to be from the western loblolly population and which ones from the east? Why?
   c. If you were a forest landowner today in TX, what family would you want to plant? If you were a forest landowner in GA what would you plant?
   d. In areas where less rainfall is likely in the future, based on climate change models, which families would be better able to survive? What are the disadvantages of planting a forest of only this family genotype?
   e. In areas where more rainfall is likely, which families should be planted? What are the disadvantages of this strategy?
   f. If you could pollinate eastern cones with western pollen, what types of trees would result? Which ones would be ideal in an uncertain climate?

8. Ask students to complete the writing assignment at the end of the student page, either in class or as homework.

9. Advanced students can graph survival on the Y-axis and height on the X-axis for each population. They can assess how well correlated survival and height are by conducting a linear regression in Excel. A correlation greater than 0.5 suggests that survival and height are well correlated, indicating that surviving trees on average are taller 50% of the time. A correlation of less than 0.5 is weaker, suggesting that survival and height are varying independently; surviving trees may be shorter or taller. Which trees would a tree farmer prefer to plant? See Teacher Answer Key on page 9.

Enrichment

Ask students to go to the Template for Assessing Climate Change Impacts and Management Options (TACCIMO) website (http://www.sgcp.ncsu.edu:8090) and explore the projected climate for your region. This is a site that enables foresters to assess the possible climate futures and make forest management projections. What genotype will be useful to help trees thrive in your area?

Resources

A Climate Change Atlas for 134 Forest Tree Species of the Eastern United States
Anantha Prasad, Louis Iverson, Stephen Matthews, and Matthew Peters; USDA Forest Service
http://www.nrs.fs.fed.us/atlas/tree
This searchable database provides information on 134 common trees in the eastern U.S. The key feature is the presentation of data for each species describing both the current distribution of that species and future suitable habitat based on climate change models.

Southern Pine Seed Sources, USDA Forest Service, General Technical Report SRS-44
Ronald Schmidtling, USDA Forest Service, 2001

www.srs.fs.usda.gov/pubs/2797
This report provides guidance on selection of seed sources for six species of southern pine trees.

Template for Assessing Climate Change Impacts and Management Options (TACCIMO)
USDA Forest Service
www.sgcp.ncsu.edu:8090
This web-based tool, intended for use by land managers, provides the most current climate change projections and research in an effort to link science to forest management and planning. Features include a geospatial mapping application, a searchable listing of peer-reviewed literature, and guides explaining how to use TACCIMO.

Trees Grow throughout Southeast with Help of UF
University of Florida
www.ufl.edu/2012/11/21/trees-grow-throughout-southeast-with-help-of-uf
This two-and-a-half minute video introduces the work of the Cooperative Forest Genetics Research Program at the University of Florida, where researchers study tree breeding to improve tree growth and disease resistance in order to meet increasing demands for wood products.

Add PINEMAP fact sheets on genetics when available

Forest Growth and Rainfall Data

Name ____________________________________

Imagine that forest landowners at three locations in the Southeast planted loblolly pine trees on their properties ten years ago. At each location, the landowners planted six different families of loblolly pine trees. Some of these families originated from western populations of loblolly pine forests and some families originated from eastern populations. For ten years, forest scientists collected data for the families at each site including rainfall, tree survival, and tree height.

The average annual rainfall at each property for years 1 to 10 was 40 inches/year at Site 1, 45 inches/year at Site 2, and 50 inches/year at Site 3.

The table below summarizes the results for survival and height for families at each site.

- Column A identifies the family.
- Column B is the average percent of the trees planted that are still alive after 10 years.
- Column C is the average height of surviving trees after ten years of growth.

	A: Family	B: % Survival at Year 10	C: Average Height at Year 10 (ft)
Site 1	A	40	20
	B	80	28
	C	20	18
	D	75	32
	E	10	25
	F	60	30
Site 2	A	80	44
	B	90	31
	C	75	39
	D	86	36
	E	40	45
	F	75	35
Site 3	A	90	48
	B	90	36
	C	88	45
	D	88	38
	E	92	50
	F	92	40

1. Use the data table to make three column graphs, one for each site. For each graph, place the families on the X axis. Percent survival and height will be on the Y axis. You will have two columns for each family. Include a key to indicate which column is percent survival and which column is height.

2. The data table is missing important information! We don't know which families came from the western population of loblolly pine trees and which came from the eastern population. Use your graphs and what you know about the average annual rainfall at each site to predict which families came from the west and which families came from the east.

For each family, write the original source of the genotype (east or west).

A: _____________

B: _____________

C: _____________

D: _____________

E: _____________

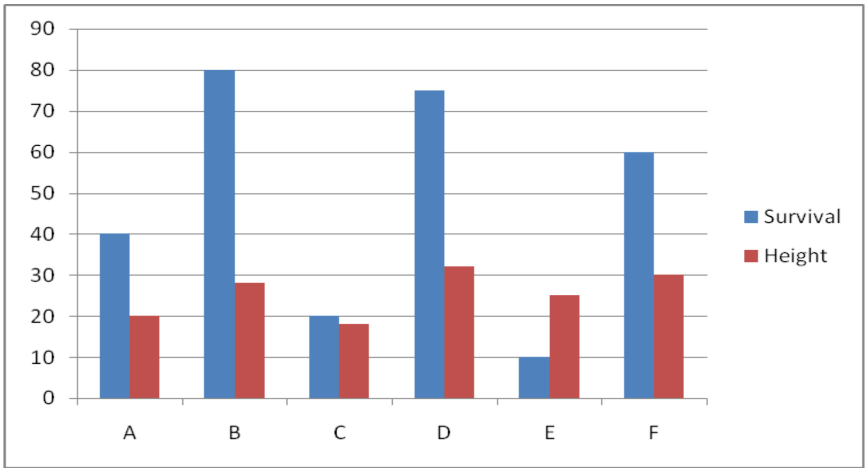
F: _____________

3. Given what you know about the different growth patterns of eastern and western populations of loblolly pine, respond to the following writing prompt:

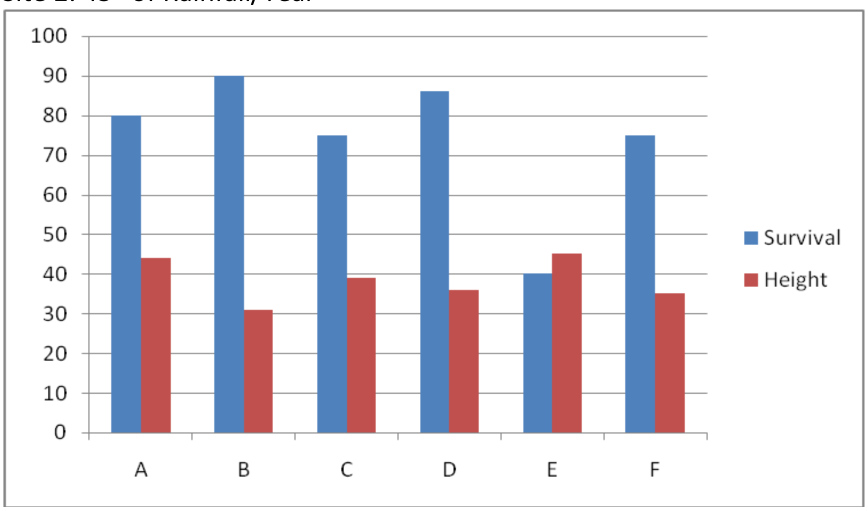
It is 2050. You've been invited to an awards ceremony honoring an elderly forest landowner who is regionally known for his wood production. Most of his trees survive changes in climate, and most of them are taller than everyone else's. He steps to the podium to receive his award and offers to reveal his secret for growing trees. The room quiets as his weak voice is carried by the microphone. "It's all in the genes," he says. "I have a brother in Texas, and another in South Carolina who both grow loblolly pine trees. About 35 years ago…" and with a collective gasp from the audience, the gentleman collapsed to the floor of a heart attack. As the EMT's administer life support and whisk him to a hospital, you leap to the stage to continue the explanation of what this landowner did. What do you say?

Survival and Height Graphs

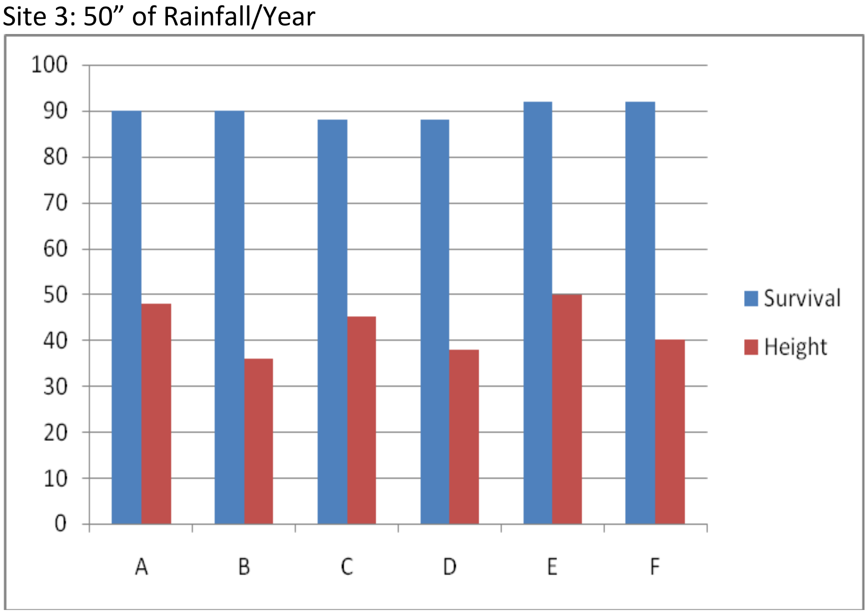
Site 1: 40” of Rainfall/Year



Site 2: 45” of Rainfall/Year



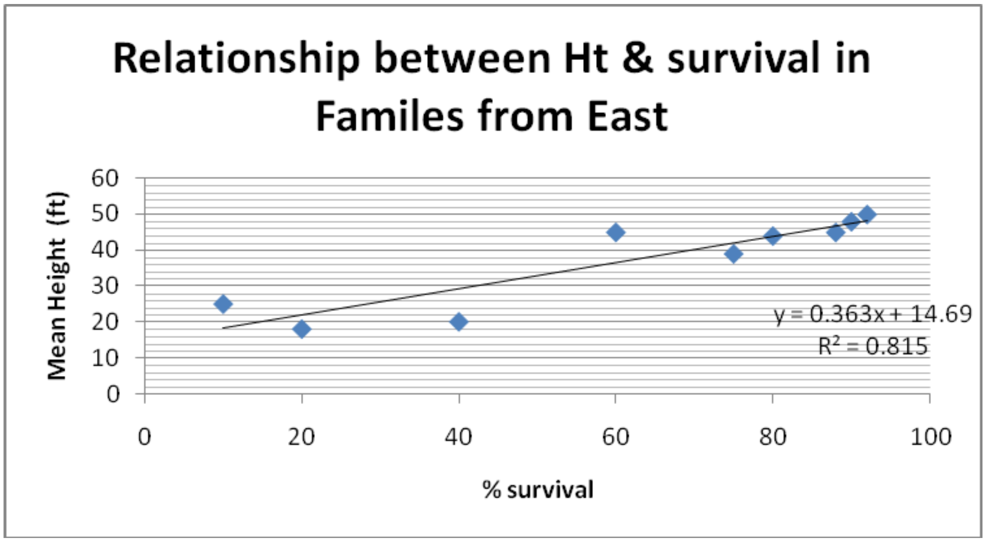
Site 3: 50” of Rainfall/Year



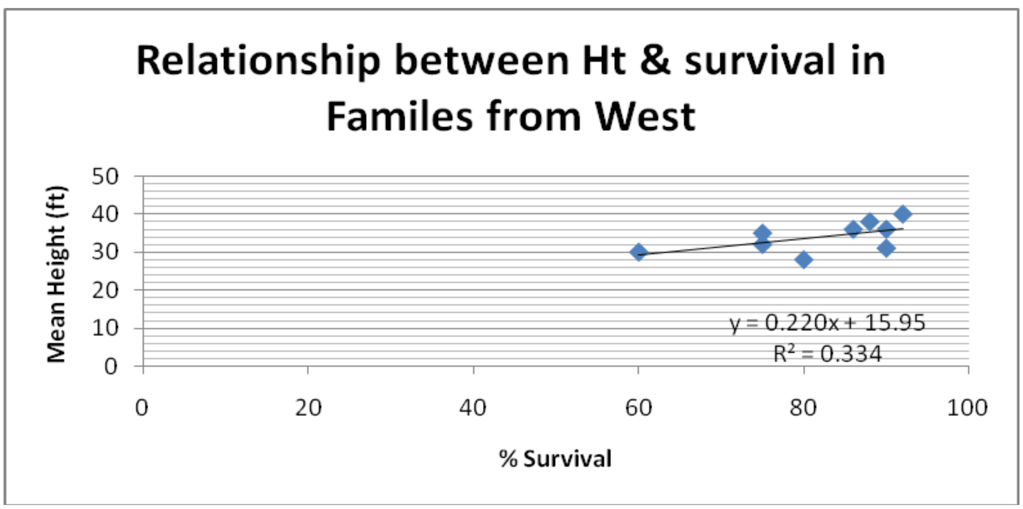
For each family, write the original source of the genotype.

A: East
B: West
C: East
D: West
E: East
F: West

Percent Survival and Height Graphs



In this graph, the correlation is 0.8157 – a strong correlation suggesting that if trees survive, they will be tall in these families



In this graph, the correlation is 0.3345 – a weak correlation. One cannot predict height from survival. Trees that survive may be short or tall. But more trees survive.

Section 3: Carbon Sequestration

Forests can be managed to reduce atmospheric greenhouse gases and to prevent greenhouse gas emissions.

Carbon, often called the building block of life, continuously cycles through all plants, animals, soils, rocks, oceans, and the ***atmosphere***. Carbon is found everywhere on Earth, and it undergoes chemical reactions and changes form as it moves. For example, carbon

- resides in the atmosphere as ***carbon dioxide***;
- is found in diamonds, one of the hardest substances on earth, and graphite, the soft lead in a pencil;
- dissolves in water to become carbonic acid;
- provides the structure of plants as cellulose;
- provides energy that organisms use to live as starch and sugar;
- resides in every living plant and animal, in the soil, and in the oceans;
- becomes calcium carbonate to form coral reefs and marine animal shells; and
- transforms to calcite in ***limestone***, for example at the limestone tops of the Himalayan mountains there are fossilized marine organisms

In addition, when fossilized carbon is burned as fuel, it can be used to power machines, turn on lights, and fly to space. Fossilized carbon is also commonly used as the feedstock for the fertilizer used to grow food, plastics that keep hospital supplies sterile, and even the packaging that keeps vegetables fresh.

Carbon naturally cycles through biological, physical, and geological systems; however, humans are also altering the natural cycle by adding more carbon to the atmosphere. Extracting and using ***fossil fuels*** for energy adds more carbon to the atmosphere. Carbon dioxide has increased since the Industrial Revolution, when we began burning fossil fuels in great quantities. According to ice core data, the atmospheric carbon dioxide levels have not been as high as they are today in over 800,000 years (NRC, 2012). As atmospheric carbon increases, most scientists agree that the average global temperature will also increase. This happens because carbon dioxide, along with other ***greenhouse gases*** like methane, nitrous oxide, and water vapor, trap heat in Earth's atmosphere. This process is known as the ***greenhouse effect*.** Oceans can also be affected by increased levels of atmospheric carbon. As the amount of carbon dissolved in the oceans increases, the water's pH changes and becomes more acidic. Continued ***ocean acidification*** can affect the health of marine organisms, especially those that build shells containing calcium carbonate, such as coral reefs, clams, and oysters.

As all systems on Earth interact and influence one another, scientists around the globe are researching the potential impacts of changes to average global temperature and ocean water PH. These impacts can be far reaching and involve changes to ***weather*** patterns, sea levels, ecosystems, and plant and animal populations. In addition, experts, engineers, policy makers, and communities are working to develop strategies and solutions to reduce carbon in the atmosphere. Some example strategies include planting and growing more trees to capture more carbon, keeping carbon stored in wood products, capturing carbon and pumping it in the ground, reducing our dependence on fossil fuels, and increasing energy efficiency.

Activity 6, **Carbon on the Move**, serves as an introduction to the carbon cycle, with an emphasis on the role of forests in the cycle. The game portion of the activity focuses on the pools and fluxes of the biological carbon cycle. Then group work and class discussion include concepts about the geological carbon cycle and putting them both together.

Activity 7, **Counting Carbon**, provides students with an understanding of the potential for carbon sequestration in a tree and to compare carbon sequestration potential for different land-use types. Students measure trees around their school and calculate their carbon storage. Students also compare the amount of carbon being sequestered by different land uses in their state. Students also compare their state ***emissions*** rate to their state sequestration rate and think about the implications of the difference.

Potential Areas of Confusion

Our pilot tests and the literature suggest there are several topics in this section that may be sources of confusion for students, based on their assumptions, prior experience, or knowledge. You may be able to use questions to uncover this confusion and steer students toward the following clarifications:

Assumption or Confusion	More Adequate Conception
Plants either do not respire, or if they do, they only respire in the dark.	Plants constantly break down sugar molecules—even to provide the energy needed for photosynthesis.
Oxygen is needed for animals, whereas carbon dioxide is needed by plants.	Oxygen in the form of water is critical to plant life.
Gases are not matter or they don't have mass.	Anything that has matter has mass. Frozen, compressed carbon dioxide is dry ice and has mass. A gas has mass, too, just a lot less.
Food that is broken down in respiration leaves an animal's body entirely by urine and feces.	The carbon may also leave an animal through sweat and exhalation.
Respiration produces energy, rather than converts energy.	Respiration converts energy from one form to another.
Energy is used up during biological processes.	Energy cycles. "Used" energy becomes waste heat.
Gases such as carbon dioxide lack sufficient mass to lead to the development of dry biomass in plants. Plants get mass from the soil.	By removing carbon from carbon dioxide and gluing carbon atoms together, plants create biomass from a gas and water.

(Table adapted from Hartley, Wilke, Schramm, D'Avanzo, & Anderson, 2011)

Key Concepts in this Section

- Carbon naturally cycles through biological, physical, and geological systems.
- Humans are altering the natural carbon cycle by adding more carbon to the atmosphere, primarily through fossil fuel combustion.
- Increased levels of atmospheric carbon dioxide will impact others systems, including oceans and forests.
- Trees absorb carbon dioxide from the atmosphere during the process of photosynthesis. Some of this carbon is stored or "sequestered" in the tree's growing roots, trunk, branches, and leaves.
- Pine forests are a particularly effective landscape for sequestering carbon because of their fast growth rates.
- Using forests to sequester all the carbon dioxide we emit through our daily activities is not possible, because there is not enough land that is not already covered in plants. We must also consider solutions such as reducing our consumption and using low-carbon energy sources.

References

Hartley, L. M., Wilke, B. J., Schramm, J. W., D'Avanzo, C., & Anderson, C. W. (2011). College students understanding of the carbon cycle: contrasting principle-based and informal reasoning. *BioScience, 61,* 65-75.

National Research Council. (2010). *Advancing the science of climate change*. Washington, DC: The National Academies Press USA. Retrieved from http://dels.nas.edu/resources/static-assets/materials-based-on-reports/reports-in-brief/Science-Report-Brief-final.pdf

6: Carbon on the Move

By becoming a carbon atom, students learn how carbon cycles through biological and physical systems. Group work and class discussions allow students to better understand global carbon pools, quantities, fluxes, and residence time—with an emphasis on how human activities can affect the cycle.

Subjects
Biology, Chemistry and AP Chemistry, Earth Science, Environmental Issues / Ecology, Environmental Science, Integrated Science, Life Science

Skills
Identifying Relationships and Patterns, Determining Cause and Effects

Materials
Module: Student pages; illustrated station cards available online at [*insert url*]
Other: 8 dice, large paper for group diagrams, markers

Time Considerations
Part A: One 50-minute class period
Part B: One 50-minute class period

Related Activities in Other PLT Guides
Climate Change and Forests (*Focus on Forests* module); The Global Climate (*PreK-8* Guide)

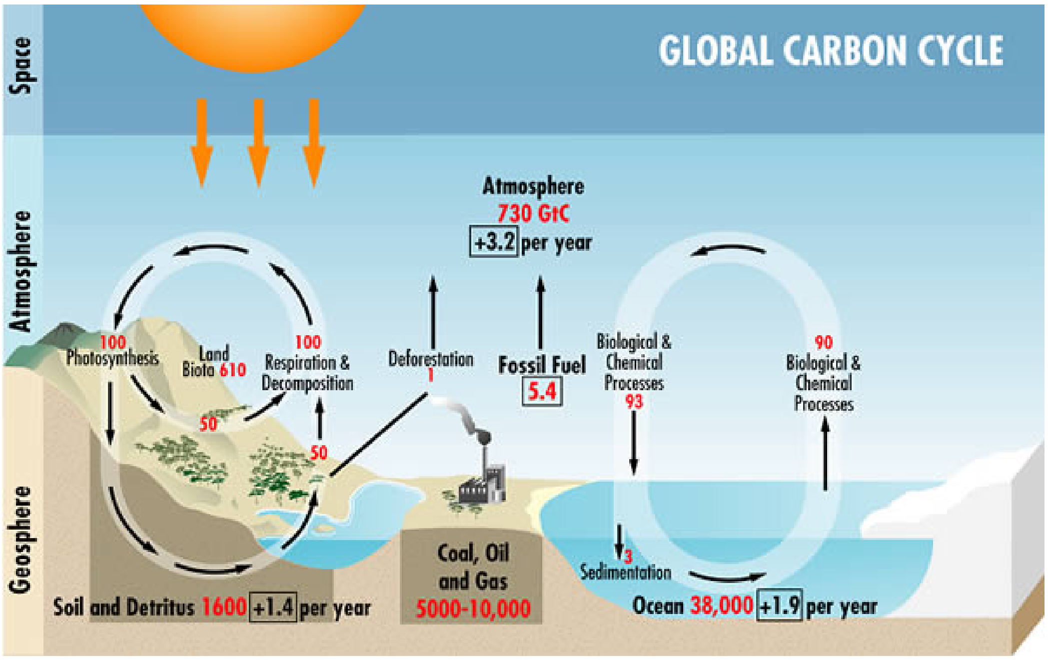
Objectives
Students will explain why the carbon cycle is important to all living organisms.
Students will describe and diagram the components of the carbon cycle, including carbon pools and carbon fluxes.
Students will explain the effects of releasing carbon stored in fossil fuels on the cycle and predict how these effects may impact other systems.

Assessment
Use the group carbon cycle diagram to assess their understanding of the major carbon pools and carbon fluxes.

Have students write a summary of what they learned during the carbon cycle game and subsequent group work and discussion. Ask them to address the following: What is the biological carbon cycle, and how does it differ from the geological carbon cycle? What are potential effects of releasing carbon stored in geological pools?

Background

The ***carbon cycle*** refers to the movement of carbon, in its various forms, from one pool to another. A ***carbon pool*** is any place where carbon can be found, such as plants or the ***atmosphere*** and even oil. Carbon pools can also be called stocks or reservoirs. ***Carbon flux*** is the process by which carbon moves from one pool to another, such as ***photosynthesis*** or ***wildfire***. When a pool absorbs more carbon than it releases, it is a ***carbon sink***. For example, the ocean and soil/detritus are carbon sinks. Forests can also be carbon sinks. Alternatively, when a pool releases more carbon than it absorbs, it is a ***carbon source***. Because ***fossil fuels*** cannot be created as fast as we are extracting and combusting them, they are considered a carbon source.



The Global Carbon Cycle, with units in Gigatons of carbon (GtC). Carbon flux and accumulation rates are annual in units of GtC/year. (Figure from http://www.bom.gov.au/info/climate/change/gallery/9.shtml)

<u>Biological Carbon Cycle</u>

Carbon flows through biological, physical, and geological systems with different processes and at different timescales. In the biological system, carbon cycles through living organisms, land, water, and the atmosphere by processes including photosynthesis, ***respiration***, and ***decomposition***. Different quantities of carbon reside in each pool, and the carbon moves at different rates between the pools. Some of these processes occur very quickly, while others can take hundreds to thousands of years. For example, some carbon atoms may cycle daily through plant photosynthesis and respiration, while other atoms may be trapped in a tree trunk for hundreds of years through carbon sequestration. ***Carbon sequestration*** is the process of transferring atmospheric ***carbon dioxide*** into other pools, such as plant ***biomass*** via photosynthesis or into soils by plant decomposition. The deep ocean and soils represent very large carbon pools, where carbon can stay for hundreds to thousands of years. On the other hand, the exchange of carbon between the atmosphere and plants, along with the exchange between the atmosphere and the surface ocean, occurs continuously. The amount of carbon flowing through the biological system is fairly stable and is considered to be "in balance."

<u>Geological Carbon Cycle</u>

The geological carbon cycle occurs over millions of year and includes processes such as rock formation, large-scale land shifts (plate tectonics), weathering, dissolution, volcanic eruptions, and fossilization. **Fossil fuels**—petroleum, natural gas, and coal—are created as layers of rock, soil, and ***sediment*** cover the remains of dead plants and animals. As this organic matter becomes compacted, pressure and heat turn the carbon into long chains of ***hydrocarbons***. Without human intervention, the carbon would mostly remain trapped far beneath Earth's surface—making fossil fuels a long-term carbon sink. Limestone is another long-term carbon sink. Limestone forms when ocean sediments, containing the shells of marine animals, are compressed and buried under the ocean floor.

Getting Ready

Make one copy of the station cards, available for download at [*insert url*].

Make copies of the "Carbon Cycle Pathway" and "Mapping Carbon" student pages (1 for each student).

Set up eight stations, each with one die. The station signs should be visible from any place in the room, and the die should be placed on a table or desk. Students need enough space between classroom furniture to gather at each station and move between them.

Doing the Activity

Part A

1. To introduce the topic of the carbon cycle, ask students to brainstorm what they already know about carbon and to provide examples of places carbon can be found. If needed, remind students that carbon is an atom on the periodic table, is the fourth most abundant element, and can be found in different forms everywhere we look. You might find these discussion questions helpful:

   a. Is there a fixed amount of carbon on the planet? *Yes. Like water, there is a finite amount of carbon on the planet. Also like water, there is a lot of carbon around and it moves through different states and pools.*

   b. Do you have any carbon in you? *Yes, in the carbohydrates, proteins, enzymes, and tissues of your body.*

   c. How is photosynthesis related to the carbon cycle? *During photosynthesis, plants convert carbon dioxide and water into sugar in the presence of sunlight.* Carbon moves from where to where? *Atmosphere to sugar in plant cells.* Then what? *It is either converted to energy in the process of respiration or stored as starch or cellulose—this process, where carbon is removed from the atmosphere and stored in biomass, is known as sequestration.*

2. Explain to students that they are about to become a carbon atom and move through the carbon cycle.

   a. The purpose of the activity is to help them better understand the variety of places that carbon can be found and how it moves from location to location.

   b. While carbon cycles geologically over millions of years, the activity only focuses on the biological component of the carbon cycle that happens on a much shorter timeframe. In this cycle, carbon moves between different pools such as living organisms, land, water, and the atmosphere.

   c. Make sure students understand the terms carbon pool, carbon flux, carbon cycle, and carbon sequestration.

3. Give each student a copy of the "Carbon Cycle Pathway" student page and provide instructions for how they should use this worksheet to record their journey through the carbon cycle. Ask them to count off by 8 and move to their first station. Students will complete eight rounds and record their journey through the carbon cycle.

   a. Students should write their first station on the first row in the table, roll the die, read the outcome from the card at their station, write down their destination, and move to that station.

   b. Even if they stay at the same location, they should write down the station name and what happened.

4. When everyone is finished, discuss the following questions as a class:

   a. Who visited the most pools? Who visited the least? Did anyone get stuck in one station or between two stations? Why do you think that happened?
   Point out that there are many different ways to enter and leave most carbon pools. The time carbon atoms spend in each pool varies. For example, some atoms might cycle very quickly between the atmosphere and forests through photosynthesis and respiration, while others may get sequestered in a tree for hundreds of years.

Part B

1. Remind students that the activity focused on the biological portion of the carbon cycle. Ask students if there are other places that carbon is stored and other ways that carbon moves? *Carbon is also stored in rocks, fossil fuels, and in sediments on the ocean floor and includes fluxes like weathering, compaction, and volcanic eruptions.*

2. Introduce the geological portion of the carbon cycle, including how fossil fuels are created. Carbon atoms in the geological portion of the cycle will be stuck for millions of years. Ask students to imagine how long it takes for carbon to move from ocean and terrestrial sediment to rock and fossils. Discuss how carbon is naturally released through weathering in small amounts over very long periods of time. When fossil fuels are burned for energy, however, large amounts of carbon are released into the atmosphere in a very short time period.

3. Show the class the global carbon diagram (in Background Information and available for download at [insert link]).
   a. Point out the major carbon pools and fluxes, and also mention the pools that were included in the activity that are missing on this diagram (animals, wood products, marine life).
   b. Reinforce that the amount of carbon flowing through the biological portion of the cycle is fairly stable and some of the carbon moves daily from atmosphere to plants or oceans and back to atmosphere.
   3. Explain that our use of fossil fuels has added carbon to the atmosphere that had been locked in fossils for millions of years. This “old” carbon is changing the balance of carbon in the atmosphere and ocean.

4. Discuss potential effects of releasing additional carbon to the system.

5. Form groups of 4-5 students and give each student a copy of the “Mapping Carbon” student page. Explain to students that they will work together to draw a carbon cycle that includes both biological and geological components. When the groups finish, ask each group to share their group diagram and report their responses until all the new ideas have surfaced.
   a. According to your diagram, what are all the ways carbon is removed from the atmosphere? List the pools and the fluxes below. *Forests through photosynthesis; Ocean through dissolving*
   b. How might each of these pools be affected by increased amounts of carbon dioxide in the atmosphere? *More atmospheric carbon dioxide may allow plants to grow more. However, several other factors may influence the amount of forested land and forest health, such as land use changes, weather events, forest disturbances, along with water and nutrient availability. An ocean with more carbon is more acidic; acidic ocean may alter coral reefs and other organisms.*
   c. How could we change these pools to remove more carbon from the atmosphere? *Plant more trees; grow trees longer; make more things out of wood; let the ocean absorb more carbon. What might be the limitations of managing these pools in this way? The amount of land on which trees will grow; wood will eventually decay; a warmer ocean will hold less carbon; a more acidic ocean will dissolve coral reefs.*

d. What are the implications of developing a piece of land that used to be forested? *The carbon from a forest could go into wood products or into the atmosphere if the forest is burned. By removing the trees, that area of land will not be able to sequester as much carbon as it did when it was forested.*

This module continues to focus on the biological portion of the carbon cycle and the ways trees and wood products can be used to remove carbon dioxide from the atmosphere or prevent future emissions. A variety of other classroom activities and programs can be used to explore other strategies for reducing atmospheric carbon dioxide. See the Resources listed at the end of the module.

Enrichment

Ask students to conduct research to learn about carbon-neutral energy sources that might replace fossil fuels. Why is using biomass, such as wood or corn, to produce energy considered carbon neutral? What factors determine neutrality? How could land-use changes impact biomass carbon neutrality?

Have students investigate how technology might be used to capture carbon from the atmosphere. For example, people around the world are working to capture carbon in trees and wood products, to remove carbon from the atmosphere and store it underground, and to reduce the amount of carbon that we add to the atmosphere by saving energy and reducing our dependence on fossil fuels. Ask students to write a report explaining one solution and to discuss its advantages and disadvantages.

Have a discussion with students on the relationship between the carbon cycle and other cycles that students are familiar with, such as water or nitrogen cycles. How are these cycles similar and how are they different? What are the key events in carbon cycle, water cycle, and nitrogen cycle?

Resources

The Carbon Cycle
Holli Riebeek, NASA's Earth Observatory
http://earthobservatory.nasa.gov/Features/CarbonCycle
The six sections of this online article provide a comprehensive look at the carbon cycle, historical changes in the carbon cycle due to climate change, contemporary changes in the carbon cycle due to human activities, effects of these changes, and how the carbon cycle is studied. Includes excellent use of photos, diagrams, graphs, and maps.

The Carbon Cycle: Forestry Never Looked So Cool
The Forest Foundation
http://www.calforestfoundation.org/pdf/carbon-poster.pdf
This poster provides a colorful depiction of the carbon cycle and highlights the role of forests and wood products. While the original poster is 19 x 25 inches, the document can be scaled to create a clear and informative 8.5 x 11 inch handout.

The Carbon Cycle: What Goes Around Comes Around
John Harrison, 2003. Visionlearning (a National Science Foundation resource), Volume 2(3).
http://www.visionlearning.com/library/module_viewer.php?mid=95
This on-line module provides basic information about the carbon cycle including human influences on the cycle. The module also includes an interactive quiz and section with links to other sources of information.

Global Warming: It's All About Carbon
Robert Krulwich, National Public Radio, 2007
http://www.npr.org/news/specials/climate/video/

As part of the Climate Connections Special Series, these five short videos teach basic concepts about carbon and its role in climate change.

GLOBE Carbon Cycle
University of New Hampshire
http://globecarboncycle.unh.edu/index.shtml
This education unit focuses on bringing cutting edge research and research techniques in the field of terrestrial ecosystem carbon cycling into secondary classrooms. It includes several activities to help students understand the carbon cycle, including a "choose your own adventure story."

Steroids and Baseball
University Corporation for Atmospheric Research (UCAR)
https://www2.ucar.edu/atmosnews/attribution/steroids-baseball-climate-change
This 2-minute video uses steroids in baseball as an analogy to carbon dioxide in climate and provides reflective comments on the purpose and value of the video.

Carbon Cycle Pathway

Name:

Instructions:
Imagine you are a carbon atom starting in one of many places that carbon is found. Write your starting location on the first line, roll the die, and determine your next location. Follow the instructions for the number you roll, which may tell you to move to another station or may tell you to stay where you are. What process was responsible for moving you from one carbon pool to another? Repeat this eight times and record what happens during each round in the table below. Make sure to record what happens, even if you have to stay at one station for more than one turn.

Round	**Starting Location (Carbon Pool)**	**What happened? (Carbon Flux)**	**Ending Location (Carbon Pool)**
Example	*Atmosphere*	*Photosynthesis*	*Forest*
1			
2			
3			
4			
5			
6			
7			
8			

Station Cards

Atmosphere

1. You continue to circulate through the atmosphere. **Stay at Atmosphere.**
2. In a forest, a pine tree needle absorbs and uses carbon dioxide during photosynthesis. **Go to Forest.**
3. In a forest, a pine tree needle absorbs and uses carbon dioxide during photosynthesis. **Go to Forest.**
4. In a forest, a pine tree needle absorbs and uses carbon dioxide during photosynthesis. **Go to Forest.**
5. Near the East coast, you dissolve into the waters of the Atlantic Ocean. **Go to Surface Ocean.**
6. Near the East coast, you dissolve into the waters of the Atlantic Ocean. **Go to Surface Ocean.**

Wood Products

1. The lumber where you are sequestered is used to build a house. **Stay at Wood Products.**
2. The lumber where you are sequestered is used to build a house. **Stay at Wood Products.**
3. After many years, the lumber where you are sequestered gets burned for firewood. **Go to Atmosphere.**
4. After many years, the lumber gets thrown in a pile of old wood and begins to rot and break down. **Go to Soil**.
5. You are eaten by termites. **Go to Animals**.
6. After many years, the lumber where you are sequestered gets burned for firewood. **Go to Atmosphere.**

Forest

1. Through respiration, a tree uses your sugar molecule for energy. **Go to Atmosphere.**
2. The pine cone where you have been stored is eaten by an Eastern fox squirrel. **Go to Animals.**
3. You become sequestered in a tree’s trunk. After several years, your tree gets cut down. **Go to Wood Products.**
4. You become sequestered in a tree’s trunk. After several years, your tree gets cut down. **Go to Wood Products.**
5. A windstorm damages the branch where you have been stored. The branch falls to the forest floor and begins to break down. **Go to Soil.**
6. A fire moves through the forest and burns the tree where you have been stored. **Go to Atmosphere.**

Surface Ocean

1. Through wave action, you mix with air and come out of the water—leaving solution as carbon dioxide gas. **Go to Atmosphere.**
2. Through wave action, you mix with air and come out of the water—leaving solution as carbon dioxide gas. **Go to Atmosphere.**
3. You continue mixing in water near the surface of the ocean. **Stay at Surface Ocean.**
4. Water currents and ocean mixing send you deeper within the ocean. **Go to Deep Ocean.**
5. An algae plant takes you in during photosynthesis. **Go to Marine Life**.
6. An algae plant takes you in during photosynthesis. **Go to Marine Life**.

Station Cards (cont.)

Soil (with Decomposing Material)

1. As the organic matter decomposes, you become carbon dioxide through soil respiration. **Go to Atmosphere.**
2. As the organic matter decomposes, you become carbon dioxide through soil respiration. **Go to Atmosphere.**
3. An insect eats the rotting material where you are located. **Go to Animal.**
4. An insect eats the rotting material where you are located. **Go to Animal.**
5. You become buried in layers of leaf litter and soil. **Stay at Soil.**
6. You become buried in layers of leaf litter and soil. **Stay at Soil.**

Deep Ocean

1. Ocean mixing and water currents send you toward the surface. **Go to Surface Ocean.**
2. Ocean mixing and water currents send you toward the surface. **Go to Surface Ocean.**
3. Ocean mixing and water currents send you toward the surface. **Go to Surface Ocean.**
4. Ocean mixing and water currents send you toward the surface. **Go to Surface Ocean.**
5. Water currents send you deeper within the ocean. **Stay at Deep Ocean.**
6. Water currents send you deeper within the ocean. **Stay at Deep Ocean.**

Animals

1. A bird eats you for dinner. **Stay at Animal.**
2. You are stored in animal fat cells. **Stay at Animal.**
3. You get released as carbon dioxide during respiration. **Go to Atmosphere.**
4. You get released as carbon dioxide during respiration. **Go to Atmosphere.**
5. When the animal produces waste, you find yourself on the forest floor in a pile of poop. **Go to Soil.**
6. The animal dies and begins to break down on the forest floor. **Go to Soil**.

Marine Life

1. You are eaten by tiny marine animal, called zooplankton. **Stay at Marine Life.**
2. You are eaten by tiny marine animal, called zooplankton. **Stay at Marine Life.**
3. You are exhaled through respiration. **Go to Surface Ocean.**
4. You are exhaled through respiration. **Go to Surface Ocean.**
5. The organism you are part of dies. You break down and sink through the waters of the Atlantic Ocean. **Go to Deep Ocean.**
6. The organism you are part of dies. You break down and sink through the waters of the Atlantic Ocean. **Go to Deep Ocean.**

Mapping Carbon

Group Members:____

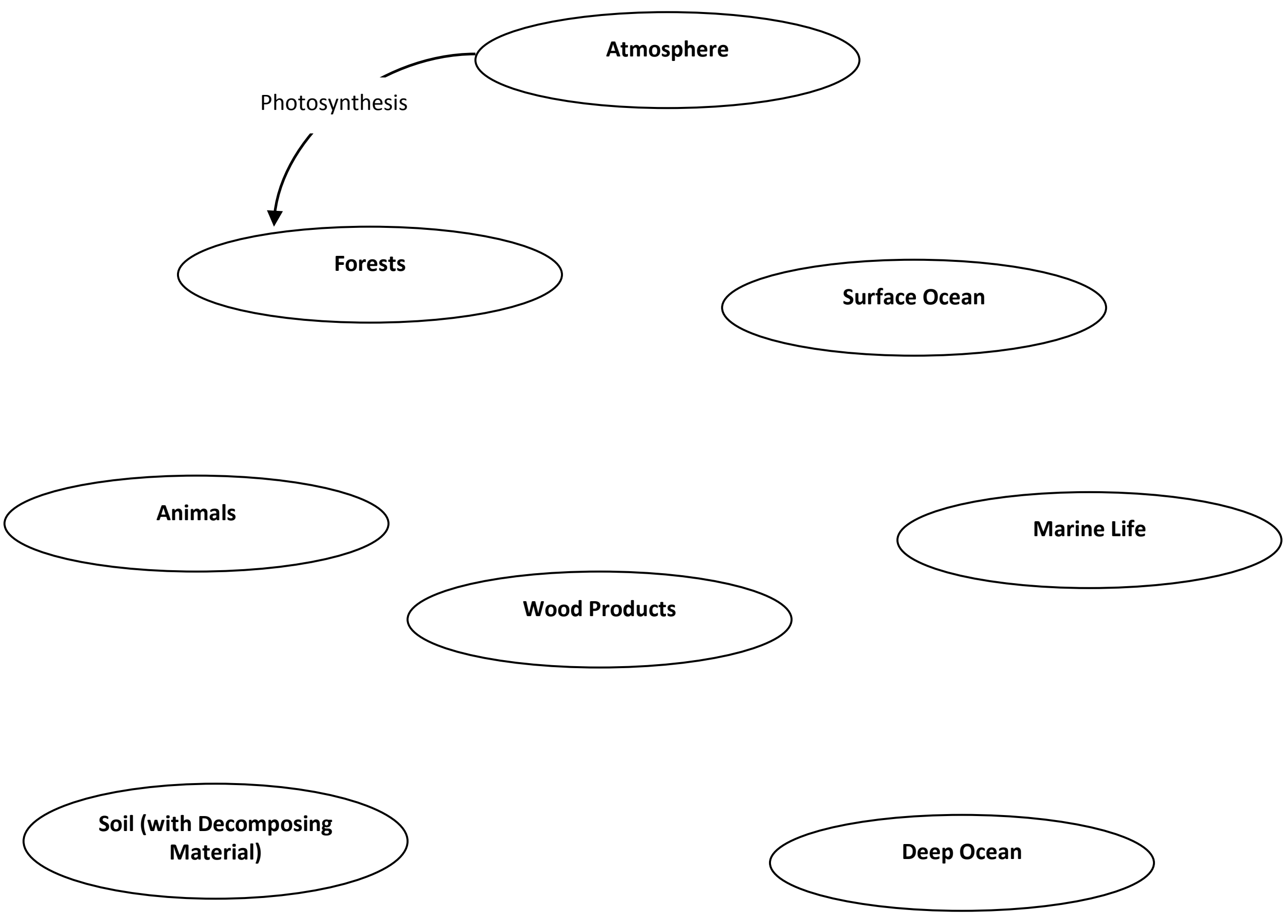
1. Using the large sheet of paper and markers, create a carbon cycle that combines the path that each group member experienced during the game. Use ovals or circles to represent the **carbon pools**. Use arrows to show how you moved from pool to pool, and label each arrow with the **carbon flux** that took you to the next pool.

   For example, one or more students in your group probably went from the atmosphere to the forest through photosynthesis. This means you would draw one oval labeled "atmosphere" and one oval labeled "forests." Then you would connect them with an arrow labeled "photosynthesis."

   Carbon fluxes that you may have experienced during the game include:

   Breaks Down
   Burns (Combustion)
   Dissolves
   Eaten (Consumption)
   Leaves Solution
   Ocean Mixing/Circulation
   Photosynthesis
   Respiration (Plant, Soil, Animal)
   Sequestration
   Waste Production

   Example Diagram for Biological Carbon Cycle



2. If needed, add additional arrows to represent any potential pathways (fluxes) between pools that are not currently on your diagram. This diagram represents the **biological part of the carbon cycle**.

3. Add new pools and fluxes to your group diagram to represent the **geological part of the carbon cycle**. Make sure to **include all the pools and fluxes listed below**.
   Carbon Pools: Fossil Fuels, Ocean Sediments, Limestone
   Carbon Fluxes: Heat and Compression, Burning (Combustion), Weathering, Rock Formation, Sinking

4. According to your diagram, what are all the ways carbon is removed from the atmosphere? **List the pools and the fluxes below.**

5. How might each of these pools be affected by increased amounts of carbon dioxide in the atmosphere?

6. How could we change these pools to remove more carbon from the atmosphere? What might be the limitations of managing these pools in this way?

7. What are the implications of developing a piece of land that used to be forested?

Carbon Cycle Pathway

Name:

Instructions:
Imagine you are a carbon atom starting in one of many places that carbon is found. Write your starting location on the first line, roll the die, and determine your next location. Follow the instructions for the number you roll, which may tell you to move to another station or may tell you to stay where you are. What process was responsible for moving you from one carbon pool to another? Repeat this eight times and record what happens during each round in the table below. Make sure to record what happens, even if you have to stay at one station for more than one turn.

Round	Starting Location (Carbon Pool)	What happened? (Carbon Flux)	Ending Location (Carbon Pool)
1	Atmosphere	Photosynthesis	Forest
2	Forest	Sequestered	Wood Products
3	Wood Products	Break down	Soil
4	Soil	Consumed	Animal
5	Animal	Respiration	Atmosphere
6	Atmosphere	Photosynthesis	Forest
7	Forest	Respiration	Atmosphere
8	Atmosphere	Dissolve	Surface Ocean

Biological and Geological Carbon Cycle Diagram

7: Counting Carbon

Students measure trees near their school and calculate the amount of carbon stored in individual trees. Students then compare the carbon sequestration potential for land-use types in their state, and compare this to the amount of carbon released by human activities to discuss forests' ability to sequester atmospheric carbon.

Subjects
Agriculture Education, Biology, Environmental Issues / Ecology, Environmental Science, Forestry / Natural Resource Management, Integrated Science, Life Science, Mathematics

Skills
Identifying Relationships and Patterns, Calculating, Comparing and Contrasting, Measuring, Analyzing, and Inferring

Materials
Module: Student pages
Other:
- For each group: 1 measuring tape (or string and ruler), protractor, straw, string, weight (something heavier than a paper clip, for example washers), meter tape, masking tape.
- For each student: scientific calculator
- Optional: DBH tape and clinometer
- Location: Outside area with enough trees that each student group can measure at least one tree.

Time Considerations
Two 50-minute periods, plus homework

Related Activities in Other PLT Guides
Climate Change and Forests (*Focus on Forests* module); How Big is Your Tree (*PreK-8* Guide)

Objectives
Students will calculate the amount of carbon stored in an individual urban tree and in one-acre of pine forest.
Students will calculate and compare the amount of carbon sequestered by different land uses: pine forest, mixed forest, urban forest, cropland, and grassland.
Students will describe how forests can play a role in addressing climate change.
Student will explain the importance of calculating the amount of carbon stored in different carbon pools.

Assessment
Use student responses on the student worksheets to evaluate their understanding

Background

All plants and animals contain and use carbon to sustain life; this element is found in the carbohydrates, fats, nucleic acids, and proteins of every biological life form. During ***photosynthesis***, trees use sunlight, water, and ***carbon dioxide*** to produce oxygen and glucose—a carbon-based molecule. While some of the glucose (or sugar) is used during plant ***respiration***, some is stored in the trunk, branches, and leaves as the tree grows. This stored carbon is removed from the ***atmosphere***. A tree's stored carbon can remain in the living tree or in cut wood for many years. Eventually, the stored carbon returns to the atmosphere when the wood decomposes, but this process can take a long time due to the tree's durable woody cells and tissues. For these reasons, forests store more carbon for longer time periods than other plants, such as corn or wheat which have much shorter life spans and decompose more quickly. By absorbing and storing atmospheric carbon dioxide, forests are a vital part of the global ***carbon cycle***. This makes forests an important consideration in ***climate change*** as well, since scientists have linked increases in atmospheric carbon with increases in the global average temperature. Estimating how much carbon trees absorb, store, and release is key to understanding climate change and is one of the first steps in exploring how forests might be used to address climate change.

Calculating Carbon Storage

The amount of carbon that an individual tree can store depends on the ***species*** of the tree and its size. To calculate ***carbon storage***, ***foresters*** and scientists first measure a tree's height and diameter. Often measurements are taken for trees within a sample plot that is representative of the larger forest, and then the average of these data is used to estimate the ***biomass*** in the larger forested area. Tree diameter can be calculated by measuring the tree's circumference with a measuring tape and dividing this number by pi (π). Because diameter can vary with tree height, measurements are taken at a standard height from the ground—4.5 feet. This is called ***diameter at breast height***, or DBH. The height of a tree can be measured in several ways; ***clinometers*** provide efficient, accurate measurements and are commonly used by foresters. Clinometers measure angles from the point where a person is standing to the top and the bottom of a tree. Through geometry and trigonometry, these angles and the distance to the tree are used to calculate tree height. Together, tree height and diameter are used to estimate the tree's weight. The weight of a living tree is called the ***green weight*** and includes both the biomass of the tree and all the water in the tree. The ***dry weight*** is calculated by subtracting the weight of the water, which is about 50% of a living tree. In general, the amount of carbon stored in an individual tree is about half of the tree's dry weight.

What is the Difference between Carbon Storage and Carbon Sequestration?

Carbon storage is the amount of carbon that exists in a tree's leaves, wood, stem, and bark at a particular point in time. Because older trees are larger than younger trees, they are able to store more carbon (see C Storage line in Figure 1). Knowing the amount of carbon stored in a tree and the tree's age allows us to calculate the rate of ***carbon sequestration***. This represents the net intake of carbon over a period of time (for example, in one year or the average per year over the tree's lifespan). Because young, growing trees add biomass at a faster rate than older trees, they are sequestering carbon at a faster rate than older trees (see C sequestration line Figure 1).

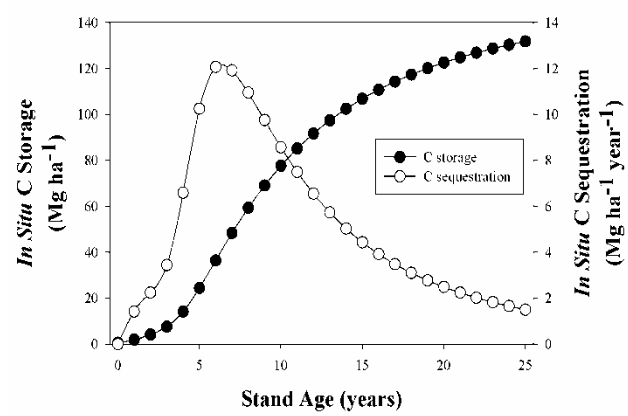


FIGURE 1. CARBON STORAGE AND CARBON SEQUESTRATION (FIGURE BY CARLOS GONZALEZ).

Carbon Sequestration in Different Landscapes
From pine to hardwood forests, the southeastern United States supports many forest ***ecosystems*** that sequester carbon. One of the most abundant trees in this region is loblolly pine (*Pinus taeda)*. This species is often planted in privately-owned pine ***plantations*** due to its fast growth rate. Almost all wood, including lumber and plywood, and paper products produced in the South are made from loblolly pine trees. Shortleaf pine, longleaf pine, and slash pine also grow in planted and natural forests in this region. In natural forests, such as those in parks and other conserved lands, pines may grow with hardwood trees. These forests differ from plantations in that they usually are not planted by people, not managed as intensively, not the same species, and not the same age. Natural forests can also be dominated by hardwood species, such as oak and hickory, or by wetland species, such as cypress. In addition to planted and natural forests, trees located in urban forests sequester carbon and can play a role in reducing atmospheric carbon.

Aside from forestland, the southern United States contains thousands of acres of agricultural lands, some of which are major economic sources for the region[6]. Similar to trees, crops sequester carbon; however, these plants do not sequester as much carbon because they only live for one growing season. Agricultural lands in the South are used for cattle and other grazing animals, fruits, vegetables, peanuts, and cotton. Finally, the South contains small ***grassland*** areas, which also sequester some atmospheric carbon each year. All plants store and sequester carbon. The longer a plant lives and the bigger it gets, the more carbon is sequestered over time.

Getting Ready

Make copies of the student pages (one per student).

There are two options for how students can calculate the carbon content of a tree.

Option A: Students will use a tape measure, a clinometer, and a formula to calculate carbon content.

Option B: Students will use a tape measure and a reference table to calculate carbon content.

Option A—Making Clinometers to Measure Tree Height
You will need 1 protractor, 1 straw, 2 pieces of tape, 1 weight, and 8 inches of string for each clinometer. Make one clinometer for each group of students. First, tape the straw to the flat edge of the protractor so that it runs from 0^{o} to 180^{o}. Next, tie one end of the string around the flat, ruler portion of the protractor at the center. On most protractors there should be a hole to mark the center; it is generally at the 3 inches point on the ruler. Tie the other end of the string to the weight. When you hold the protractor with the straw on top and with the straw parallel to the floor, the string should cross the degrees portion of the protractor at the 90^{o} line.

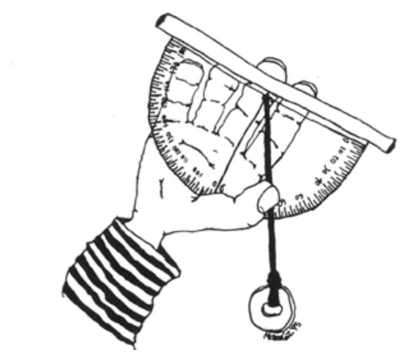


Illustration by Michele Kruegel

Assess the trees around your school to find ones that are suitable for students to measure. The students should be able to get close enough to the tree to put a measuring tape around its trunk and be able to stand far enough away to have a clear view of the top of the tree. Count the number of suitable trees. One tree could work, but assigning several trees to each group would be even better, so they can practice and improve. Divide the class into groups based on the number of trees you have available.

See Table 1 at the end of this activity to obtain current population and land use areas for your state (also available online at [*insert url*].

Doing the Activity

Part 1 – Calculating the Amount of Carbon in a Tree

1. Make sure students understand the connection between carbon and climate change. *Carbon dioxide is a greenhouse gas; scientists have linked increases in atmospheric carbon to increases in global average temperature.*

2. Remind students that trees absorb carbon dioxide from the atmosphere during the process of photosynthesis. *Some of this carbon dioxide is respired by the tree every minute of the day and night and goes back into the atmosphere as CO_2 and some of the carbon is stored in its growing roots, trunk, branches, and leaves. The process of photosynthesis enables a plant to remove or "sequester" carbon from the atmosphere.*
3. Explain to students that today they will investigate: How much carbon is stored in an individual tree? How much carbon can be removed from the air or sequestered by a forest? How much carbon can be sequestered by other land-use types? Why would it be important to know how much carbon a certain land-use can sequester? How can we use this information to explore strategies for addressing climate change?

4. Split the class into groups based on the number of suitable trees. Explain to students that to measure carbon, they have to first measure the tree. Each group will measure at least one tree and determine how much carbon is stored there. Give each member of the group a copy of the "Tree Data" student page, walk students to the area you have selected, and assign each group to at least one tree.

5. Demonstrate how to take tree measurements and then provide approximately 30 minutes for students to measure their assigned trees.
   a. Circumference (Options A and B): Students will measure the circumference of the tree trunk at approximately 4.5 feet from the ground. Explain why tree diameter measurements are taken at this height and how to calculate diameter. One student should take the measuring tape (or string and a ruler if measuring tape is not available) and wrap it around the trunk approximately 4.5 feet above the ground; other group members should record this value on the "Tree Data" student page.
   b. Height (Option A Only): Students will measure the height of the tree using the homemade clinometer. Explain how to use the clinometer and how these measurements can be used to calculate the height of the tree. Two students should walk away from the tree until they can easily see the top of the tree. Measure the distance from that point to the tree and record it on the "Tree Data" student page. Standing at that point, one student should hold look through the straw to the top of the tree from the 0^{o} side of the protractor. Once that student says he or she can see the top of the tree, another student should read the angle off the protractor by noting the degree where the string crosses the protractor. This is the Top of Tree Angle Measurement on the "Tree Data" student page. Another pair of students should then repeat the process while looking at the base of the tree from the same point. This will be the Base of Tree Angle Measurement. If the protractor has two scales on it, make sure both angles are less than 90^{o}.

Illustration by Michele Kruegel

6. Back in the classroom, ask the students to sit in their groups and complete the rest of the "Tree Data" student page using their calculators. Make sure that if only one student was recording data that all group members write down the measurements. You may need to remind them of the geometry that allows them to use the tangent of the angle to estimate the length of the far side of a right triangle. Also, review the equation used to determine how much carbon is stored in the tree. If you want students to practice using an Excel spreadsheet, you can download the template for this activity at [*insert url*].

7. Lead a class discussion about the carbon storage results that students calculated.
    a. What was the most amount of carbon that was stored by a single tree? Was it clearly the biggest tree? What was the least amount of carbon stored by a tree?
    b. Make a table on the board showing how much carbon was stored in the trees measured by each group. As a class, calculate the average amount of carbon stored by the sample of trees you measured.
    c. Discuss the formula the students used by asking:
        i. Besides diameter, what other factors might influence how much carbon a tree can absorb? *Height, wood density, evergreen or deciduous. Tree species and leaf area are often included in more complicated formulas.)* Why are these factors not included in the formula? *For our purposes, we do not need to be so specific. We are looking at an average tree.*
        ii. For how long will the carbon in each of those trees be stored? *As long as the tree is alive. What is likely to kill trees in this area? Development? Road widening? Lightning? Old age?*
        iii. Where does the carbon go after it leaves the tree? *Some will decompose into the soil; some will move to the atmosphere; some will be eaten and become part of animal biodiversity.*
        iv. How does carbon storage relate to growth? What does carbon content tell us about the age of the tree? *More carbon means an older tree.*
        v. Does all of the carbon that is taken up by the tree end up in the tree as carbon storage? If not, where does some of the carbon go? *Some of the carbon is released during respiration. Total carbon uptake is not the same as carbon storage.*

Part 2 – Exploring Carbon in a Pine Plantation

1. Using the data presented on the “Carbon in Pines” student page, have the students use the same formulas they used in part 1 to calculate how much carbon is stored in a sample plot of a pine forest.

2. Have the students discuss the amounts of carbon stored in the pine forest that they calculated. Why might this amount be different from the amount they measured in the urban trees? *The faster a tree grows, the more carbon it sequesters, and pine forests are very efficient at sequestering carbon.*

3. Present the idea of carbon sequestration and how it differs from carbon storage. Using the age of the sample forest, have the students calculate the sequestration rate for the pine forest. What does this sequestration rate show? *How quickly the trees uptake carbon; how efficient they are at absorbing atmospheric carbon*.

4. Are there any other land uses that can sequester carbon other than the urban trees they measured and the pine forest? *Yes, crop land, grassland, and mixed deciduous forests are other land-use types that can sequester carbon*.

5. For homework, assign the “Your Carbon Footprint” student page. Each student should come to class the next day with an estimate of the amount of pounds of carbon dioxide he/she emits in one year.

Part 3 - Comparing Carbon in Different Landscapes

1. Divide the students into groups of five students and have them discuss their responses to the homework assignment. How much do their responses differ? What behaviors do they think are responsible for those differences?

2. Re-introduce the concept of carbon sequestration and how it differs from the idea of carbon storage. Explain to students that they will be calculating the amount of carbon that can be sequestered by different land-use types in their state, and then comparing that to the average amount of carbon that is emitted by the population in their state, if they all live like the students do.

3. Give each student in the group a copy of the "Carbon in Different Landscapes" student page. Also, give the students the data that they will use in this part (from Table 1 at the end of this activity, or online at [*insert url*].

4. Explain that each group will use their worksheet to calculate how much carbon, on average, the different land types in their state sequester in one year. Before the groups begin working, ask students to predict which of the five land uses they think will store the most carbon. Why? What plants in each landscape is sequestering carbon?

5. When the groups finish, lead a discussion about different landscapes and carbon sequestration.
    a. Which landscape sequestered the most carbon? Why do they think that landscape sequestered the most carbon? Was this landscape type able to sequester all the carbon emitted by the state's population?
    b. What are the implications of requiring land from another state to sequester the carbon from your state? What equity issues are associated with this? Who should make this decision? If your state has an excess of sequestration potential, is this a resource you could sell? Should you?
    c. If students decide to convert more land to the most efficient land use for sequestration, how do they convince landowners of this plan, and what should happen to the people who live there? Is this idea of carbon sequestration within the state practical?
    d. What other landscapes would they like to know about?
    e. Explain that some people give money to organizations which plant trees to offset specific carbon-generating activities. What is the purpose of this arrangement? Do they think this is a good idea? Why or why not?

Enrichment

Have students investigate different carbon emissions reduction strategies and carbon sequestration strategies. Then ask students to develop a climate change mitigation plan for their state and present it to the class. Should their state be able to sequester all their emissions? If not, who should?

Give students a scenario in which they are traveling on vacation with their family. Remind them that traveling by car, plane, or bus emits carbon. Explain that organizations exist that will plant trees to offset the carbon emissions from various activities. People and businesses calculate how much carbon dioxide they produce during a particular activity and then pay the organization to plant enough trees to offset those emissions so that the activity is carbon neutral. Ask the students to write an essay/letter to their parents explaining the rationale behind planting trees to offset carbon emissions and why they would or would not suggest it for their vacation trip.

Resources

Carbon in U.S. Forests, Online Tools
Forest Inventory and Analysis National Program, USDA Forest Service
http://www.fia.fs.fed.us/Forest%20Carbon/default.asp
This webpage provides a fact sheet and graphics, along with data tables for the estimations of carbon storage in US forests.

Greg McPherson's Tree Carbon Calculator
EarthSky
http://earthsky.org/earth/greg-mcphersons-tree-carbon-calculator
In this podcast, scientist Greg McPherson talks about a tool he developed to help determine how much carbon a tree sequesters and the value of knowing this information.

National Tree Benefit Calculator
Casey Trees and Davey Tree Expert Co.
http://treebenefits.com/calculator/
Based on USDA Forest Service's i-Tree tools, this online calculator provides data about the environmental and economic value of street-side trees on an annual basis. After entering the tree's location, species, and size, users receive data regarding the tree's environmental and economic value related the following variables: stormwater, property value, energy, air quality, and carbon dioxide.

Urban Forests and Climate Change
USDA Forest Service
www.fs.fed.us/ccrc/topics/urban-forests/ctcc/
This webpage provides downloadable software that allows users to enter information on climate region and tree size or age to calculate the amount of carbon dioxide stored in the tree over time, the amount of carbon dioxide sequestered in the past year, and the dry weight of the aboveground biomass.

References

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Tree Data

Name:

Group Members:

Measuring the Tree
In the first part of this activity, you will measure the height and circumference of at least one tree near your school. You will use the data to calculate the amount of carbon stored in the tree.

1. Use the table below to record the circumference, angle to top of the tree, the angle to the bottom of the tree and the distance from you to the tree in the columns with the data you collected from the tree.

Tree	**C** Circumference (in)	**Θ_1** Angle to top of tree	**Θ_2** Angle to base of tree	**AB** Distance from person to tree (ft)
1				
2				
3				
4				
5				

2. Use the equation $D = C \div \pi$ to calculate the diameter of the tree (where D = Diameter; C = Circumference; and $\pi = 3.14$). Use the table below to record tree diameter.

Tree	**Diameter (in)**
1	
2	
3	
4	
5	

3. Next, use the diagram and equations below to calculate the height of each of your tree. Θ_1 is the angle to the top of the tree. Θ_2 is the angle to the base of the tree. AB is the distance between you and the tree. Record the tree height in the table.

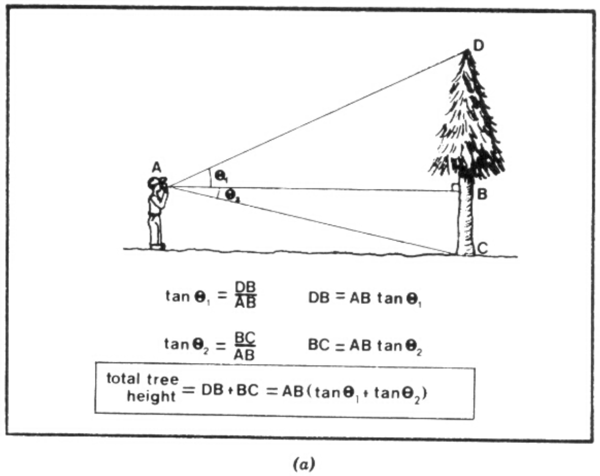

Figure 10.3 *a* Three measurements are required to determine the total height of the tree using *trigonometric* principles: the angle Θ_1 from horizontal to the top of the tree, the angle Θ_2 from horizontal to the base of the tree, and the horizontal distance *AB* from the observer to the tree.

Tree	Tree Height (ft)
1	
2	
3	
4	
5	

Calculating Carbon Storage

- If you measured both tree height and circumference, complete Option A.
- If you measured only the tree's circumference, complete Option B.

Option A *(adapted from Trees for the Future, 2007)*

1. Calculating Green Weight (GW)
   The green weight of a tree is an estimate of the weight of the tree when it is alive. This weight includes all of the wood content and any water that is in the tree. Because the water in the tree can be up to hundreds of gallons, the green weight can be quite large. To find the green weight, insert the values you obtained for diameter and height into one of the two equations listed below:

For a tree whose diameter > 11:

$GW = 0.15\ (d)^2 \times H$

For a tree whose diameter < 11:

$GW = 0.25\ (d)^2 \times H$

Green weight = ____________ lbs

2. Calculating Dry Weight (DW)
   Because of the water content in trees, the weight of the tree varies based on green weight or dry weight. Dry weight represents the weight of the wood in the tree if it was dried in an oven and all water was taken out. Estimates of dry weight to green weight show a 50:50 ratio and so, to find the dry weight, multiply green weight (GW) by 50%.

   $DW = GW \times 0.5$

   Dry weight = _______________ lbs

3. Calculating Carbon Storage (C)
   Carbon storage is the amount of carbon that is within the wood of the tree, negating other minerals and elements. This is the total amount of carbon that is made during photosynthesis as well as the amount of carbon sequestered from CO_2 by the tree. Carbon storage is about half as much as the total dry weight of the wood since the wood contains other materials and elements than just carbon. To find carbon storage, multiply dry weight (DW) by 50%.[1]

   $C = DW \times 0.5$

   Carbon content = ____________ lbs

<u>Option B</u>

1. The table below provides carbon content values for trees, based on their diameter value. This table is specific to urban trees in a developed area. Using the table below, match the diameter you measured for your tree with the diameter in the left column. Find the carbon storage capacity of the tree.

Diameter Range (in)	Per Tree Carbon Storage (lbs)
0 - 3	7
3 -6	41
6 - 9	127
9 - 12	296
12 -15	492
15 - 18	957
18 - 21	1331
21- 24	1637
24 - 30	3525
30 - 33	4482
33 – 36+	6908

Carbon content = ____________ lbs

Carbon in Pines

The southern United States is home to many different species of pine trees, specifically: loblolly, slash, longleaf, and shortleaf pines. Pine forests are important for many reasons. They provide wildlife habitat, recreation, clean water, and as you have learned, the trees store carbon as they grow. In the South, pine trees are commonly grown in plantations to provide wood products, such as timber and paper.

Foresters and scientists measure pine trees, similar to the way you measured a tree in your schoolyard. Using this information they can determine how much carbon is stored in a forest. Rather than measuring every tree in the forest, they measure a sample of trees and then use those numbers to estimate carbon storage for the entire forest.

To estimate how much carbon typically exists in one acre of pine forest in the southern United States, you will use real data collected by high school students in recent field trip to a pine forest sample plot in North Central Florida.

In a 1/20th acre size plot, the students measured ten trees and found that the trees have an average diameter of 10.1 inches; they also found an average height of 106.7 feet. Because the trees in this area are generally the same species, age, and size, we can use their average data to estimate the amount of carbon contained within one acre of this forest.

STUDENTS MEASURE TREE HEIGHT AND DIAMETER ON A SAMPLE PLOT OF LOBLOLLY PINE TREES IN A FOREST IN NORTH CENTRAL FLORIDA.
PHOTOS BY JESSICA IRELAND.

Complete the calculations below, where d = diameter; H = height; GW = green weight; and DW = dry weight.

Because the average tree diameter is less than 11 inches, we will use the following formula to determine green weight:

$GW = 0.25 (d)^2 \times H$

Green weight = ____________ lbs/tree

$DW = GW \times 0.5$

Dry weight = ______________ lbs/tree

$C = DW \times 0.5$

Carbon content = ___________ lbs C/tree

Total carbon content of plot = carbon content lbs C/tree × 10

Total carbon content of plot = _____________ lbs C/20th acre plot

Total carbon content of 1 acre = total carbon in plot × 20

Total carbon in 1 acre = ___________ lbs C/acre

This final number illustrates the total carbon stored in one acre of pine plantation where the students took measurements. However, this is not the same as the amount of carbon that the trees sequestered in one year of growth. Carbon sequestration is the net intake of carbon by the tree over a period of time. In this case, the forest where students sampled is 25 years old. Use the equation below to determine what rate carbon is sequestered by the forest annually.

Total carbon in 1 acre ÷ 25 years = Carbon sequestration rate lbs C/acre/year

Carbon sequestration rate = _________________ lbs C/acre/year

Your Carbon Footprint

The carbon footprint of a person is the total amount of carbon emitted based on his or her daily actions and choices. A carbon footprint is measured based on factors such as fossil fuel consumption, food consumption, good and services bought, as well as housing conditions. The Nature Conservancy has an interactive site where you can answer questions to measure your own carbon footprint. This website allows you to see how much carbon you emit per year measured as pounds of CO_2. Follow the outline below in order to obtain your own personal footprint.

1. Go to the website http://www.nature.org/greenliving/carboncalculator/index.htm.

2. Read the directions and select "For Me Only" because we are only interested in your personal emissions. Use the quiz to answer background questions as well as questions about household vehicles, home energy and waste disposal. Answer the questions based on your personal or family lifestyle.

3. The second part of the quiz estimates your carbon output associated with home energy usage. In the US, most CO_2 is from energy generation. This part of the quiz measures how much CO_2 you are responsible for emitting as a result of using electricity in your house. Answer the information as accurately as possible.

4. The third part of the quiz is based on your fossil fuel consumption associated with travel.

5. The fourth part of the quiz evaluates how your choice of food and your diet affects your carbon emissions. Depending on the type of food, the amount of meat and where you buy your food, your emissions will vary.

6. The final part of the quiz evaluates your level of waste and the impact that recycling has on it. If you recycle on a regular basis, your carbon estimate will be smaller. This is because recycled material requires less carbon to process than extracting and processing new resources.

7. Upon completing the quiz, the results will display how much CO_2 you produce yearly as a result of your choices. It will also compare this to the national average as well as provides options for you to decrease your carbon emissions.

8. Record your results: ____________________ tons of CO_2 per year.

9. Convert your result to pounds. 1 ton= 2,000 pounds

   _________________ X 2,000 = _________________

   Tons of CO_2 per year   Pounds of CO_2 per year

10. Are the results surprising to you? Why or why not?

11. What do you think was the variable that impacted this result the most?

Carbon in Different Landscapes

Using the data from your group members from the homework, find the average carbon emissions from your group in pounds of CO_2.

____
Average CO_2 emissions of group (lbs/year)

1. Because most sequestration rates are calculated in terms of carbon and not in carbon dioxide, convert your emissions of pounds of CO_2 to pounds of carbon.

_______________________ × 0.2727 = ______________________
Average CO_2 emissions of group (lbs/year) Average C emissions of group (lbs/year)

2. If everyone in your state acted the way you do, find the total emissions for your state. To do this, take your average carbon emissions and multiply by the population of that state. Your teacher will give you this information.

_____________________ × _____________ = ________________________________
Average emissions of C (lbs/year) state population Total C emissions of population (lbs/year)

Since there are multiple land uses that can sequester carbon, you will determine the relative abilities of each of these land uses in carbon sequestration: pine forest, mixed forest, cropland, grassland, and urban forest. Complete the chart below, using the acreage provided by your teacher.

Land Use Type	Area in State (acres)	Multiply	Carbon Sequestration Rate (lbs C/acre/year)	Equals	Amount of Carbon Sequestered per year (lbs)
Pine Forest (Johnson et al., 2001)		×	5,442	=	
Mixed Forest (Johnson & Coburn, 2010)		×	4,220	=	
Urban Forest[7] (Norwak & Crane, 2002)		×	714	=	
Cropland (Lal, Kimble, Follett, & Cole, 1999)		×	1,347	=	
Grassland (Lal, 2004)		×	892	=	

3. Total the amount of carbon that is sequestered by your state's land uses by adding the total carbon sequestered from the last column in the table.

____
Total C (lbs) sequestered in state per year

4. Is there a deficit in carbon sequestration or an excess of potential in your state? To find out if your state has the ability to sequester all of the carbon that it on average emits, subtract the total carbon sequestered in step 4 from the total carbon emitted by the population in step 3.

______________________________ – _____________________ = ___________________________
Total C emissions of population (lbs) Total C sequestered (lbs) Amount not sequestered (lbs)

5. If your answer to step 5 is negative, that means that your state is not in a deficit and that on average the state has the ability to sequester all of the carbon that it emits. What factors might make a state able to sequester the carbon emitted by the population?

6. If your state is in a deficit and cannot sequester the total carbon emitted, what could be done to increase the amount of carbon sequestered in your state?

7. If your state is in a deficit and any neighboring states are not, would you recommend that your state rely on the land uses of another state to sequester your carbon? Is this fair to the population of the other state to be responsible for your carbon emissions?

Carbon in Pines

Complete the calculations below, where d = diameter; H = height; GW = green weight; and DW = dry weight.

Because the average tree diameter is less than 11 inches, we will use the following formula to determine green weight:

$GW = 0.25\ (d)^2 \times H$

Green weight = ___2721.1___ lbs/tree

$DW = GW \times 0.5$

Dry weight = ___1360.6_____ lbs/tree

$C = DW \times 0.5$

Carbon content = ____680.3___ lbs C/tree

Total carbon content of plot = carbon content lbs C/tree × 10

Total carbon content of plot = ___6802.8____ lbs C/20^{th} acre plot

Total carbon content of 1 acre = total carbon in plot × 20

Total carbon in 1 acre = __136055.8_ lbs C/acre

This final number illustrates the total carbon stored in one acre of pine plantation where the students took measurements. However, this is not the same as the amount of carbon that the trees sequestered in one year of growth. Carbon sequestration is the net intake of carbon by the tree over a period of time. In this case, the forest where students sampled is 25 years old. Use the equation below to determine what rate carbon is sequestered by the forest annually.

Total carbon in 1 acre ÷ 25 years = Carbon sequestration rate lbs C/acre/year

Carbon sequestration rate = ___5442.2________ lbs C/acre/year

TABLE 1. POPULATION AND LAND USE IN THE UNITED STATES BY REGION, SUBREGION, AND STATE (UNITED STATES CENSUS BUREAU, 2012; UNITED STATES DEPARTMENT OF AGRICULTURE, 2012).

Region, Subregion and State	Population *(thousands)*	Cropland	Rangeland	Pine *(in thousands of acres)*	Mixed Forest	Urban area
Northeast						
Maine	1,328	462	105	5	17,355	223
New Hampshire	1,316	103	90	8	4,422	359
Vermont	625	487	261	0	4,504	96
Massachusetts	6,547	169	54	68	2,240	1,837
Rhode Island	1,052	22	8	12	313	254
Connecticut	3,547	136	33	0	1,413	1,153
New York	19,378	4,140	2,414	78	16,168	2,571
New Jersey	8,791	479	51	439	1,472	1,816
Pennsylvania	12,702	5,264	1,123	92	16,119	2,799
Delaware	897	423	23	62	383	200
Maryland	5,773	1,279	464	352	2,386	1,189
District of Columbia	602	0	-	0	-	39
Northeast	62,558	12,967	4,627	1,116	66,774	12,537
Lake States						
Michigan	9,883	8,014	1,697	0	19,019	2,189
Wisconsin	5,686	10,203	2,768	0	16,168	1,063
Minnesota	5,303	22,342	3,020	0	15,572	966
Lake States	20,872	40,559	7,486	0	50,759	4,218
Corn Belt						
Ohio	11,536	10,923	1,924	0	7,666	2,603
Indiana	6,483	12,747	1,642	40	4,533	1,450
Illinois	12,830	24,056	1,940	26	4,363	2,341
Iowa	3,046	26,730	2,460	0	2,864	521
Missouri	5,988	16,561	8,423	225	14,838	1,186
Corn Belt	39,883	91,018	16,390	291	34,264	8,102
Northern Plains						
North Dakota	672	27,676	11,935	0	699	95
South Dakota	814	19,853	23,263	0	1,640	109
Nebraska	1,826	21,612	23,191	0	1,234	298
Kansas	2,853	28,548	16,438	0	2,104	562
Northern Plains	6,165	97,688	74,827	0	5,677	1,063
Appalachian						
Virginia	8,001	3,251	2,463	2,877	15,350	1,555
West Virginia	1,853	921	1,249	176	11,833	372
North Carolina	9,535	4,843	1,231	5,746	18,037	2,357
Kentucky	4,339	7,621	3,516	179	11,686	799
Tennessee	6,346	6,019	2,093	921	13,913	1,594
Appalachian	30,074	22,654	10,551	9,899	70,819	6,677

Region, Subregion and State	Population *(thousands)*	Cropland	Rangeland	Pine	Mixed Forest	Urban area
		(in thousands of acres)				
Southeast						
South Carolina	4,625	2,001	795	6,067	12,646	1,230
Georgia	9,687	4,619	1,292	11,058	24,267	2,465
Florida	18,801	2,760	5,558	7,396	15,649	4,052
Alabama	4,779	3,104	2,642	9,550	22,587	1,140
Southeast	37,892	12,483	10,288	34,071	75,150	8,887
Delta States						
Mississippi	2,967	5,556	2,055	7,998	19,579	607
Arkansas	2,915	8,240	3,293	5,563	18,596	589
Louisiana	4,533	4,435	1,860	5,747	14,142	1,088
Delta States	10,415	18,230	7,209	19,308	52,317	2,284
Southern Plains						
Oklahoma	3,751	12,840	18,707	1,087	7,620	736
Texas	25,145	34,115	101,735	5,298	17,159	4,646
Southern Plains	28,896	46,955	120,442	6,385	24,779	5,382
Mountain						
Montana	989	17,867	46,051	0	19,875	171
Idaho	1,568	5,980	18,082	0	17,455	269
Wyoming	564	2,218	44,653	0	7,661	110
Colorado	5,029	11,428	28,871	0	18,236	831
New Mexico	2,059	2,367	52,122	0	14,977	493
Arizona	6,392	914	40,648	0	16,780	1,099
Utah	2,764	1,738	26,120	0	16,058	450
Nevada	2,700	731	46,850	0	10,436	356
Mountain	22,065	43,244	303,397	0	121,478	3,779
Pacific						
Washington	6,724	7,626	6,789	0	19,225	1,397
Oregon	3,831	4,934	22,726	0	27,813	675
California	37,253	9,550	27,524	0	26,983	5,166
Pacific	47,808	22,110	57,040	0	74,021	7,239
48 States	306,628	407,908	612,257	71,070	576,037	60,167
Alaska 3/	710	86	738	0	93,801	167
Hawaii 4/	1,360	145	738	0	1,552	227
U.S. Total	308,698	408,139	613,733	71,070	671,390	60,562

Section 4: Life Cycle Assessment

Consumer choices can play a role in reducing and preventing carbon emissions.

With the convenience with which we can obtain a huge diversity of good and services, determining which products have a lower impact of the environment is a challenge. Most of us think about the life of our products as beginning when we open the box and ending when we throw them away, but when scientists refer to the "life cycle" of a product, they include everything from the acquisition of the raw materials through to the disposal of those materials. ***Life cycle assessments*** provide key information that help scientists and citizens understand how human activities affect the environment. By understanding a product's life cycle, consumers can compare the environmental impacts of various products and choose those that support their values and beliefs. In particular, consumers can choose products that mitigate ***climate change*** by:

- producing fewer ***greenhouse gases*** in their production, shipping, and use;
- sequestering carbon, such as wood products;
- and being reused or ***recycled*** instead of being thrown away.

<u>Life Cycle Assessment</u>
Life cycle assessment involves taking a detailed look at the entire life cycle of a good or service. To do this, we define a product system and look at the material and energy flows into and out of that system during each step in the life cycle. Think about something as common as a cell phone. The circuits within your cell phone require an assortment of metals, including copper, gold, and lead, as well as lesser known metals such as tantalum and beryllium. The battery contains still more metals—usually nickel or lithium. These metals are mined and collected from all around the world. Then there's the casing and the screen for the phone, both usually made of synthetic plastics or resins. Each of these materials must be put into a form in which they can be used to manufacture the various parts of the phone. Then those parts must be assembled. Of course energy and additional materials are used at each step along the way. In short, a world of activity has taken place before our new phone ever reaches us. Likewise, the phone's impact does not end when we throw it away. The materials within the phone continue to have both ecological and economic impacts. Some of those materials are toxic, and many are quite valuable as they can be recycled and used in other electronic products. Those materials that are not recycled eventually return to the ecological system, typically via landfills.

Figure 1 illustrates the generalized steps of a product's life cycle. The blue arrows represent transportation from one step to another. Energy and materials that flow into the product system at each stage are called resources. Materials flowing out of the system are called ***emissions***. Life cycle assessment looks at the environmental effects both of the resource use and of the emissions created.

The three activities in this section allow students to learn about the environmental impact of products and to consider how the decisions and actions of consumers can affect local and global systems.

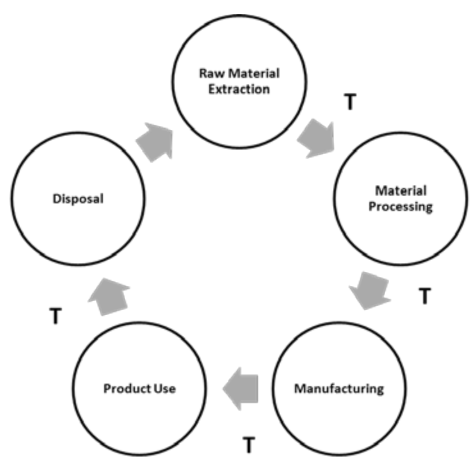

FIGURE 1. GENERALIZED LIFE CYCLE: STAGES OF THE LIFE CYCLE OF A SERVICE OR PRODUCT WITH ARROWS REPRESENTING TRANSPORTATION FROM ONE STAGE TO ANOTHER.

Activity 8, **The Real Cost: Shopping for Externalities**, introduces the hidden impacts of everyday products that students might buy, such as t-shirts, fruit, and pencils. Through a simulated shopping experience, students take on the role of a consumer and make choices about which of two similar products to buy—once without and once with information about the environmental externalities of those products.

Activity 9, **Adventures in Life Cycle Assessment**, is an opportunity for students to investigate actual life cycle data from the National Renewable Energy Laboratory's (NREL) U.S. Life-Cycle Inventory Database. This activity asks students to imagine a scenario where the school has asked them to decide which type of outdoor dining furniture should be purchased for a new cafeteria patio. Using a three act play or group presentations, students uncover life cycle data for the greenhouse gas emissions of wood, aluminum, and plastic resin furniture. An optional enrichment includes a tutorial that walks advanced students through the process of using the NREL database to create a life cycle assessment for a product of their choice.

Activity 10, **Life Cycle Assessment Debate**, concludes this section by encouraging students to consider the key questions that can be asked of any product when considering whether or not to buy it. Recognizing that life cycle data is not readily available and that answers are not always easy to find, the outcome of this activity is a "blueprint" for students to help guide their consumer decisions. To do this, groups will first engage in a debate, where students will research the advantages and disadvantages of products and gain an appreciation for what it means to "buy green."

Potential Areas of Confusion

Our pilot tests and the literature suggest there are several topics in this section that may be sources of confusion for students, based on their assumptions, prior experience, or knowledge. You may be able to use questions to uncover this confusion and steer students toward the following clarifications:

Assumption or Confusion	More Adequate Conception
Recycled is another word for renewable resources.	Recycled means that the product was returned to a pre-production state and used to make new products. Glass is melted down and paper is re-pulped. Renewable means the original ingredients of the product are from capable of reproducing or reforming, such as deer, trees, and soil. Resources that are not renewable are in limited supply, such as minerals. Plastic bottles made from petroleum are recyclable but not from a renewable resource.
Life cycle assessment is easy to do on any product.	The more ingredients a product has, the more difficult it is to determine the impact of every ingredient. Everyday products, like a cell phone, are comprised of dozens of different materials and parts, which can each have a separate path of production. Some production processes are proprietary information and not available to curious consumers. While everything has some level of environmental impact, it is often difficult to know what it is.
The way a product is produced represents the largest impacts of a product's life cycle.	The materials and energy needed to make a product may represent larger impacts than other stages of the life cycle, but this is not always the case. For example, with cotton clothing, the amount of energy consumed to wash the article with hot water and to dry the article can be more than the energy used during production.
Life cycle assessment can tell us which product is better.	Determining 'better' is often difficult because there is not a direct comparison between impacts (even if they are all quantifiable). Which is worse, water pollution or climate change? Using a nonrenewable feedstock for a product that lasts 50 years, or using a disposable and renewable material? Such questions are the essence of interesting debate and often decided with values, not science.
All products are made the same way.	People can tell the difference between different brands of ice cream because they have different ingredients and may be made in a different manner. The same may be true for various brands of anything. This makes life cycle analysis difficult, since brands may be produced differently.

Key Concepts in this Section

- Negative externalities often impact the environment or society; their cost is either born by everyone or ignored.
- By analyzing life cycles of comparable products, one can determine if there are critical environmental impacts that should be considered prior to purchasing.
- Life cycle impacts include more than the ingredients and distance traveled. How the product is used and maintained (dry clean or wash; hang dry or electric drier; dispose or repair) and whether the product can be recycled or composted can vary.
- Product selection can affect climate change.
- Enough consumers can make a difference.

8: The Real Cost

Through a simulated shopping activity students will learn about the impact of their consumer choices on the environment. They will explore questions such as: What factors do we use to make decisions about the products we buy? What are the hidden environmental costs of everyday items? Who should pay for these hidden costs?

Subjects
Biology, Economics, Environmental Issues / Ecology, Environmental Science, Government / Politics, Integrated Science, Language Arts, Life Science

Skills
Analyzing, Comparing and Contrasting, Determining Cause and Effects, Concluding,

Materials
Module: Student pages; "8: LCA and Externalities" slide presentation and Product and Externality Cards available at [*insert url*]
Other: None

Time Considerations
Two 50-minute class periods

Related Activities in Other PLT Guides
Climate Change and Forests (Focus on Forests module); Far-Reaching Decisions (Places We Live module); The Global Climate (PreK-8 Guide); Resource-Go-Round (PreK-8 Guide)

Objectives
Students will define the term externality.
Students will provide three examples of the externalities of a product.
Students will propose ideas for how to internalize the environmental externalities of a product.

Assessment
Use essay responses to assess understanding of externalities and how they can be reduced or internalized.

Background

Every product we buy has environmental impacts, which occur at different stages of a ***product's life cycle***—the period of time that extends from raw material extraction to disposal. These environmental impacts may take the form of air pollution, water use, deforestation, and chemical leaching, for example. Through conducting ***life cycle assessments*** of specific products, environmental impacts associated with each stage of the product's life cycle can be quantified and measured. Many of those impacts are externalities. An ***externality*** is an impact on a third party, in this case the environment, caused by a decision made by a producer or consumer. Externalities can be social as well, where individuals or communities are the third party impacted by the decision.

A ***negative externality*** means that costs are incurred by the third party. For example, farming practices at an agricultural operation can cause water pollution when fertilizers or animal waste is carried by rain to nearby streams or rivers. Neither the producer nor the consumer pays the cost for the loss of clean water and so the environmental cost is *external* to the economic one, resulting in an externality. An externality can be removed or internalized by making the economic costs or benefits the same as the social or environmental costs or benefits. In the example above, the externality could be internalized by including the cost of the clean water in the cost of the product. The agricultural operation might adopt practices that do not pollute the river or pay to clean up the river after it has been polluted. Since these practices will most likely be more expensive, the company will internalize the cost of clean water in its operation and most likely pass this cost to consumers by increasing prices. Externalities can be positive as well. A ***positive externality*** means that effect is beneficial to the third party. For example, a landowner may decide to conserve their forested land instead of developing it. While the landowner may receive some benefits from this action, most of the benefits are external as the action will have positive impacts on the environment and nearby land values.

Getting Ready

Download the slide presentation "8: LCA and Externalities" from [*insert url*] and review it to determine how much you wish to present to students.

Make one copy of the Product Cards and the Externality Cards, or download the larger cards at [*insert url*].

Each student will need one copy of the "Money" student page, with pieces cut. Alternatively, you could use nickels and pennies, two different color poker chips, or other items you have on hand to represent money.

Doing the Activity

1. Place the Product Cards around the room, with similar products next to each other.

2. Explain to students that they will do an activity to learn about the connection between the products they buy and the environment.
   A. Give each student "30 dollars" and explain that they need to buy a shirt, a snack, and a drink. They can keep whatever money is left over.
   B. Point out where you have placed the product cards and note that there are two similar choices for each product; for example, there are apples from Virginia and oranges from California.
   C. Students need to take a scratch sheet of paper and writing utensil for recording their decisions.

3. Instruct students to walk around the room and buy whichever version of the three products they want. To buy a product, students should write down which product they want to buy and its price. Ask them to tally their total and bring you the correct amount of money.

4. Poll students about which products they bought. Keep a tally of how many of each product was bought; see diagram below step 7 for example. Ask students what factors they considered in their decision for which item to buy? Make a class list of the factors.

5. Explain that in addition to the factors like cost, color, and taste that products can be selected based on the environmental impacts that result from the product's creation, use, and disposal. Use the slide presentation "8: LCA and Externalities" to introduce students to the concepts of life cycle assessments and externalities.

6. Next, place the Externality Cards around the room, and return $30 to each student. Instruct students to select and purchase products again, but this time students should consider the externality information before deciding which product to purchase. Have students write down their choices, tally their total, and give you the appropriate amount of money.

7. Poll the class to see which product they bought this time and compare it to the tally from the previous game. See diagram below for example. Ask students if they see any obvious trends in the products selected between both rounds. What factors did students consider this time when making their choice? Add any new factors to the class list.

Round	Cotton Shirt	Organic Cotton Shirt	California Oranges	Virginia Apples	Bottled Water	Reusable Water Bottle
1						
2						

8. Split students into three groups and assign each group one product (snacks, shirts, or drink). Give each group member a copy of the "Product Assessment" student page and instruct students to work together to answer the questions. Each group should select one member to report their answers to the whole class.

9. Have each group report their responses to the following questions:
    a. What are the environmental externalities of your group's product? Which ones are positive and which ones are negative?
    b. At what stage of the product's life cycle do the externalities occur?
    c. How can the negative externalities be reduced?
    d. Who should pay for reducing the externalities?
    e. Did group members' opinions vary based on which product they preferred?

10. After each group reports their answers, discuss the following questions as a class:
    a. Were there any similarities in the externalities of the different products? *Many of the externalities were related to greenhouse gas emissions or water; they occurred in similar stages of the life cycle.*
    b. How could these hidden environmental costs become more visible? *Eco-labels, commercials, people could do their own research.*
    c. What generalizations can you make that will help you choose products with fewer negative externalities? *Buy locally produced food, organic products, reusable products, etc.*

11. For homework, distribute the "Externalities Essay" student page and ask students to write an essay to describe externalities and how they can be reduced or internalized. Students should pick at least one externality for each pair of products and explain how that externality could be internalized.

Enrichment

Challenge students to select a product and to think "outside the box" about how to make this product more environmentally friendly. To inspire students, show examples of products, buildings, or other items that are created with zero waste, biomimicry design, or using sustainable practices.

Resources

The Secret Life of Things

www.thesecretlifeofthings.com

This website provides a set of short animated videos exploring the hidden environmental impacts of everyday things. Each video comes with a free pack of learning resources.

The Story of Stuff Project

www.storyofstuff.org

This website contains links to several short videos related to how things are created, used, and thrown away. Video scripts and resources are available for using these materials in classrooms.

Stuff: The Secret Lives of Everyday Things

John Ryan and Alan Durning, Sightline Institute, 1997

http://www.sightline.org/research/stuff/

This book explores how nine common items are made. Each product is something that you might use or buy on a typical day, such as coffee, newspaper, or a t-shirt. The website for the book provides a curriculum guide to accompany the book and a short quiz about the book's content

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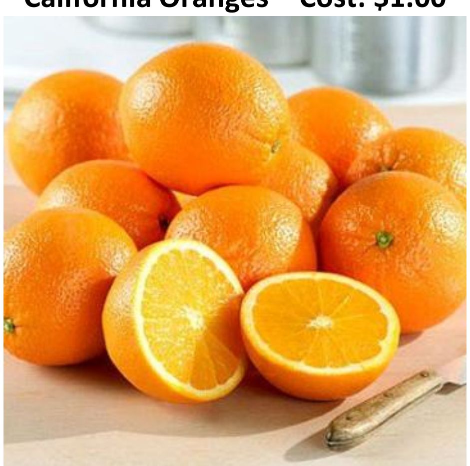
Money

$5	$5	$5
$1	$1	$1
$1	$1	$1
$1	$1	$1
$1	$1	$1
$1	$1	$1

Product Cards

Cotton Shirt – Cost: $5.00 	**Organic Cotton Shirt – Cost: $16.00** 
Bottled Water – Cost: $2.00 	**Reusable Water Bottle– Cost: $10.00** 
California Oranges – Cost: $1.00 	**Virginia Apples – Cost: $1.00** 

Externalities Cards

Cotton T-Shirt
Cotton production involves heavy use of pesticides; from planting to harvest the cotton is treated with herbicides, fungicides, and insecticides. Pesticides can be damaging to organisms that live in the soil and can be wash into streams when it rains, polluting waterways.

On average, it takes approximately 659 gallons of water to produce the cotton used to make a shirt (Water Footprint Network). Cotton is one of the most heavily irrigated crops because the water runs quickly off the fields, especially if beneficial soil organisms have been impacted by pesticide use.

Researchers have calculated that an average cotton shirt has a carbon footprint of 6.34 kg of CO_2 (Continental Clothing Co. Ltd, 2009).

Organic Cotton Shirt
Organic cotton is grown without using synthetic chemicals. This means that that only natural fertilizers, pesticides, and weeding techniques are used to produce the cotton. Growing organic cotton can use less water than growing conventional cotton, and results in fewer pollutants entering waterways (Jorgensen et al., 2006).

During the cleaning and spinning process only natural oils are used. These oils easily biodegrade, thereby reducing the number of times the shirt needs to be washed during production. In addition, only natural dyes are used. When the shirt is disposed of, it will be easily biodegradable since it is made of all natural materials (Jorgensen et al., 2006).

Researchers have calculated that the total carbon footprint for an organic cotton shirt id 2.34 kg of CO_2 (Continental Clothing Co. Ltd, 2009).

Bottled Water
Petroleum, which is a nonrenewable resource, is used to make the plastic for bottled water. Producing the bottles is an energy intensive process. In 2006 alone, bottling water produced over 2.5 million tons of carbon dioxide (Pacific Institute, 2012). Energy is needed not only to produce the bottle but also to ship it and the water around the world. This releases greenhouse gases which contribute to climate change. A great deal of water is also used in the process. Approximately three liters of water are used to manufacture one liter of bottled water (The Water Project).

Most likely this bottle will be used only once before it is disposed of. If it is a PET bottle then it can be recycled; otherwise it will take over 1,000 years to biodegrade in a landfill (The Water Project).

Reusable Water Bottle
This reusable bottle is made from aluminum; aluminum production is one of the most energy-intensive industries, contributing to greenhouse gas emissions (Tufvesson, 2011).

Since the bottle can be refilled from any tap, the transportation cost for the water is significantly lower than for bottled water. The bottle can be reused, which reduces waste. When the bottle is disposed of it can be recycled; in fact 75 percent of the primary aluminum ever produced is still in use (Tufvesson, 2011).

California Oranges
California produces over 250 different crops; much of this production is dependent on irrigation. Approximately 9.6 million acres of cropland in California require irrigation, this uses 43 million acre-feet of water a year. One acre-foot of water is equal to 325,851 gallons (California Department of Water Resources, 2010).

California oranges travel thousands of miles to the southeastern Unites States and the truck that is transporting them gets an average of 6 miles per gallon. This means that hundreds of gallons of gasoline are used, resulting in air pollution and carbon dioxide emissions which contribute to climate change.

Also, since the oranges are traveling a greater distance, the packaging is often heavier in order to protect the fruit, and this creates more waste. The oranges may be picked before they are ripe, in order to prevent them from spoiling during transportation, and then ripened later using chemicals. These chemicals will eventually be washed off, polluting waterways (Lanford, 2011).

Virginia Apples
In Virginia, the warm days, cool nights and the rich soil makes growing different apple types ideal. They are typically grown with little or no use of irrigation due to the distribution of rainfall in the area and so there is less reliance on public water for irrigation (Virginia Apple Board).

The apples are typically transported to markets in about 15 states, mostly in the eastern part of the United States (Virginia Apple Board). Therefore the apples travel a considerably shorter distance than the California oranges, reducing their fuel consumption, air pollution, and carbon footprint.

Additionally, since the apples do not travel as far they are less likely to contain preservatives and more likely to be ripened on the tree (Lanford, 2011). This reduces the number of chemicals polluting the environment.

Product Assessment

Name:

Group Members:

1. Which product did each of you chose during each round? Why?

2. What are the advantages and disadvantages of each product?

   Product 1: ___________________________

Advantages	Disadvantages
_______________________________________	_______________________________________
_______________________________________	_______________________________________
_______________________________________	_______________________________________
_______________________________________	_______________________________________

   Product 2: ___________________________

Advantages	Disadvantages
_______________________________________	_______________________________________
_______________________________________	_______________________________________
_______________________________________	_______________________________________
_______________________________________	_______________________________________

3. Which of the disadvantages are considered negative externalities? Which of the advantages are considered positive externalities?

4. At what stage in the product's life cycle do the negative externalities occur? (Hint: the life cycle stages are raw material extraction, processing, manufacturing, product use, and disposal)?

5. Who should be responsible for reducing negative externalities? Who should pay the extra cost? (For example, should the company or producer of the product pay? Should everyone pay through increased taxes?)

6. Do the responses in your group for Question 5 vary based on which product group members' preferred?

Externalities Essay

Using the information you learned from the shopping game and the group activity, write an essay to describe externalities and how they can be reduced or internalized. You should pick at least one externality for each pair of products (writing utensils, snack, and t-shirts) and explain how that externality could be internalized.

9: Adventures in Life Cycle Assessment

Students investigate the life cycle data for three types of outdoor dining furniture (plastic resin, cast aluminum, and pine) and make conclusions regarding their relative impact on global climate change. The information necessary to perform the assessment is provided in two formats: 1) a three-act stage play and 2) student presentations.

Subjects
Biology, Economics, Environmental Issues / Ecology, Environmental Science, Integrated Science, Life Science

Skills
Analyzing, Determining Cause and Effects, Concluding, Identifying Relationships and Patterns, Organizing Information, Predicting

Materials
Module:
- Stage play: Student pages, "9: LCA Play" slide presentation and "9: LCA Play Script" available at [*insert url*]
- Student presentation: Student pages, presentation materials as needed.

Other:
- Stage play: props and costumes (optional)
- Student presentation: presentation materials (as needed)

Time Considerations
Stage play: Three to four 50-minute class periods
Student presentation: Two 50-minute class periods

Related Activities in Other PLT Guides
Climate Change and Forests (*Focus on Forests* module); Far-Reaching Decisions (*Places We* Live module); The Global Climate (*PreK-8* Guide); Resource-Go-Round (*PreK-8* Guide)

Objectives
Students will describe the stages of a product's life cycle.
Students will evaluate life cycle data for three products.
Students will draw conclusions regarding advantages and disadvantages of products, as related to global climate change.
Students will explain how life cycle assessments provide important information for individual consumers.

Assessment
Ask students to draw a life cycle diagram, labeling each stage of the diagram and providing a brief description of each stage.

Have students write a report summarizing their outdoor dining furniture life cycle assessment. The report should include an introduction to life cycle assessment, a description of the products analyzed, life cycle data for each product, and a discussion comparing each product's impact on global climate change.

Ask students to decide which type of dining furniture the school should buy and defend their choice by describing their personal values and the consequences of that choice using life cycle assessment.

Background

To evaluate and compare the environmental impacts of products, scientists take a detailed look at the entire life cycle of a good or service—or conduct a ***life cycle assessment***. A ***product's life cycle*** begins with extracting and processing raw materials, includes how the product is used, and ends with disposal of the product. At every step, resources are used and ***emissions*** are created. Life cycle assessments identify these resources and emissions and summarize their environmental effects. This information can be used by scientists, policy makers, and citizens to make decisions about which products we should produce and purchase.

The National Renewable Energy Laboratory's (NREL) U.S. Life-Cycle Inventory Database is one resource where scientists and other interested people can access data to conduct life cycle assessments (http://www.nrel.gov/lci/). Data for utilities, transportation, and basic mining and forestry materials are all included in this database. The life cycle data provided in this activity was calculated using the U.S. Life-Cycle Inventory Database, and a step-by-step tutorial for using this database to find information for other products is available on the module website (see Enrichment).

The life cycle data provided in this activity to compare three types of outdoor dining furniture focuses on greenhouse gas emissions resulting from the manufacturing, use, and disposal of the product. We focus on greenhouse gas emissions so that students can calculate the ***global warming potential*** of each of the three furniture sets.

Greenhouse gases trap heat in the Earth's ***atmosphere***. A certain amount of greenhouse gases are necessary to keep the Earth warm enough to sustain life. However, increasing amounts of greenhouse gases in the atmosphere creates a gradual increase in the average global temperature, which is known as ***global warming***. Greenhouse gases include the following:

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_2O)
- Hydrofluorocarbons
- (HFCs)
- Perfluorocarbons (PFCs)
- Sulfur hexafluoride (SF_6)
- Water vapor (H_2O)

Of all the greenhouse gases, atmospheric ***carbon dioxide*** (CO_2) levels have increased the most in recent years. However, methane and nitrous oxide are important greenhouse gases to consider in the ***life cycle assessment*** as well. Not all greenhouse gases are equal. Some gases are able to capture more energy than others. For example a kilogram of methane in the atmosphere will trap about 21 times as much energy over a 100-year period as a kilogram of carbon dioxide. Therefore, it is said to have a global warming potential of 21. When scientists measure the impacts of greenhouse emissions, they often use the term ***carbon dioxide equivalents***. This is basic unit for measuring the global warming potential of emissions. Since 1 kilogram of methane traps as much heat as 21 kilograms of carbon dioxide, that one kilogram of methane has a global warming potential of 21 kilograms of carbon dioxide equivalents.

Getting Ready

Based on available time, number of students, and student interest**, you may choose to conduct this activity by performing a play or through student presentations**. The same information for conducting life cycle assessments on three types of outdoor dining furniture is provided in both formats.

Perform a Play

Students act out the play in class, and as the characters discover life cycle data for each product, the audience records this information using the "Comparing Outdoor Furniture" student page. The play is divided into three acts—one for each set of furniture. Each act has 10-11 actors and takes 20-25 minutes to perform. The acts can be performed on separate days or together if you have a long class period. You may also choose to perform one or two of the acts, and provide the "Life Cycle Information" student pages for the remaining products. After the performance, students discuss and compare each product's impact on global ***climate change***.

- Download the "9: LCA Play Script" from [*insert url*], and make the appropriate number of copies depending on the number of actors and acts being performed.
- Download the "9: LCA Play" slide presentation from [*insert url*].
- Make copies of the "Comparing Outdoor Furniture" student page, one for each student.
- You may wish to invite other students, teachers, or parents to enjoy the play. Consider practicing the performance first.

Student Presentations

Using the "Life Cycle Information" student pages, student teams give short presentations to share the product's life cycle and the greenhouse gas emissions resulting from each stage. As each team presents, students in the audience complete the "Comparing Outdoor Furniture" student page. As a class, students discuss and compare each product's impact on global ***climate change***.

- Divide the class into three teams: Plastic Resin, Cast Aluminum, and Pine. Make copies of the appropriate "Life Cycle Information" student pages, one for each student in the group.
- Make copies of the "Comparing Outdoor Furniture" student page, one for each student.

Doing the Activity

1. To introduce the topic of the life cycle assessment, ask students to select one item they have recently bought. On a scratch piece of paper, ask students to brainstorm ideas about the materials and processes it takes to make the product; what resources are used to care for or maintain the product; and where it goes once they are finishing using it. Have a few students share their ideas.

2. Explain that life cycle assessments are used to measure and calculate the environmental impact of a product. Draw the life cycle diagram on the board (see Background Information), and ask students if they can see where their ideas fit into this diagram and whether there are any circles for which they are missing ideas (or would need more info to fill).

3. Tell students to imagine that they have been charged with choosing new outdoor dining furniture for the cafeteria patio. Because your school is concerned with its environmental footprint, the students have to investigate the life cycles of three types of outdoor dining furniture before making a decision: a table and four chairs made from plastic, from aluminum, and from wood. For these assessments, we are going to focus on greenhouse gas emissions. Remind students that carbon dioxide, methane, and nitrous oxide are greenhouse gases. Through either a play or student presentations, they will gather real data for greenhouse gas emissions for each step of each product's life cycle.

4. Ask students to predict which product they think will have the lowest greenhouse gas emissions. Which do they think will have the highest? Why?

6a. Stage the Play

a. Based on the number of acts you plan to perform and the number of students, assign characters or allow students to choose their character, and pass out copies of the script.
b. For homework, ask students to read through the script and become familiar with their role. They may wish to bring props or "dress" the part of the day of the performance.

c. The “LCA Play” slide presentation provides an instant “set” for the play. Slides also provide the life cycle data for each stage, which students in the audience will need to write down on the “Comparing Outdoor Furniture” student page. You can advance the slides as noted in the script, or assign the “narrator” to do this.

6b. Student Presentations

a. Divide the class into three groups (Plastic Resin, Cast Aluminum, and Pine). Pass out the appropriate “Life Cycle Information” student pages to each group member.
b. Provide time for the students to read their “Life Cycle Information” student pages and to organize their presentation. Suggest that one to two people cover each life cycle stage, so that all group members can participate. During the presentation, they need to describe what happens during that stage and provide life cycle data.
c. Encourage students to make their presentations interesting. If giving a slide presentation, they can include relevant photos or graphics. They can also use the board, flip chart paper, or any other visual presentation style. They should finish any remaining tasks for homework, and come to the next class prepared to give their presentation.
d. While each group presents, the audience should record data on the “Comparing Outdoor Furniture” student page.

7. After the performance or presentations, give students a few minutes to complete the calculations for the greenhouse gas equivalents on the “Comparing Outdoor Furniture” student page. Then use the following wrap-up questions to guide a class discussion:

a. What are greenhouse gas equivalents? How did this change the life cycle data?
b. What surprised you as you learned about the life cycles of outdoor dining furniture?
c. What conclusions can you make about the relative impact of each product on global climate change?
d. How could production change to reduce emissions?
e. What factors do people usually consider when choosing between similar products?
f. Should life cycle information be available for more products? Why or why not?
g. Based on what you learned from the furniture comparisons, what types of general questions can you ask about a product prior to buying it? Using it? Disposing of it? Think of items that you tend to buy; what should you know about them to decide which is better for the environment?

Enrichment

Use “Create Your Own LCA” tutorial in the Appendix to have students investigate and calculate greenhouse gas emission data for another product.

Resources

Consortium for Research on Renewable Industrial Materials (CORRIM)
www.corrim.org
This website provides many resources related to life cycle assessments, including several videos, presentations, and fact sheets.

Life Cycle Impacts of Forest Management and Wood Utilization on Carbon Mitigation: Knowns and Unknowns
Bruce Lippke, et al., 2011. Carbon Management 2(3), 303–333.
http://www.corrim.org/pubs/articles/2011/FSG_Review_Carbon_Synthesis.pdf
This short article examines the complexities in accounting for carbon emissions in life cycle analyses, given the many different ways that wood is used.

The Life Cycle of Everyday Stuff
Mike Reeske and Shirley Watt Ireton, National Science Teachers Association, 2001
http://www.nsta.org/store/product_detail.aspx?id=10.2505/9780873551878
This supplemental curriculum guide uses central science concepts to explore the energy, raw materials, and waste issues that are associated with manufactured products.

U.S. Life Cycle Inventory Database
National Renewable Energy Laboratory
www.nrel.gov/lci
This database helps life cycle assessment practitioners answer questions about environmental impact. It provides accounting of the energy and material flows into and out of the environment that are associated with producing a material, component, or assembly in the U.S.

Which Do You A-Door? Comparing the Energy Needed to Make Wood and Steel Doors
Melissa Huff, Robert Ross, and Janet Stockhausen; USDA Forest Service; 2009. Natural Inquirer 9(1): 13-25.
www.naturalinquirer.org/Comparing-the-Energy-Needed-to-Make-Wood-and-Steel-Doors-a-82.html
This article, written for secondary students, describes research that compares portions of the life cycle for wood and steel doors.

References

Fox, T. R., Jokela, E. J., & Allen, H. L. (2004). The evolution of pine plantation silviculture in the southern United States. In H. M. Rauscher & K. Johnsen (Eds.), *Southern forest science: Past, present, and future* (pp. 63-82). General Technical Report SRS-75. Asheville, NC: USDA Forest Service.

Life Cycle Information: Plastic Resin Furniture

Our plastic resin set of furniture is made from polypropylene resin—a plastic polymer with a wide range of uses, including car parts, diapers, and of course, outdoor furniture. It is made from bi-products of processing natural gas and refining crude oil. Since each piece of the set is made from one mold, no fasteners are required. The total mass of the four chairs and table is approximately 30 kg. All emissions reported here are based on this mass.

A set of plastic furniture, like the one above is made from polypropylene resin.

Oil and Natural Gas Extraction

Over 300 million years ago, countless zooplankton, algae, and diatoms died and sunk to the bottom of oceans all over the globe, leaving us with billions of gallons of oil today. Crude oil is generally located in cavities several hundred feet underground. Sometimes the oil is under high enough pressure that simply drilling a deep hole causes it to gush forth out of the earth—an event that has caused many an oil prospector to dance excitedly as his new oil well showers him in a brown, goopy mess. Most of the time, however, it must be pumped to the surface. Oil from the ground usually contains water. This water is removed before sending the oil to a refinery. Some leakage of gas always occurs when bringing these substances to the surface. In addition, it takes energy to collect these substances and prepare them for refining and processing. The emissions that result from this step of the life cycle are reported below.

Stage of Life Cycle	CO_2 Emissions (kg/set)	CH_4 Emissions (kg/set)	N_2O Emissions (kg/set)
Oil and Natural Gas Extraction	4.20	0.164	0.00000588

Refining Crude Oil and Processing Natural Gas

Most of the United States refineries are in Gulf Coast states. The majority of our oil (62 percent) is imported; 32 percent comes from the lower 48 states, and the remaining 6 percent comes from Alaska. The top three providers of foreign oil to the United States are Canada, Saudi Arabia, and Mexico. Scientists use these figures to create a weighted average of the emissions associated with transporting oil to our refineries by pipeline or ship.

Once at a refinery, impurities are removed from the oil through a series of chemical processes. During this process hydrocarbons, such as methane and propane, are removed from the oil. These hydrocarbons are used in many different products, including the production of polypropylene. The greenhouse gas emissions associated with the transportation of oil to the United States refineries and refining the oil and natural gas are listed below.

Stage of Life Cycle	CO_2 Emissions (kg/set)	CH_4 Emissions (kg/set)	N_2O Emissions (kg/set)
Refining Oil / Processing Natural Gas	6.87	0.0571	0.0000350

Producing Polypropylene Resin

Propylene is made from a combination of chemicals made from oil and natural gas, including hydrocarbons such as ethane, propane, and other gas oils. These molecules are put through a process called thermal cracking. The term “cracking” refers generally to a process in which heavy molecules are broken down into smaller ones. In this case, the hydrocarbons are combined with steam and the mixture is heated to around 1000 degrees Celsius. The combination of high temperature and pressure breaks the larger hydrocarbons into smaller molecules, including propylene. The propylene must then be separated from the other products of this process.

The next step is to convert the propylene into polypropylene. The prefix “poly” means many. For example, the term “polygon” from geometry refers to a shape with many angles. In chemistry “polymer” refers to molecules that consist of many smaller molecules. Polypropylene is a molecule made up of many propylene molecules connected together. The polymerization of propylene is accomplished through the use of catalysts at fairly moderate temperatures (80-90 degrees Celsius) and high pressures (30-35 atmospheres). The greenhouse gas emissions listed below represent emission associated with the propylene portion of the thermal cracking stage as well as the polymerization of propylene into polypropylene.

Stage of Life Cycle	CO_2 Emissions (kg/set)	CH_4 Emissions (kg/set)	N_2O Emissions (kg/set)
Manufacturing Polypropylene	32.4	0.427	0.000280

Manufacturing the Furniture

Polypropylene in the form of small pellets is shipped by rail to furniture manufacturing plants. Those pellets are melted and mixed with other substances. The mixture is hydraulically injected into a mold using a 1000-ton injection molding machine. After the resin hardens, the mold is opened, a small amount of resin is trimmed from the seams, and the piece is boxed for shipment. The greenhouse gas emissions reported here represent direct energy use necessary for melting, mixing, and injecting the polypropylene resin in to the molds.

Small polypropylene pellets are packaged and shipped to manufacturing facilities that create plastic products.

Stage of Life Cycle	CO_2 Emissions (kg/set)	CH_4 Emissions (kg/set)	N_2O Emissions (kg/set)
Manufacturing Plastic Furniture	15.6	0.0372	0.0000622

Use/Maintenance

Maintenance and upkeep of the furniture is minimal, consisting of washing with soap and water. Therefore, greenhouse gas emissions associated with this stage of the life cycle are assumed to be negligible and not included in this analysis.

Stage of Life Cycle	CO_2 Emissions (kg/set)	CH_4 Emissions (kg/set)	N_2O Emissions (kg/set)
Use	0.00	0.00	0.00

Disposal

While many plastic resins can be recycled in curbside recycling programs, the mixture made during the furniture manufacturing process is not readily recyclable. Therefore, disposal of this furniture set consists of a trip to a municipal landfill. One of the criticisms of plastic resin is that it takes a very long time to decompose. Plastic can exist in a landfill for hundreds of years. In the context of greenhouse gases, this trait works in favor for plastics. Over the hundred-year period within the scope of this analysis, only 6 percent of the carbon in the plastic set will have decomposed and formed greenhouse gases—4 percent to carbon dioxide and 2 percent to methane. The greenhouse gas emissions listed below include these emissions as well as those associated with the collection and management of solid waste.

Most plastic chairs end up in a landfill after being thrown away.

Stage of Life Cycle	CO_2 Emissions (kg/set)	CH_4 Emissions (kg/set)	N_2O Emissions (kg/set)
Disposal	12.8	0.292	0.0000319

Life Cycle Information: Cast Aluminum Furniture

This aluminum cast furniture is approximately 60 kg.

Our aluminum set of dining furniture is made of cast aluminum. While manufacturers often use primary aluminum, we have based these calculations on a combination of primary and recycled aluminum often produced by aluminum plants in the United States. The energy requirements are decreased substantially by the inclusion of recycled aluminum. The mass of aluminum in our four chairs and table is approximately 60 kg.

Extracting Aluminum

Aluminum manufacturing involves use of both primary aluminum, from aluminum ore called bauxite, and secondary aluminum, which is recycled from aluminum scrap.

Producing primary aluminum first requires mining bauxite from the ground. While aluminum is the third most plentiful element in the earth's crust, it's usually found as part of a chemical compound with other elements. Trying to produce pure aluminum from most of these compounds is not economically feasible. In other words, it would cost more to produce the aluminum than the aluminum is worth. Bauxite, a type of rock that contains high amounts of aluminum is the exception, though even with bauxite, producing pure aluminum requires a lot of effort. First, the bauxite must be mined. In some cases, the bauxite is found in relatively soft rock which can be easily dug up, often in open-pit mines. In other cases more substantial drilling and the use of explosives are required. Mixing secondary aluminum with the primary aluminum decreases the amount of bauxite that must be mined. Greenhouse gas emissions are listed below for just primary aluminum (no recycling) and for the roughly 50/50 mix of primary and secondary aluminum (with recycling).

Stage of Life Cycle	CO_2 Emissions (kg/set)	CH_4 Emissions (kg/set)	N_2O Emissions (kg/set)
Bauxite Mining (No recycling)	21.0	0.00422	0.000461
Bauxite mining(With recycling)	10.1	0.00203	0.000221

Processing Aluminum

Often processed aluminum is a mixture of primary and secondary aluminum. The numbers provided for greenhouse gas emissions here are based on a roughly 50/50 split. Most of those emissions, however, are the result of the energy-intensive process of producing pure aluminum from bauxite. Once out of the ground, the bauxite is crushed into small pieces and sent to a processing plant. At the processing plant, those pieces are brought to a high temperature and pressure and mixed with sodium hydroxide in order to dissolve the ore and separate the aluminum from the other materials found in the ore. Then the liquid containing the dissolved aluminum is pumped into tanks where it is cooled, allowing alumina hydrate crystals to form. Those crystals are filtered from the tank and dried in a kiln at approximately 400 degrees Celsius to produce aluminum oxide.

Producing aluminum from the aluminum oxide requires chemical reactions at temperatures over 1000 degrees Celsius. The aluminum oxide is placed with a carbon rod into a cell where the combination of electricity and high temperatures causes a chemical reaction that produces carbon monoxide, carbon dioxide, and of course aluminum. The molten aluminum collects at the bottom of the cell where it can be separated from the other materials. Depending on the intended use of the aluminum, it will be mixed with small amounts of other metals to produce the desired characteristics. This mixture is called an alloy. The aluminum is made into an alloy while it is still in its molten form. The alloyed aluminum is then cast into ingots or billets (terms for rectangular and cylindrical pieces of aluminum alloy).

At this point the ingots of version aluminum can be mixed with secondary aluminum. Recycling scrap aluminum is a way to avoid the most energy intensive (and costly) steps of aluminum production. Scrap aluminum has already been separated from the impurities in bauxite and already been converted from aluminum oxide. To process secondary (recycled) aluminum, scrap aluminum must first be collected. Aluminum can be recycled without losing quality in the material. This makes scrap aluminum relatively valuable. As a result, collecting and recycling scrap aluminum has become its own sub-industry. Ideally, aluminum is collected in a closed-loop process based on the particular aluminum alloy. For example, soda cans are collected in order to be made into new soda cans. By including only one aluminum alloy in a batch of scrap, manufacturers can be confident that the final product will have the same desired characteristics for that particular use. In other cases, the various scrap aluminum alloys are mixed together.

In either case, once the aluminum is collected, it is shaved into small pieces for processing. Often scrap aluminum has enamel, paint, or some other substance that would reduce the purity of the final product if not removed. The aluminum is heated close to the melting point of aluminum (660°C) to remove these substances. The aluminum can then be melted down and cast into ingots or billets, similar to the process for primary aluminum, though the aluminum from the mixed scrap may require extra steps before the aluminum is again ready for use. As a result, producing recycled aluminum results in a 90% reduction of greenhouse gas emissions, compared to primary aluminum. The aluminum in our table is likely a combination of primary and recycled aluminum, but we include figures both the all primary and 50/50 mix to show the difference that recycling aluminum makes.

Scrap aluminum is melted to remove impurities.

Stage of Life Cycle	CO_2 Emissions (kg/set)	CH_4 Emissions (kg/set)	N_2O Emissions (kg/set)
Processed aluminum (all primary aluminum)	311	0.312	0.554
Processed aluminum (½ primary and ½ secondary)	187	0.302	0.266

Manufacturing Furniture

To make cast aluminum, the ingots are melted and poured into molds of the desired shape. Unlike the plastic resin, each mold corresponds to just a part of the actual furniture piece. Once the pieces have been cooled and hardened, any excess aluminum can be removed and recycled. The pieces are then shaped and welded together. The cast aluminum set also has cushions made from plastic resin. Greenhouse gas emissions from the production of the plastic resin for these cushions are also included in the calculations for this step. Still, the bulk of the greenhouse gas emissions from this step the energy needed to melt the aluminum for casting.

Stage of Life Cycle	CO_2 Emissions (kg/set)	CH_4 Emissions (kg/set)	N_2O Emissions (kg/set)
Furniture Manufacturing	108	0.437	0.000113

Use/Maintenance

Like the plastic resin furniture set, the maintenance of a cast aluminum set requires few inputs. Therefore, greenhouse gas emissions resulting from this stage are assumed to be negligible.

Stage of Life Cycle	CO_2 Emissions (kg/set)	CH_4 Emissions (kg/set)	N_2O Emissions (kg/set)
Use	0.00	0.00	0.00

Disposal

If processed correctly, aluminum can be recycled indefinitely. Also, because of the relatively high value of scrap aluminum, rates of recycling are high. For this study, we assume that all of the aluminum in the furniture set is recycled. Greenhouse gas emissions associated with the collection and processing of recycled aluminum are included in the numbers reported here.

Stage of Life Cycle	CO_2 Emissions (kg/set)	CH_4 Emissions (kg/set)	N_2O Emissions (kg/set)
Recycling Aluminum	1.76	.0000299	.0000440

If instead, the furniture set was taken to the landfill, the greenhouse gas emissions are much higher.

Stage of Life Cycle	CO_2 Emissions (kg/set)	CH_4 Emissions (kg/set)	N_2O Emissions (kg/set)
Recycling Aluminum	16.1	0.0383	.0000640

Life Cycle Information: Pine Furniture

This furniture is made from lumber harvested from southern pine trees

Our set of pine furniture weighs 70 kg in total. Slightly more wood than that is needed to account for wood lost during cutting and sanding. The emissions provided in this section are based on this mass for the final product, with adjustments made to account for wood loss at each step.

Managing Forests and Harvesting Wood

You may recall from previous exercises that when looking at the carbon dioxide emissions resulting from harvesting wood, it is important to distinguish between CO_2 produced from burning fossil fuels and CO_2 released from wood. The carbon trapped in trees is on a relatively short cycle. Trees live for decades or perhaps centuries, absorbing CO_2 as they grow. When a tree dies, it decomposes, and the carbon stored in the tree is again released to the atmosphere in the form of CO_2. Of course even as a tree dies, other trees are still growing and still absorbing CO_2 from the atmosphere. Therefore, if a forest is managed sustainably—that is, if it is harvested no faster than its ability to grow new trees—then the CO_2 released by harvested trees is, over time, balanced out by the CO_2 consumed by the new trees as they continue to grow. Because this carbon cycle is balanced, scientists typically do not include it when calculating CO_2 emissions over time.

Most trees produced in the southeastern United States for lumber are grown on large plantations.

Conversely, when we burn fossil fuels, we are taking carbon that has been trapped for hundreds of millions of years and converting that to CO_2. Since new fossil fuels are not being produced at anywhere near the rate that we are using them, this represents a flow of greenhouse gas into the atmosphere with no corresponding sink. Therefore, in our life-cycle analysis, we will focus on the greenhouse gas emissions resulting from the use of fossil fuels.

Most trees produced in the southeastern United States for lumber are grown on large plantations. In fact with more than 32 million acres of southern pine plantations, the southeastern United States has been called "the wood basket of the world" (Fox, Jokela, & Allen, 2004). Harvesting of the trees requires fuel for cutting and trimming the trees into logs and then transporting those logs to a mill. Sustainable management of a pine plantation, however, requires much more than harvesting trees. New seedlings must be produced and planted to replace harvested trees. Fostering the growth of these new trees requires application of fertilizer and removal of weeds.

The intensity at which pine plantations are managed varies. Scientists label a plantation as low, medium, or high intensity based on its level of production. Currently, 37 percent of the pine plantations on the southeastern United States are managed at low intensity, 58 percent at medium intensity, and 5 percent at high intensity. The level of greenhouse gas emissions varies with the level of intensity. In order to calculate the greenhouse gas emissions that result this step of the life cycle of our pine furniture set, a weighted average was calculated. The emissions resulting from the production of the amount of logged wood necessary to produce our furniture set are listed below.

Stage of Life Cycle	CO_2 Emissions (kg/set)	CH_4 Emissions (kg/set)	N_2O Emissions (kg/set)
Sustainable Wood Production	2.84	0.00245	0.0000352

Lumber Manufacturing

The manufacturing process for lumber starts with logs being taken from the unloading deck of the lumber mill and placed on a chain conveyor that takes them into the mill where they are sorted, cut to a desired length, and debarked. The sawdust and bark made during these steps are collected and used for fuel. A large band saw cuts the logs into pieces roughly the size and shape in which they need to be to be sold as lumber. The sawyer takes care to cut the log so that he gets the maximum amount of lumber from the log. These pieces are then trimmed and taken to the kiln for drying. The sawdust is again collected for fuel.

When a tree is felled, roughly a quarter of its weight is from moisture stored in the trunk. At this point in the process, the wood pieces are called "green lumber" because they still have most of that moisture. Most of this moisture is removed using a kiln, which is fueled largely by the bark and sawdust collected during the other steps of the process. Since the combustion of these wood products mimics the decomposition of wood in a forest, the carbon emitted from this combustion need not be included in this analysis.


This lumber has been processed and is ready for sale.

Once the wood has been dried, it is planed. During this step, the surfaces of the lumber are smoothed and the wood is trimmed again if necessary. Finally, the lumber is sorted by size and quality and prepared for sale. The emissions reported below include those related to energy from fossil fuels necessary for this step.

Stage of Life Cycle	CO_2 Emissions (kg/set)	CH_4 Emissions (kg/set)	N_2O Emissions (kg/set)
Wood Processing—Lumber Production	5.96	0.0110	0.0000134

Pressure-Treating Lumber

Lumber designated for outdoor use is typically pressure-treated in order to protect it from insects and moisture, extending the useful life of the lumber. In a typical pressure-treating process, the lumber is placed in a large horizontal cylinder which is then tightly sealed. Preservative chemicals are then pumped into the cylinder. High pressure is used in order to increase the degree to which the chemicals penetrate into the wood. The drying process in the lumber processing also helps to increase the amount of preservative absorbed by the wood.

The emissions numbers provided for this step include direct emissions from the high-pressure treatment process as well as emissions associated with the production of the preservative chemicals used during the process. These emissions are listed below.

Stage of Life Cycle	CO_2 Emissions (kg/set)	CH_4 Emissions (kg/set)	N_2O Emissions (kg/set)
Pressure Treatment	6.17	0.0143	0.0000741

Manufacturing Furniture

Of the three sets of furniture, manufacturing the wood furniture is perhaps the easiest for the general public to picture. The pieces treated of lumber must be cut to the correct size and shape and sanded smooth. Those pieces are then fastened together with stainless steel fasteners. The production of these fasteners must also be included when considering the emissions associated with this step of the life cycle.

Stainless steel is a combination of iron, chromium, and nickel. Scrap iron can be used. The rest of the ingredients must be mined from the ground and separated from their ores. The ingredients are melted in mixed in an arc furnace at temperatures over 1600 degrees Celsius. The molten steel is then transferred to a refining vessel, where impurities are removed. The steel is then cast and rolled out into flat sheets. The sheets are then cut into the desired dimensions for making screws, nuts, and washers. The combined weight of the screws and other steel pieces in our example furniture set is 1 kg. The combined emissions associate with the production of the stainless steel fasteners and the manufacturing of the wood furniture are provided below.

Stage of Life Cycle	CO_2 Emissions (kg/set)	CH_4 Emissions (kg/set)	N_2O Emissions (kg/set)
Furniture Manufacturing	5.24	0.00686	0.0000410

Use/Maintenance

Wood sealer is typically applied to outdoor furniture in order to protect it from damage from environmental conditions. For this study, it is assumed that one treatment of sealer is used over the ten-year life of the furniture set. The emissions listed for this section take into account the gases emitted during the production of the wood sealant.

Stage of Life Cycle	CO_2 Emissions (kg/set)	CH_4 Emissions (kg/set)	N_2O Emissions (kg/set)
Use	4.25	0.00976	0.0000432

Disposal

Treated wood must be disposed of in a municipal landfill because of the potential harmful affects of the preservative chemicals added to the wood during pressure treatment. Emissions associated with ordinary decay of wood are assumed to parallel the emissions that would result from wood decay in a forest. Therefore, those emissions are not included among the figures for this analysis. However, when wood decomposed in a forest, the process is aerobic. In other words, decomposers use oxygen to break down the wood, producing carbon dioxide. Decomposition in a landfill is anaerobic. Since no oxygen is present, the chemical reactions taking place result in the production of methane instead of carbon dioxide. This methane would not have been produced under normal forest conditions. Therefore, the methane emissions resulting from the anaerobic decomposition of wood in landfills are included in the emissions figures for this step of the life cycle. Other emissions result from fuels used in the collection of waste and the management of landfills. These numbers are provided below.

Stage of Life Cycle	CO_2 Emissions (kg/set)	CH_4 Emissions (kg/set)	N_2O Emissions (kg/set)
Disposal	24.6	1.63	0.0000733

Comparing Outdoor Furniture

Name:

Instructions: As you listen to the play or to the student presentations, collect information about the following questions.

Plastic Resin Furniture Set

1. What are the basic raw material inputs necessary to produce polypropylene and other plastic resins?

Aluminum Furniture Set

2. When processing aluminum, most of the emissions of the result of which step?

3. How many times can aluminum be recycled?

Pine Furniture Set

4. Why don't scientists typically include carbon dioxide emitted from burning wood when calculating emissions over time?

Summary

5. Which furniture would be best for your school? Why?

6. If every school in your state purchased this type of outdoor furniture, what might the short and long-term impacts be?

Greenhouse Gas Emissions Tables

Use the tables below to keep track of the greenhouse gas emissions associated with each step of the lifecycle.

Remember

CO_2 = Carbon dioxide CH_4 = Methane
N_2O = Nitrous oxide   kg = kilogram

Plastic Resin Set

Stage of Life Cycle	CO_2 Emissions (kg/set)	CH_4 Emissions (kg/set)	N_2O Emissions (kg/set)
Oil and Natural Gas Extraction			
Refining Oil / Processing Natural Gas			
Manufacturing Polypropylene			
Manufacturing Plastic Furniture			
Use			
Disposal			
TOTAL EMISSIONS			

Cast Aluminum Set

Stage of Life Cycle	CO_2 Emissions (kg/set)	CH_4 Emissions (kg/set)	N_2O Emissions (kg/set)
Bauxite Mining			
Recycling Aluminum			
Processed Aluminum			
Furniture Manufacturing			
Use			
Disposal (Recycling)			
TOTAL EMISSIONS			

Cast Aluminum Set (without recycling)

Stage of Life Cycle	CO_2 Emissions (kg/set)	CH_4 Emissions (kg/set)	N_2O Emissions (kg/set)
Bauxite Mining			
Processed aluminum			
Furniture Manufacturing			
Use			
Disposal			
TOTAL EMISSIONS			

Pine Set

Stage of Life Cycle	CO_2 Emissions (kg/set)	CH_4 Emissions (kg/set)	N_2O Emissions (kg/set)
Sustainable Wood Production			
Wood Processing—Lumber Production			
Pressure Treatment			
Furniture Manufacturing			
Use			
Disposal			
TOTAL EMISSIONS			

Global Warming Contribution Calculation:
After you have recorded the greenhouse gas emissions from each step and totaled the results, there's still one more step left to see which furniture set will have the highest impact on climate change. Not all greenhouse gases are equal. Some gases are able to capture more energy than others. For example a kilogram of methane in the atmosphere will trap about 21 times as much energy over a 100-year period as a kilogram of carbon dioxide. Therefore, it is said to have a global warming potential of 21. When scientists measure the impacts of greenhouse emissions, they often use the term "carbon dioxide equivalents." This is basic unit for measuring the global warming potential of emissions. Since 1 kg of methane traps as much heat as 21 kilograms of carbon dioxide, that one kilogram of methane has a global warming potential of 21 kilograms of carbon dioxide equivalents. Now you can calculate the global warming potential of each of the three furniture sets. Use the table below to help you with your calculations.

Calculating the Global Warming Contribution of Greenhouse Gas Emissions

Gas	Emissions (kg)	Global Warming Potential (100-year period)	Carbon dioxide Equivalents (kg CO_2-eq)
Plastic Resin Set			
Carbon dioxide		x 1	
Methane		x 21	
Nitrous Oxide		x 310	
		TOTAL	
Aluminum Set			
Carbon dioxide		x 1	
Methane		x 21	
Nitrous Oxide		x 310	
		TOTAL	
Pine Set			
Carbon dioxide		x 1	
Methane		x 21	
Nitrous Oxide		x 310	
		TOTAL	

Comparing Outdoor Furniture

1. Crude oil and natural gas.

2. Most emissions are the result of the energy-intensive process of producing pure aluminum from bauxite, (not from the process of recycling aluminum scrap).

3. If processed correctly, aluminum can be recycled indefinitely.

4. Trees absorb CO_2 as they grow, and when a tree decomposes or burns, the carbon stored in the tree is released to the atmosphere in the form of CO_2. Over time, the CO_2 emitted to the atmosphere is consumed by new growing trees. This assumes that trees are not harvested faster than new ones can grow. Because this carbon cycle is balanced, scientists typically do not include it when calculating CO_2 emissions over time.

5. Answers may vary. In the context of global climate change, the wood set results in the least amount of greenhouse gases. Buying wood from the Southeast may also be desirable in order to support local economies.

6. To answer this question, you can estimate how many sets of furniture might be needed to supply the all the schools in your state. From there, you can multiply that number to the savings in greenhouse gas emissions (from buying the pine set rather than the plastic or aluminum sets). This will provide the number of greenhouse gas emissions avoided statewide. Short term impacts for schools in the Southeast may include a boost to local economies and a preservation of forests as forest owners opt to maintain their forests rather than shift to other means of income from their land. Long-term impacts include the decrease in the effects of climate change discussed elsewhere in this module.

Greenhouse Gas Emissions Tables

Plastic Resin Set

Stage of Life Cycle	CO_2 Emissions (kg/set)	CH_4 Emissions (kg/set)	N_2O Emissions (kg/set)
Oil and Natural Gas Extraction	4.20	0.164	0.00000588
Refining Oil / Processing Natural Gas	6.87	0.0571	0.0000350
Manufacturing Polypropylene	32.4	0.427	0.000280
Manufacturing Plastic Furniture	15.6	0.0372	0.0000622
Use	0.00	0.00	0.00
Disposal	12.8	0.292	0.0000319
TOTAL EMISSIONS	71.9	0.977	0.000415

Cast Aluminum Set (With recycling)

Stage of Life Cycle	CO_2 Emissions (kg/set)	CH_4 Emissions (kg/set)	N_2O Emissions (kg/set)
Bauxite Mining	10.1	0.00203	0.000221
Processed aluminum	187	0.302	0.266
Furniture Manufacturing	108	0.437	0.000113
Use	0.00	0.00	0.00
Recycling Aluminum	1.76	.0000299	.0000440
TOTAL EMISSIONS	307	0.740	0.266

Cast Aluminum Set (without recycling)

Stage of Life Cycle	CO_2 Emissions (kg/set)	CH_4 Emissions (kg/set)	N_2O Emissions (kg/set)
Bauxite Mining	21.0	0.00422	0.000461
Processed aluminum	311	0.312	0.554
Furniture Manufacturing	108	0.437	0.000113
Use	0.00	0.00	0.00
Disposal	16.1	0.0383	0.0000640
TOTAL EMISSIONS	456	0.791	0.555

Pine Set

Stage of Life Cycle	CO_2 Emissions (kg/set)	CH_4 Emissions (kg/set)	N_2O Emissions (kg/set)
Sustainable Wood Production	2.84	0.00245	0.0000352
Wood Processing—Lumber Production	5.96	0.0110	0.0000134
Pressure Treatment	6.17	0.0143	0.0000741
Furniture Manufacturing	5.24	0.00686	0.0000410
Use	4.25	0.00976	0.0000432
Disposal	24.6	1.63	0.0000733
TOTAL EMISSIONS	49.0	1.67	0.000280

Calculating the Global Warming Contribution of Greenhouse Gas Emissions

Gas	Emissions (kg)	Global Warming Potential (100-year period)	Carbon dioxide Equivalents (kg CO_2-eq)
Plastic Resin Set			
Carbon dioxide	71.9 kg	x 1	71.9 kg CO_2-eq
Methane	0.977 kg	x 21	20.5 kg CO_2-eq
Nitrous Oxide	0.000415 kg	x 310	0.123 kg CO_2-eq
		TOTAL	**92.5 kg CO_2-eq**
Aluminum Set (with recycling)			
Carbon dioxide	307 kg	x 1	307 kg CO_2-eq
Methane	0.740 kg	x 21	15.5 kg CO_2-eq
Nitrous Oxide	0.266	x 310	78.9 kg CO_2-eq
		TOTAL	**402 kg CO_2-eq**
Aluminum Set (without recycling)			
Carbon dioxide	456 kg	x 1	456 kg CO_2-eq
Methane	0.791 kg	x 21	16.6 kg CO_2-eq
Nitrous Oxide	0.555 kg	x 310	164 kg CO_2-eq
		TOTAL	**637 kg CO_2-eq**
Pine Set			
Carbon dioxide	49.0 kg	x 1	49.0 kg CO_2-eq
Methane	1.67 kg	x 21	35.1 kg CO_2-eq
Nitrous Oxide	0.000280 kg	x 310	0.0829 kg CO_2-eq
		TOTAL	**84.3 kg CO_2-eq**

10: Life Cycle Assessment Debate

After a debate where students compare products, students develop a set of life cycle questions that can be used to guide consumer choices.

Subjects
Biology, Economics, Environmental Issues / Ecology, Environmental Science, Integrated Science, Life Science

Skills
Comparing and contrasting, Oral presentation skills

Materials
Module: Student pages
Other: None

Time Considerations
Two 50-minute class periods

Related Activities in Other PLT Guides
Climate Change and Forests (Focus on Forests module); Far-Reaching Decisions (Places We Live module); The Global Climate (PreK-8 Guide); Resource-Go-Round (PreK-8 Guide)

Objectives
Students will compare the environmental impacts of different products.
Students will explain how products are rarely only environmentally good or bad but rather embody a mix of factors and considerations.
Students will identify questions they think are important to ask about a product before buying it.

Assessment
Using their notes taken during the debates, ask students to pick one product pair (e.g., paper cups vs. glass cups) and describe the environmental impacts for each of the five stages of the products' life cycle. They should compare the impacts of the two products and indicate which one has fewer negative environmental impacts and defend why that product is more environmentally friendly.

Background

Life cycle assessments do not provide a black and white picture of which products are good for the environment and which are not. Each stage in the life cycle can have so many externalities that it may not be clear which of two products is the "winner." For example, in this activity, students will debate whether print books or E-books are more environmentally friendly. If someone values tree ***conservation***, they might choose E-books since one device can hold millions of pages of paper. On the other hand, if someone is concerned about pollution from electronic waste, they may feel that print books are better for the environment.

There are ways to reduce negative externalities in each stage of a product's life cycle. For example, during the material extraction phase, renewable resources are often better for the environment than ***nonrenewable resources*** that will eventually be depleted. A ***renewable resource*** is a natural material that can be replenished within the span of a human lifetime. Also, choosing materials made with wood can lower the ***carbon footprint*** for a product. When a tree is cut down and turned into a product such as a desk, the carbon that was stored in that tree is now stored in the desk. Since the product is helping to store carbon as well as emitting carbon during production and transportation, the overall amount of carbon added to the atmosphere will be lower than it would be for a plastic or metal product. Reusing and recycling products can reduce the amount of material that ends up in landfills and ultimately reduce landfill ***emissions*** of methane.

Getting Ready

Make copies of the three student pages. Each student in the debate groups (Cups; Books; Bottles and Cans; Grocery Bags) should have the respective "Product Information Sheet" which contains information about their product and their opposing product. Every student in the class should also receive copies of the "Debate Guide" and "Reflection" student page.

Consider completing *The Real Cost* and *Adventures in Life Cycle Assessment* activities in this module first.

Doing the Activity

Day 1- Introduction to LCA

1. Start a discussion by asking students what characteristics they consider and what their parents consider when deciding which of two similar products they should purchase? For example, how do they choose between two similar food products, between two small electronic products, or between two sizable purchases (such as a car)? Do the types of considerations change?

2. Split the class into 8 groups and assign each to a product. Pair up groups who have been assigned to parallel products (foam cups and paper cups; paperback books and e-books; plastic bottles and aluminum cans; paper bags and plastic bags). Each group will defend their product in the debate about the environmentally-friendly life cycle factors. Give each student the respective "Product Information Sheet" for the pair of products and the "Debate Guide" student page to help prepare them for the debate.

3. Ask students to read their "Product Information Sheet" and answer the questions on the "Debate Guide." Give the students adequate time to plan a strategy for their debate based on the information they have.

Day 2- Debates

4. Each group will attempt to convince the class which product is more environmentally friendly based on the environmental impacts of each stage of the life cycle assessment. Each should require approximately 14 minutes. Each student in the group should speak during the debate. Each group should take 3 minutes to present their perspective, then respond for 2 minutes to answer or raise more questions, and finally 2 minutes to summarize their main points and concede others. It will be helpful if you have a

timer to keep track of time. It will also be helpful to look at the "Debate Guide" handout to make sure they are hitting all the key points. Each side should explain the inputs and environmental impacts for each of the five stages of the life cycle assessment and explain why their product has more positive or fewer negative environmental impacts than the other product. Students not participating in debate should take notes for their assessment.

5. Lead a class discussion about the debate using the following questions:
   A. Does everyone agree with the position that they argued in the debate?
   B. Did anyone change their mind? What information was convincing?
   C. Which product do they now favor for each pair?
   D. What made it difficult to decide which product is best?
   E. Are the environmental impacts externalities or are they included in the cost of the product?

6. Distribute the "Reflection" student page to each student, and ask them to complete the questions for homework.

Enrichment

Ask students to consider the questions they generated in response to Question 6 on the "Reflections" student page for a product they want to purchase. Have students write a short essay that describes the product, the questions they asked of the product, and how the responses influenced their intention to buy the product.

Using the Life Cycle Assessment Tutorial that is part of this module, advanced students can conduct a complete life cycle assessment on another pair of products and report on the environmental benefits of one.

Resources

Ecolabel Index Website
Big Room, Inc.
http://www.ecolabelindex.com/
This website provides an informative directory of environment-related product labels from around the world.

Purchasing Guidelines for the Environmentally Conscious Consumer, CDFS-180-08
Joe Heimlich, The Ohio State University, 2008
http://ohioline.osu.edu/cd-fact/pdf/0180.pdf
This fact sheet provides a general discussion about buying environmentally-friendly products and includes a set of questions that consumers can ask before buying a product.

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Product Information Sheet: Cups

Paper Cups

Paper cups are made from trees, a renewable resource. They are designed as a disposable product that is typically used one time. It takes approximately 0.55 megajoules to manufacture a paper cup (Hocking, 1994). While some paper cups have a small amount of recycled content, most are created from virgin tree fiber. Paper cups are coated with a thin lining, typically made from polyethylene, which is a type of plastic (Packer, 2009).

The plastic lining keeps the paper from being ruined by the liquid, but it also makes the cups non-recyclable. Therefore, paper cups usually go with trash to a landfill. Landfills have different decomposition rates, depending on sunlight, moisture, and air exposure. In some cases, paper cups can spend over one hundred years in a landfill due to the lack of water and oxygen needed to breakdown the product. Paper and paperboard materials made up 29 percent of the 250 million tons of total municipal solid waste generated in the United States in 2010. Approximately 62.5 percent of these materials were recovered through recycling—leaving almost 27 million tons in landfills (US EPA, 2011).

Drinking Glass

Glass is a mixture of sand, gypsum, soda ash, limestone, and dolomite; all are acquired through mining. The raw materials are brought to the manufacturing plant by train, where they are mixed together and melted down to form glass at around 3,000 degrees Fahrenheit (Hess, 2006). The energy to create one glass is approximately 5.5 megajoules (MJ).

Drinking glasses are reusable, and many are used daily for many years. Each time a glass is used, it must be washed which requires energy and water. Assuming a dishwasher uses 0.18 MJ to wash each glass and that it took 5.5 MJ to manufacture the glass cup, a glass cup must be used 15 times before it becomes as energy efficient as a paper cup (Hocking, 1994). When a person is finished owning a glass it could be donated or sold at a garage sale. Drinking glasses are not accepted at many recycling facilities because of the type of glass used to make them. Therefore, when glasses are broken or thrown away, they often end up at a landfill.

Product Information Sheet: Books

Paperback books

A traditional paperback book is made from paper, cardboard, ink and glue. Paper is made from trees, a renewable resource. Most of the wood used by paper companies in the United States comes from privately-owned tree farms, where trees are grown, harvested, and replanted. Paper can be made from harvesting whole trees, from wood chips and sawdust that are the byproduct of harvesting trees for lumber or other purposes, or from recycled paper products. The energy used at paper-making facilities can come from fossil fuels or from using their own wood waste, such as sawdust. It is estimated that the paper used to make one book requires two kilowatt hours of energy (Goleman & Norris, 2010). The facility produces wastewater that can be a pollutant to local waterways. All water and air pollution is monitored to ensure it adheres to current environmental regulations.

Every year, Americans use an average of 700 pounds of paper products, including books, magazines, and newspapers (TAPPI, 2013). The amount of paper that can be produced from one tree depends on many factors. In general, it takes 12 trees to produce one ton of non-recycled paper (Conservatree, 2012). This means that one tree makes about 167 pounds of paper, which could be used to produce about 83 books.

An advantage of paper books is that they can be given or sold to others, allowing for a post-consumer market. Some people find value in a book that they can hold, as opposed to a digital book. Depending on how owners treat them, books can last hundreds of years. Books can also be recycled once people are done with them. In 2010, paper and paperboard materials made up 29 percent of the 250 million tons of total municipal solid waste generated in the United States. Approximately 62.5 percent of these materials were recovered through recycling—leaving almost 27 million tons in landfills (US EPA, 2011).

E-book Readers

Electronic books, or e-book readers, are gaining popularity. Depending on the device's memory space, e-book readers can more than 1,000 books, saving both physical space and paper resources. These products require fewer trees to be harvested than the print alternative.

Heavy metals used to make e-book readers, such as gold, silver, cadmium, lead, mercury and chromium, must be mined and processed. One e-book reader requires the extraction of 33 pounds of minerals. The facilities that manufacture e-book readers most likely use fossil fuels to power their machines. To make an e-reader, it takes 100 kilowatt hours, which results in 66 pounds of carbon dioxide (Goleman & Norris, 2010). During the use of the product, consumers will be able to download books automatically, which does not require transportation to a book store or library. The device does need to be charged, which requires energy.

Used electronics can be passed on to other people. When e-book readers break or the battery runs out, they are likely to be thrown away by consumers, leading to toxic metals in landfills. Used electronics are also sent to other countries where workers, including children, dismantle it by hand. In the process, workers are exposed to a wide range of toxic substances (Goleman & Norris, 2010).

Product Information Sheet: Bottles and Cans

Plastic Bottles

Plastic bottles are made from petroleum through an energy intensive process that produces CO_2 emissions. While some energy is used when the plastic is molded into the bottle shape, the largest amount of energy is used to actually produce the plastic itself (University of Cambridge, 2005). Producing a one liter bottle, cap, and packaging requires around 3.4 megajoules of energy (Pacific Institute, 2012).

Plastic can take hundreds of years to decompose in a landfill. However, many plastic bottles are recyclable. Plastic containers are assigned a number one through seven based on the type of plastic they are made. Most plastic beverage bottles are produced in number one or two containers, which are recyclable in most areas. In 2010, over 13 percent of plastic containers—mostly soft drink, milk, and water bottles—were recycled (US EPA, 2011). Recycling uses about 10 percent of the energy that is required to produce one pound of plastic from virgin materials (US EPA, 2002). During the recycling process, the chemical structure of the plastic is altered, so the recycled plastic cannot be remade into plastic bottles. When plastic containers are recycled, they are often made into products like carpeting and jackets.

Aluminum Cans

Aluminum is produced by refining bauxite, a mineral ore that contains alumina. It takes four tons of bauxite to produce two tons of alumina. The alumina is then processed into aluminum metal through a smelting process. 6.2 kilowatt hours of electricity is required to produce one pound of aluminum. In the United States, most of the aluminum is produced from bauxite imported Japan or Australia (Reynolds Aluminum, 1999).

The entire aluminum can is recyclable–it be melted down and reused with little loss in quality. In as little as 60 days, aluminum can be recycled and back on the shelf (Gardner, 2010). In states with bottle laws, people pay a small deposit when they purchase a can, which is returned when the can is brought back for recycling. In 2010, the recycling rate of aluminum cans was about 49.6 percent. Recycling 1 ton of aluminum cans conserves more than 207 million Btu, which is the equivalent of 36 barrels of oil or 1,665 gallons of gasoline (US EPA, 2011).

Product Information Sheet: Grocery Bags

Paper Bags

Paper bags are made from cellulose from trees, a renewable resource. Most of the wood used by paper companies in the United States comes from privately-owned tree farms, where trees are grown, harvested, and replanted. Paper can be made from harvesting whole trees, from wood chips and sawdust that are the byproduct of harvesting trees for lumber or other purposes. To improve durability and strength, paper bags are typically made from mostly virgin wood fibers, although they can contain various amount of recycled paper materials as well. The energy used at paper-making facilities can come from fossil fuels or from using their own wood waste, such as sawdust. The facility produces wastewater that can be a pollutant to local waterways. All water and air pollution is monitored to ensure it adheres to current environmental regulations.

About 10 to 15 percent of paper bags are recycled by consumers (Project GreenBag, 2009). For those bags that end up in a landfill, the length of time it takes for paper to decompose depends on a number of factors, such as temperature, pH, presence of bacteria and nutrients, as well as composition of the paper (Chaffee & Yaros, 2010).

According to a life cycle assessment, the overall energy use for 1,000 paper bags that contain 30 percent recycled material is 2,622 megajoules (Chaffee & Yaros, 2010).

Plastic Bags

Plastic bags are made from a material called polyethylene, which is produced from petroleum and natural gas (LaJeunesse, 2004). In 2001, between 500 billion and 1 trillion plastic bags were used worldwide. It is estimated that one to three percent of theses bags ended up neither in landfills or in recycling systems, but as litter (Roach, 2003).

Plastic bags are 100 percent recyclable. In 2010, 12 percent of plastic bags, sacks, and wraps were recycled (US EPA, 2012). Because the plastic used in grocery bags is so thin, the recycled material is often not turned back into bags and instead used in other items (Progressive Bag Alliance). Many plastic bags end up being neither recycled nor put in the trash, but as litter that makes its way to rivers, streams, and oceans. This litter can impact marine, freshwater, and forest habitats.

According to a life cycle assessment, the overall energy use for 1,000 plastic bags is 509 megajoules (Chaffee & Yaros, 2010).

Debate Guide

Group Members:

Think about the following questions as you read the information sheet for your product. Make sure that you are able to answer each question. Addressing all of these points will make your debate more well-rounded and convincing. Focus on what is environmentally friendly about your product!

Each debate will last 14 minutes. Each group will have 3 minutes to present their side, 2 minutes to respond to the other group, and 2 minutes to summarize their main points. You should take notes during the other debates you do not participate in.

1. What are the raw materials that go into your product (ex. trees, aluminum, etc.)? How is this material harvested and processed?

2. How is the product made? How much energy goes into creating it?

3. How many times can the product be used? If it can be reused, does it require maintenance such as washing? Are there ways to use and maintain the product that require less water, less energy, or extend the amount of time it can be used?

4. What happens when the consumer no longer wants the product? Can it be given to someone else? Can it be recycled? Does it go to the landfill or incinerator?

Reflection

Name:

For questions 1 through 4, provide a one to two sentence response. For question 6, respond with one to two paragraphs.

1. Thinking just about the acquisition of raw materials part of the life cycle, what characteristics would make a product more environmentally friendly?

2. Thinking just about the production part of the life cycle, what characteristics would make a product more environmentally friendly?

3. Thinking just about the consumption part of the life cycle, what characteristics would make a product more environmentally friendly?

4. Thinking just about the disposal part of the life cycle, what characteristics would make a product more environmentally friendly?

5. Often when making decisions about what products to buy, we don't have access to information summarizing and comparing product life cycles. However, we still must make decisions for what to purchase. In your opinion what are the most important questions to ask when deciding among products? Why?

Section 5: Solutions for Change
Working toward healthy, sustainable forests and communities

Whether you've used all thirteen activities or selected the three most appropriate for your class, students are likely to need additional time to make connections between these concepts and reflect on how this information can be used. In addition, many students are most interested in what they can do, now, to affect the issue of ***climate change***. This section provides three activities that will help you and your students link concepts together, apply them to local forests, and consider ways to take action.

Activity 11, **The Carbon Puzzle**, helps students connect the concepts of carbon sequestration in pine forests, carbon in wood products, and wood product substitution. It is a good culmination to the life cycle assessment activities in Section 4 and the carbon sequestration calculations in Activity 7. This activity is based on research that assesses these three carbon pools to understand how to maximize the removal of atmospheric carbon. Students will participate in a "six bits" group exercise where students will assess a series of facts to answer the question: How can we best manage forests and wood to reduce atmospheric carbon dioxide? In addition, you can walk students through a complex graph that combines multiple carbon pools; they can use this information to answer questions as they interpret the graph.

Activity 12, **Future of Our Forests**, allows student teams to become experts on one aspect of southern forests and climate change; each aspect reflects a component of the module and summarizes the activities they have completed. After researching their topic, students give a presentation to the class and then compile a report, letter, or essay that synthesizes all the presentations about the future of southeastern forests. This may be a challenging activity if students have not participated in all the activities.

Activity 13, **Starting an Environmental Action Project**, provides guidance to plan and complete an environmental action project related to local forests and climate change solutions. Using the knowledge they have gained by completing the module activities, teachers help students to take action within their communities.

Potential Areas of Confusion
Our pilot tests and the literature suggest there are several topics in this section that may be sources of confusion for students, based on their assumptions, prior experience, or knowledge. You may be able to use questions to uncover this confusion and steer students toward the following clarifications:

Assumption or Confusion	More Adequate Conception
We can completely reverse or solve climate change with the right solutions.	The solutions we implement today can lessen, but not completely stop, climate change and its impacts.
If we can implement climate change mitigation strategies, we don't need to worry about adapting to projected changes. If we focus on how to adapt to project climate changes, we don't need to change our behaviors using mitigation strategies.	Solutions should consider both mitigation and adaptation strategies so that we can reduce climate change impacts as much as possible and prepare for projected changes that cannot be avoided.

Key Concepts in this Section

- The impact of a product includes the carbon savings accrued by not using an alternative product that is fossil-fuel intensive to produce, use, or dispose.
- Many strategies can be used to enhance forests, mitigate climate change, and adapt to future climate changes; these strategies will work best when implemented together.
- While there may be many details that people disagree on, they are likely to agree that forests are important to their community, maintaining healthy forests is a good goal, and many people can work together to do so.
- Students can make a difference by being leaders in creating positive change within their communities.

11: The Carbon Puzzle

Using a group activity, students assess a series of facts to understand how to manage forests to maximize the removal of atmospheric carbon.

Subjects
Agriculture Education, Biology, Environmental Issues / Ecology, Environmental Science, Forestry / Natural Resource Management, Integrated Science, Mathematics

Skills
Communicating, Group Participation, Interpreting, Organizing Information, Problem Solving, Synthesizing

Materials
Module: Student pages, "11: Graphing Carbon" slide presentation available at [*insert url*]
Other: Scissors

Time Considerations
One to two 50-minute periods

Related Activities in Other PLT Guides
Climate Change and Forests (*Focus on Forests* module)

Objectives
Students will synthesize individual pieces of information to draw conclusions about the role of forests in carbon mitigation.
Students will explain the role forests can play in reducing atmospheric carbon using three carbon pools: forest carbon, wood products, and forest products substitution.
Students will interpret a graph to explain the combined effect of assessing three carbon pools.
Students will cooperate as a group to solve a problem.
Students will identify skills that enhance cooperative work.

Assessment
Ask students to write a one-page summary that explains the role forests can play in reducing atmospheric carbon. Students should frame their response using the three carbon pools discussed in this activity: forest carbon, wood products, and forest products substitution.

Background

Across the globe, scientists are investigating both how to sequester more ***carbon dioxide*** in ***carbon sinks***, such as forests, and how to reduce the amount of carbon emitted, through improving efficiency or using less carbon-intensive products, for example. These two lines of actions are not unrelated – and in fact – can work together. In particular, researchers with the Consortium for Research on Renewable Industrial Materials (CORRIM) have tracked and analyzed carbon across multiple ***carbon pools***. This research ties together several key concepts conveyed in this module by using ***life cycle assessments*** to explore how forests can be managed to reduce atmospheric carbon dioxide.

<u>Carbon Pools</u>

A well-known ***climate change*** solution involves reducing the amount of carbon dioxide in the ***atmosphere*** through ***carbon sequestration*** in forests. Trees remove atmospheric carbon dioxide and store it in their trunks, leaves, and roots as they grow. Because young, growing trees add ***biomass*** at a faster rate than older trees, they sequester carbon at a faster rate than older, mature trees. Mature southern pine trees maintain the carbon they have sequestered, but do not add a lot of additional carbon each year. Nevertheless, if one only considers the forest carbon pool, sequestration is maximized by maintaining old, mature trees in the forest. In addition to carbon stored in the living forest, we must also consider the carbon stored in dead wood and leaf litter on the forest floor.

If trees are ***harvested*** for wood products, such as paper or lumber, the carbon in the wood is stored in products. Paper is a ***short-lived wood product***; the carbon in these products returns to the atmosphere when they decay or are burned. Lumber, on the other hand, is a ***long-lived wood product***. Depending on how the lumber is used, carbon can stay stored in wood for many years. When forest carbon and wood products are assessed together, sequestration is maximized by growing trees quickly, harvesting before growth slows down, and storing the wood in long-lived products.

Forest product substitution is the practice of using wood instead of other non-wood products. For example, lumber can be used instead of other construction materials, such as concrete, to build houses and buildings. Life cycle assessments have shown that producing concrete requires a great deal of ***fossil fuel***—making it a carbon-intensive product. However, for buyers to choose lumber over concrete, lumber must be readily available and sold at a competitive cost. When using wood, which sequesters carbon, instead of products that cause more carbon to be put into the atmosphere, huge reductions in atmospheric carbon can be projected. These are referred to as “carbon savings” in this activity.

We must consider all of these carbon pools to answer the question: How can we best manage forests to reduce atmospheric carbon dioxide? Research shows that reductions in atmospheric carbon dioxide can be maximized by harvesting forests on short rotation cycles so that a constant supply of solid wood products is available to be substituted for carbon-intensive products (Perez-Garcia, Comnick, & Manriquez, 2005). Note: This research was conducted in the Northwest, where it takes trees about 45 years to reach merchantable size. However, in the Southeast, loblolly pine trees can be harvested for solid wood products, such as lumber, between 25-35 years.

These concepts are introduced in this activity in two ways, through a cooperative learning exercise called Six Bits and through interpreting a graph that combines all the carbon pools.

<u>Six Bits</u>

In Part A of this activity, students solve a puzzle about how trees, forests, and wood products help remove carbon from the atmosphere. It would be most helpful if students have already become familiar with the carbon cycle (Activity 6), carbon sequestration (activity 7), and life cycle assessment (Section 4).

Six bits operates by separating the problem to be solved into small “bits” of information. Students are organized into groups of six where each is given one of six cards, each with bits of often unrelated facts. Card 1 contains the question, and students are asked to answer that question. If students are comfortable working in groups and tackling challenges, they will quickly realize that if they reveal all of their facts to each other they can collectively determine how they fit together and solve the puzzle. Less adept students, however, may wait to be given more information. You can decide how much to reveal to your students, based on their abilities.

The only rule on each card is that students are not allowed to show or give their card to another student. This guarantees that everyone will be actively engaged in reporting their information, but some students misinterpret this rule as they are not allowed to reveal the information on their card. Or they may just be confused. You might help them understand they are supposed to talk and work together; they can read their card but cannot abdicate responsibility by giving all the cards to one person to sort through!

Students who have had practice working in cooperative groups may, on their own, designate a group leader (or perhaps the person with easy access to paper and pencil will become the leader), and begin to ask group members to report any facts related to one concept at a time. You can help students by asking them to choose a leader and a secretary, writing the question on the board to focus everyone on the problem, and suggesting they first ask for all the bits of information related to carbon in trees and forests, and then carbon in wood products. You may need to explain the concept of substitution (where wood is used instead of a product that is responsible for a greater amount of carbon emission during production).

Through this activity, students learn not only about forests and carbon, but also about the power of cooperation in learning and problem solving. Since each group of six receives the same instructions, the activity wrap-up can include discussion on why some groups worked well and others may have stumbled. The importance of identifying a leader, along with leadership and teamwork skills, can be discussed. Six bits models an important societal skill showing how cooperative actions help solve problems and how everyone has valuable knowledge to contribute. In conducting this activity with your students, you may point out that collaboration works on more than just the classroom level—it may also help people think through real-world issues such as climate change. Discussion question 9 focuses on the process of solving the puzzle and thinking about the skills involved in cooperative activities. You may wish to notice how single-sex groups work differently than groups of both girls and boys, and ask the students why that might be. How that might affect how we solve problems in the real world?

<u>Combining Carbon Pools in a Graph</u>
To reinforce the answer to the Six Bits puzzle, Part B of this activity presents a graph that combines data for five carbon pools over the course of 150 years (forests, dead wood, short-lived wood products, long-lived wood products, and carbon saved). As you can imagine, this graph is complex and provides a great opportunity to sharpen graph reading and interpreting skills. The “11: Graphing Carbon” slide presentation provides a step-by-step explanation of the graph, and the notes section of the presentation explains each carbon pool and how they combine to build the final figure. You can use this presentation to guide your students through the complex graph and enable them to answer questions as they interpret the graph.

Getting Ready

Download the slide presentation “11: Graphing Carbon” from [*insert url*] and review it.

Make copies of the “Six Bits” student page, one for each group of six students. Cut each student page along dotted lines to form sets of six cards for each group.

Doing the Activity

Part A – Six Bits

1. Remind students of the carbon cycle (See Activity 6, Carbon on the Move), and prompt them to list the different ways carbon enters and leaves the atmosphere. Remind them of life cycle assessment (Section 4) and ask them where the carbon goes when a tree is used to build a house.

2. Divide the class into groups of six students. If the class is not evenly divisible, make a few groups with less than six students rather than groups with more than six students.

3. Explain to students that they are going to work in small groups to solve a puzzle related to climate change and forests. Each group will get the same set of six different cards, and each student will get one of the six cards. One of the cards has the question that the group must answer. Information from all of the six cards will be necessary to answer the question; however, some of the statements may be irrelevant to solving the puzzle. Instruct students in the rules of six bits:

- Students are not allowed to show their card to anyone else.
- Students are not allowed to look at anyone else's cards.
- Students should tell people in their group, verbally, what is written on their cards.
- Each group is responsible for answering the question posed on Card 1.
- The puzzle is also a challenge to see which group solves the mystery first.

4. Distribute one set of "Six Bits" cards to each group. Each student should receive one card, face down. Ask students not to look at their card yet. For groups with less than six students, hand a student an extra card so that the group still has all the information needed to solve the puzzle.

5. When everyone has received a card ask students to read their card silently and then work together to answer the question. Remind them that only one student has the question and the first step will be for that student to read the question to their group. Or, you might ask one student to read the question to everyone and write it on the board. Every group is solving the same puzzle, but they will likely take different strategies to do so. Invite them to pay attention to *how* they solve the problem. Provide as little or as much guidance as you wish, depending on how comfortable your students are with ambiguity and cooperative tasks.

6. Circulate throughout the room, noting how leadership develops, what causes difficulty, and the order in which groups finish.

7. Once all the groups have solved the puzzle, ask students the question posed by the activity: "How can we best manage forests to reduce atmospheric carbon dioxide?"

8. Have each group of students share their answer to the question. Students should have discovered that reductions in atmospheric carbon dioxide can be maximized by harvesting forests on short rotation cycles of 25 to 35 years so that a constant supply of solid wood products is available to be substituted for carbon-intensive products.

9. Broaden the discussion to talk about <u>how</u> students solved the puzzle. Use the following questions as a guide.

a. Who took a leadership role in your group? What skills and resources did that person have? *Leadership may manifest itself in many ways during a six bits activity. It could be that a person with the foresight to ask everyone else questions is the one who gets the ball rolling on solving the puzzle. It could be the person who has a pencil and is able to take notes. It could even be the gender ratio in a group that either favors or hinders group cooperation.*

b. Did everyone participate equally? What prevented or encouraged equal participation?

c. How effectively did the group function? What might have improved efficiency? You may ask the group that finished first why they solved the problem so quickly.
d. What skills were used to complete this task as a group?
e. What different strategies enabled some groups to finish before others?

10. Discuss with students the advantages of group collaboration. You may ask if they enjoyed depending on each other for information, or whether they were frustrated because they couldn't work by themselves. Most real-world situations require cooperation between parties with different interests, including climate change and forest management issues. Learning how to capitalize on the skills and knowledge of all participants is in the best interests of all.

Part B - Combining Carbon Pools in a Graph

1. Explain to students that the answer to the Six Bits puzzle can also be displayed visually, through a graph that combines five carbon pools over 150 years. Use the "11: Graphing Carbon" slide presentation to guide students through the data regarding each carbon pool and through how those data can be combined to provide a more complete view of carbon sequestration. The notes section of the PowerPoint presentation provides an explanation for each carbon pool and for how to build the final figure.

2. Once you have gone through the presentation with the students, leave up the figure with the combined data from all five carbon pools and ask students to answer the questions on "Combining Carbon Pools" student page.

3. Review the correct responses as a class to ensure student understanding.

Enrichment

Have students read the CORRIM fact sheet [http://www.corrim.org/pubs/factsheets/fs_05.pdf], which includes other carbon pools not covered in this activity. Ask students what those other pools represent and how each new pool affects the numbers regarding carbon sequestered.

Tell the students to place the various carbon pools into groups based on whatever criteria they like. Have the students describe their chosen groupings in class. Possible groupings include human-made (short-lived and long-lived wood products) versus natural (forest, dead wood). The substitution pool may not fit well with the other groups. It's fine to leave it on its own. Other groupings may be based on the length of time the pool is intact with short-lived pools (dead wood and short-lived products) in one pool and long-lived pools (forests, long-lived wood products) in another. If students do not mention this distinction on their own, be sure to emphasize for them. You can wrap up the discussion by reminding the students that the substitution pool involves carbon that has not been in the atmosphere for millions of years.

Resources

CORRIM Presentations
Consortium for Research on Renewable Industrial Materials (CORRIM)
www.corrim.org/presentations/index.asp
This portion of the CORRIM website provides several videos and presentations related to assessments of carbon storage, life cycles, and product substitution.

Forest Management Solutions for Mitigating Climate Change in the United States
Robert W. Malmsheimer, et al., 2008. Journal of Forestry 106(3): 115-171.

www.ntc.blm.gov/krc/uploads/399/Forest%20Management%20Solutions%20for%20Mitigating%20Climate%20Change.pdf
This report contains an executive summary and chapters related to preventing greenhouse gas emissions through wood substitution and biomass substitution, as well as reducing atmospheric greenhouse gases through sequestration in forests and storage in wood products.

Maximizing Forest Contributions to Carbon Mitigation
Consortium for Research on Renewable Industrial Materials (CORRIM), 2009
http://www.corrim.org/pubs/factsheets/fs_05.pdf
This fact sheet summarizes CORRIM research findings for life cycle assessment studies related to carbon in forests, forest products, and wood product substitution.

References

Perez-Garcia, J., Comnick, J., & Manriquez, C. (2005). An assessment of carbon pools, storage, and wood products market substitution using life-cycle analysis results. *Wood and Fiber Science, 37 Corrim Special IssueI:* 140–148.

Six Bits

Instructions: For each group of six students in your class, make one copy of this sheet. Cut the six cards along the dotted lines. Distribute a set of cards for each group—one card per person for each group of six. Remind students that they cannot show others their cards to each other.

Card 1: Do not show this card to anyone in your group. You may read the information on the card to anyone in your group. Some information may not be necessary to answer the question. • How can we best manage forests to reduce atmospheric carbon dioxide? • Lumber is a long-lived, solid wood product; the carbon can stay stored in wood for many years, depending on how the lumber is used. • Forest product substitution is the practice of using wood instead of other products. • Fertilizer application helps trees grow faster.	*Card 2: Do not show this card to anyone in your group. You may read the information on the card to anyone in your group. Some information may not be necessary to answer the question.* • When wood is substituted for more carbon-intensive products, it leads to more significant reductions in atmospheric carbon than forest carbon and forest products. • For buyers to choose lumber over concrete, lumber must be available and sold at a competitive cost. • Growing trees faster is one way to sequester more carbon. • Concrete requires a great deal of fossil fuel to produce—making it a carbon-intensive product.
Card 3: Do not show this card to anyone in your group. You may read the information on the card to anyone in your group. Some information may not be necessary to answer the question. • Forest product substitution is a carbon pool. • Trees that grow on pine plantations are harvested for forest products. • The average useful lifespan of a wooden house is 80 years. • Harvest cycles of 25 to 35 years provide a steady supply of solid wood products that can be substituted for carbon-intensive products.	*Card 4: Do not show this card to anyone in your group. You may read the information on the card to anyone in your group. Some information may not be necessary to answer the question.* • As trees grow, they remove atmospheric carbon dioxide and store it in their trunks, leaves, and roots. • Recycling paper is one way to keep carbon out of the atmosphere. • Lumber can be used instead of other construction materials, such as concrete, to build houses and buildings. • Young, growing pine trees up to about 25 years old sequester significantly more carbon than mature trees.
Card 5: Do not show this card to anyone in your group. You may read the information on the card to anyone in your group. Some information may not be necessary to answer the question. • Forest carbon (stored in trunks, leaves, and roots) is an important carbon pool. • After trees are harvested, carbon in the wood can be stored in forest products, such as paper and lumber. • For landowners to manage their forests for lumber, there must be a market to sell their wood. • Mature southern pine trees over 40 years old maintain the carbon they have sequestered, but do not add a lot of additional carbon.	*Card 6: Do not show this card to anyone in your group. You may read the information on the card to anyone in your group. Some information may not be necessary to answer the question.* • Paper is a short-lived wood product; the carbon in these products returns to the atmosphere when they decay or are burned. • If one only considers the forest carbon pool, sequestration is maximized by maintaining old, mature trees in the forest. • Life cycle assessments of concrete and wood reveal that concrete has significantly higher impacts on atmospheric carbon than wood. • Forest products (such as lumber and paper) are an important carbon pool.

Combining Carbon Pools

Name:

Based on the discussion about the five carbon pools and using the graph of data from those pools, answer the following questions.

1. Where does the carbon come from when trees grow?

2. When the forest is cut (years 2045, 2090, and 2135), which carbon pool(s) decrease immediately? Which carbon pools increase immediately? For each carbon pool, explain why it increases or decreases.

3. What happens immediately to the total carbon (represented by the black line) during the years that trees are harvested? Explain why in terms of your answer to Question 2.

4. What happens to the total carbon sequestered during the decade after each harvest year (2045-2055, 2090-2100, and 2135-2145)? Explain this behavior in terms of the carbon pools.

5. What happens to the total carbon sequestered at year 2125? Which carbon pool is responsible for this behavior? Explain why this carbon pool changes during this year.

6. Describe what the “Carbon saved” pool refers to. Why is this the biggest component on the graph? If it is so much bigger than the forest pool – can we obtain these benefits without the forest carbon pool?

Combining Carbon Pools

1. Where does the carbon come from when trees grow?
   When trees grow, they use carbon from atmospheric carbon dioxide and convert that carbon into biomass (i.e. wood).

2. When the forest is cut (years 2045, 2090, and 2135), which carbon pool(s) decrease immediately? Which carbon pools increase immediately? For each carbon pool, explain why it increases or decreases.
   Forest pool: decreases since trees are being cut from the forest
   Dead wood: increases due to the amount of dead wood produced as a waste product during harvesting
   Short-lived wood products: increases as some of the harvested wood is used to make these products
   Long-lived wood products: increases as some of the harvested wood is used to make these long-lived products
   Carbon saved: increases as the wood products are used instead of other, carbon-intensive products

3. What happens immediately to the total carbon (represented by the black line) during the years that trees are harvested? Explain why in terms of your answer to Question 2.
   The total amount of carbon sequestered increases immediately. This is because the substantial increases in the pools for long-lived wood products and carbon saved more than balance out the decreases seen in the forest pool. Dead wood and short-lived wood products also increase (though not nearly as much) contributing to the total increase during harvest years.

4. What happens to the total carbon sequestered during the decade after each harvest year (2045-2055, 2090-2100, and 2135-2145)? Explain this behavior in terms of the carbon pools.
   In the decade following harvest years, the total amount of sequestered carbon decreases slightly. This is because the dead wood and short-lived wood products both decompose relatively quickly, so carbon is lost from those pools.

5. What happens to the total carbon sequestered at year 2125? Which carbon pool is responsible for this behavior? Explain why this carbon pool changes during this year.
   At 2125 the total amount of carbon sequestered drops from about 560 metric tons per hectare (MT/ha) down to about 500 MT/ha. This is because the assumed lifespan of the long-lived wood products is 80 years. Therefore, the long-lived wood products produced from the wood of the 2045 harvest has reached its lifespan and is burned as waste in 2125.

6. Describe what the “Carbon saved” pool refers to. Why is this the biggest component on the graph? If it is so much bigger than the forest pool – can we obtain these benefits without the forest carbon pool?
   The “carbon saved” pool refers to carbon emissions from fossil fuels that have been avoided by using wood products instead of carbon-intensive products, such as concrete. The size of this pool indicates the large amount of fossil fuels that go into producing carbon-intensive products. To answer the final part of this question, consider other ways to avoid manufacturing carbon-intensive products.

12: Future of Our Forests

Student teams review what they have learned in this module by compiling a report on the future of southeastern forests. Students can share their knowledge by writing a letter to state or county forester, city arborist, local newspaper, community leaders, or other audiences that are relevant in your area.

Subjects
Agriculture Education, Biology, Environmental Issues / Ecology, Environmental Science, Forestry / Natural Resource Management, Integrated Science, Language Arts, Life Science

Skills
Analyzing, Critical Thinking, Predicting, Researching, Synthesizing

Materials
Module: Background sections, videos, and slide presentations as needed for groups
Other: Access to Internet

Time Considerations
Two 50-minute periods

Related Activities in Other PLT Guides
Who Owns America's Forests? (*Focus on Forests* module); Climate Change and Forests (*Focus on Forests* module)

Objectives
Students will summarize the potential impacts of projected climate changes in the region.
Students will describe how research is documenting changes in forests and leading to new strategies to help landowners adapt to an uncertain climate.
Students will explain how forests sequester carbon from the atmosphere and the role forests can play in reducing atmospheric carbon dioxide.
Students will explain how purchasing products that have lower carbon emissions and/or products that sequester greater amounts of carbon can help reduce atmospheric carbon dioxide.
Students will report recommendations for forest managers to adapt to future climate uncertainty.

Assessment
Use the summary reports to assess how well they understand the connections between climate, forest, emissions, and consumer choice.

Background

Southeastern forests are very important resources. While these forests account for only 2 percent of the world's total forest cover, they produce 16 percent of its timber-related products. Forest land also protects watersheds, offers wildlife ***habitat***, and provides outdoor recreation experiences. Healthy, resilient forests are important to the future of the Southeast, the nation, and indeed, the world.

The previous activities in this module introduce students to the potential impacts of ***climate change*** on southern forests, the research underway to understand these changes and develop strategies to protect forest resources, the management possibilities that could reduce atmospheric ***carbon dioxide*** and increase ***resilience*** of forests, and the role that consumers could play in encouraging wood substitution to sequester carbon or emit fewer pollutants.

You can help students synthesize this information and understand how each section of this module contributes to the future of southeastern forests by asking teams of students to summarize key points related to one topic in a one-page summary and short presentation. Group assignments are based on using several activities in this module. If you have not had time to use them all, you may need to change the group assignments to reflect those activities you have completed. The activity and section background readings, slide presentations, and module resources can serve as a starting point for the group's research. Students can then work in groups to write a summary report, essay, or letter for the state or county ***forester***, city arborist, local newspaper, community leaders, or other audiences that are relevant in your area.

Getting Ready

Make copies of student pages.

Doing the Activity

1. Divide the class into six equal groups, and assign each group a different role. Each group will need to access websites, videos, and background information associated with the activities in this module.

2. Invite each group to review the data, summarize the information in a one to two page report, and make a presentation to the class with their findings and synthesis. Their report should include at least three supporting references.

3. Provide each student a copy of the "Reflection Questions" student page, and ask them to answer these questions while they listen to the group presentations.

4. After all groups have presented, discuss the following questions as a class:
    a. What are some general trends for how climate change might affect forests in your area?
    b. How can forests help reduce atmospheric carbon dioxide and why?
    c. What can forest landowners do to reduce their risk to climate variability and climate change?
    d. What could consumers do to reduce atmospheric carbon dioxide in the atmosphere?

5. After hearing all the presentations and receiving a copy of the written reports, ask each group of students to write a summary report, essay, or letter to explain the importance of forests, how forests are likely to be impacted by climate change, and what landowners and citizens can do to mitigate the effects of climate change by reducing atmospheric carbon dioxide and protect the health of southern forests. As a class, select the audience(s) for these documents. For example, you may wish to communicate this information to the state or county forester, city arborist, local newspaper, community leaders, or other members of the community. You could choose to share all of the reports with one audience or have different groups write for different audiences.

Enrichment

Ask a local forester or forest landowner to visit your classroom to listen to the student presentations. This person could share their knowledge about the topics being discussed and also share career information with students.

Allow students the opportunity to give their presentations as part of a Climate Change forum that is open to the public or another event.

Resources

Southern Forest Futures Project
USDA Forest Service
www.srs.fs.usda.gov/futures
This website provides summary reports, a webinar, and other resources related to a multi-year research effort that forecasts changes in southern forests between 2010 and 2060.

Southern Forests for the Future
World Resources Institute
www.seesouthernforests.org
This website contains maps, photos, case studies, and other information to highlight key features and trends for southern forests.

Group Assignments

Climate Scientist Group

Your task: As a group, create a 5-10 minute presentation to explain why scientists believe that humans are impacting the climate and focus on the types of changes that will affect your state.

You can start your research using information from the following activities:

- Clearing the Air
- Atlas of Change (projected climate changes in your state)

In addition the following websites and documents will be helpful:

- TACCIMO Climate Report (www.sgcp.ncsu.edu:8090/about.aspx): Under the tab, Generate a Report, Click "Climate Report" and select your state from the drop down menu. This report will contain a range of potential future climate projections represented by different combinations of Global Climate Models and scenarios.
- NOAA Climate.gov (www.climate.gov). This website provides information, maps, and videos to help you understand climate science.
- Climate Change: Evidence, Impacts, and Choices (http://nas-sites.org/americasclimatechoices/more-resources-on-climate-change/climate-change-lines-of-evidence-booklet/). This National Research Council booklet summarizes the current state of knowledge about climate change, explains some impacts expected in this century and beyond, examines how science can help inform choices about managing and reducing the risks posed by climate change. You can also find a video and figures that will help your presentation.
- NASA Global Climate Change (http://climate.nasa.gov/). This website provides information on the evidence, causes, effects, and uncertainties of climate change. There is also recent data on Earth's "vital signs" including global temperature, carbon dioxide levels, and the rate of sea level rise.

Forest Climatologist Group

Your task: As a group, create a 5-10 minute presentation to build on the Climate Scientists' summary and apply these projected climate changes to forests. Which changes are likely to affect the forests in your state? How? What types of changes could people experience?

You can start your research using information from the following activities:

- Atlas of Change (projected changes to suitable habitat for forests)
- The Changing Forest (changes to forests)
- Managing Forests for Change (relationships between climate and forest health)

In addition the following websites or documents will be helpful:

- EPA, Climate Change, Forest Impacts and Adaptation (www.epa.gov/climatechange/impacts-adaptation/forests.html).
- Southern Region Emerging Forest Threats (*add url when final version ready*). This pamphlet summarizes information from over 300 peer-reviewed science papers found in the USDA Forest Service's TACCIMO tool.
- Earth & Sky, "Neil Sampson Says Climate Change Speeding Flux of Forest Ecosystems" (http://earthsky.org/earth/climate-change-speeding-flux-of-forest-ecosystems). During this 90-second interview, scientist Neil Sampson describes how forests may be affected by climate change.

Forest Manager Group

Your task: As a group, create a 5-10 minute presentation about managing forests under changing climate conditions. You have significant expertise in local forests and how forests can be managed to be more resilient. What exactly should forest landowners be doing to protect and conserve their forest resources? Why?

You can start your research using information from the following activities:

- Managing Forests for Change (management strategies for dealing with variations in climate)

In addition the following websites or documents will be helpful:

- Southern Forests for the Future (www.seesouthernforests.org). This website contains maps, photos, and information you can use in your presentation.
- Southern Region Emerging Forest Threats (*add url when final version ready*). This pamphlet summarizes information from over 300 peer-reviewed science papers found in the USDA Forest Service's TACCIMO tool.
- Explore the website for your state's forest agency.

Forest Researcher Group
Your task: As a group, create a 5-10 minute presentation that provides insights into the many ways researchers are helping managers improve southern forests.

You can start your research using information from the following activities:
- Mapping Seed Sources
- The Changing Forest (research and monitoring of forest health)

In addition the following websites will be helpful:
- State Climatologist Interview with NC People (http://www.nc-climate.ncsu.edu/interviewNCpeople). This video is an interview with the North Carolina State Climatologist to explain how climate impacts forests in the region.
- *The Forest Service and Climate Change (*www.fs.fed.us/video/climate).This 12-minute video that introduces climate change science, impacts on forest ecosystems, and how the USDA Forest Service is responding to climate change.
- PINEMAP. This website contains research summaries, newsletters, photos, and videos that describe current research related southern pine plantations and climate change. (http://pinemap.org/)

Tree Biologist Group
Your task: As a group, create a 5-10 minute presentation about the carbon cycle and how trees sequester carbon. Your group can discuss the estimated levels of carbon sequestration that can be expected from this maintaining the productivity of southern forest levels and planting some less productive agriculture land in trees.

You can start your research using information from the following activities:
- Carbon on the Move
- Counting Carbon

In addition the following websites will be helpful:
- Earth & Sky—"Greg McPherson's Tree Carbon Calculator" (http://earthsky.org/earth/greg-mcphersons-tree-carbon-calculator). Scientist Greg McPherson talks about a tool he developed to help determine how much carbon a tree sequesters and the value of knowing this information.
- The Carbon Cycle, NASA (http://earthobservatory.nasa.gov/Features/CarbonCycle/).
- I-Tree (http://www.itreetools.org/index.php). Gives information on the benefits provided by urban trees.

Forest Industry Group
Your task: As a group, create a 5-10 minute presentation about how forest products play a role in reducing atmospheric carbon. You produce a variety of products from forest resources–particularly lumber, OSB (oriented strand board), and plywood. When consumers purchase items made from wood they sequester carbon in that wood. If the alternative they did not purchase relies on fossil fuels for production (like concrete or steel), the use of wood products prevents even more carbon from being released into the atmosphere. You can explain the life cycle assessment of wood products and how using them can be a valuable contribution to mitigating the effects of climate change.

You can start your research using information from the following activities:
- Adventures in LCA
- The Carbon Puzzle

In addition the following websites and documents will be helpful:
- Consortium for Research on Renewable Industrial Materials, CORRIM (http://www.corrim.org). This website provides fact sheets, videos, and other resources. In particular the Editorials (under Publications tab) provide helpful information for your presentation.
- The Carbon Cycle Poster, The Forest Foundation. (http://www.calforestfoundation.org/pdf/carbon-poster.pdf).

Reflection Questions

Name:

As you follow along with the group presentations, answer the following questions on this worksheet. Also, make sure to write down any information that you think will be important to include in your letter.

1. How are temperature and precipitation projected to change in your state?

2. How can these projected changes in climate affect forests in your state?

3. What management strategies should forest landowners use to protect and conserve their forest resources? Why?

4. Describe current research being conducted to help managers improve southern forests.

5. How can forests reduce atmospheric carbon dioxide?

6. What is life cycle assessment?

7. How can life cycle information help us reduce atmospheric carbon dioxide?

13: Starting an Environmental Action Project!

Students use the knowledge gained throughout this module to plan and complete an environmental action project related to forests and climate change solutions in their community.

Subjects
Agriculture Education, Biology, Environmental Issues / Ecology, Environmental Science, Forestry / Natural Resource Management, Government / Politics, Integrated Science, Life Science

Skills
Defining environmental issues, Investigating, Problem solving, Evaluating, Communicating

Materials
Module: None
Other: Chart paper, pencils, dependent on project

Time Considerations
Varies: dependent on project

Related Activities in Other PLT Guides
Improve your place (*PreK-8* Guide); PLT *GreenSchools!* Investigations

Objectives
Students will identify ways they can improve nearby forests and/or work locally to address climate change.
Students will plan and carry out an environmental action project to improve their local area.

Assessment
Ask students to write one to two paragraphs describing the need for the project based on the data collected, and assess the thoroughness and clarity of the problem identified.

After completing the project, have students (1) evaluate the effectiveness of the project based on the criteria they identified in the plan, (2) describe intended and unintended consequences of the project, (3) reflect on ways the project could be more effective by providing either next steps or tips for others trying to do a similar project.

Background

Congratulations! You have taught your students a number of key concepts about the future of forests in the South: the role of forests in ***climate change***, the ***carbon cycle*** and ***carbon sequestration***, ***forest management*** strategies, and the role of consumer choices in climate change through ***life cycle assessment*** and product comparisons.

Now what? Your students can apply what they have learned in this module to establish an environmental action project. An environmental action project is an educational activity that involves students in tackling an environment issue or problem with the goal of improving their area. Environmental action projects can be related to many topics and be implemented in many ways. For this activity, the projects should relate to improving nearby forests and/or working locally to address climate change.

<u>Components of a Successful Service Learning Projects</u>

Effective environmental action projects often share similar characteristics with ***service learning*** projects. Service learning is a teaching strategy that integrates meaningful community activity with instruction and reflection to enrich the learning experience, teach civic responsibility, and strengthen communities. Through service learning, young people use what they learn in the classroom to help address real problems. They not only gain from the practical applications of their studies, they become actively contributing citizens and community members through the service they perform. Important components of service-learning action projects include the following:

- Students play a key role in designing and implementing the project: The student voice is a key part of service learning projects. Students should identify community needs and issues, help choose and plan the project, reflect on each stage of the project, evaluate it at the end, and celebrate its success.
- The project benefits the community and meets an identified need: Service learning tackles real-world complex problems in complex settings, not simplified issues in isolation. Students learn that they can impact their community and make meaningful change.
- The project is integrated into the curriculum: By connecting service learning projects to the curriculum it promotes deeper understanding of the material. The results are immediate and meaningful; students are not simply trying to find the right answer. The project should engage students in active problem solving and encourage them to gain specialized knowledge, rather than generalized knowledge such as might come from a textbook. Service learning promotes social, emotional, and cognitive learning and development.
- Relevant community partners are involved: Community partners can include students, parents, community based organizations, teachers, school administrators, and service recipients. All partners should contribute to the planning and implementation of the project and benefit from it.
- Students are given time to evaluate, reflect, and celebrate project achievements: Students should be given time to reflect before, during, and after the project. Students should evaluate the progress they have made toward the learning and service goals of the project. Achievements should be celebrated to reinforce the good work students are doing.

This means that educators, students, and local partners must be involved in helping to select the “right” project for your community.

<u>Project Ideas</u>

Environmental action projects can take many forms—costing various amounts of money and time to complete. For example, with relatively little funds, your students can establish an appropriate tree planting plan for the school grounds or the local community. They could also develop forest and climate outreach activities to presents to elementary or middle school students. For projects that require more funding, such as buying and planting trees, you can help students seek funding from PLT *Greenworks!*, school board, or a small green grant from environmental organization to actually carry out the project.

The following list provides ideas that may help get your brainstorming session started:

- Explore student or community attitudes and knowledge about climate change, local forests, and climate change solutions. Based on the results, students could create appropriate educational materials and events (e.g., videos, brochure, school festival, media event, presentation to community leaders) to increase knowledge, awareness, or change behaviors of other students, parents, or community members.
- Calculate the personal ***carbon footprint*** of students in one class, grade level, or the entire school and determine strategies for reducing carbon footprints by certain amounts. Students can organize competitions among classes or grades and track progress over time. The following are useful personal carbon footprint calculators for students:
  - U.S. EPA, Carbon Footprint Calculator http://epa.gov/climatechange/kids/calc/index.html
  - The Nature Conservancy, Carbon Footprint Calculator http://www.nature.org/greenliving/carboncalculator/index.htm
- Investigate and determine appropriate actions for reducing the school's carbon footprint. There are many possibilities for energy saving projects from campaigns for turning off lights to changes in air conditioning and heating practices. Students may also be interested in raising funds to offset the carbon ***emissions*** from various school activities. This can be done by purchasing carbon credits through an organization that plant trees for carbon sequestration purposes.
- Create a plan for managing a nearby forest. This could involve measuring and monitoring tree growth, calculating carbon sequestration, assessing potential impacts from climate change, and recommending management actions. Students can present their plan to the landowner, organization, or agency.
- Determine an area that could be improved with more trees and work with community partners to create a plan and hold a tree planting event.
- Learn about and assess ***forest health*** issues in the area (e.g., ***wildfire*** risk, ***invasive species***, insects/diseases) and plan a community work day to improve conditions at a specific forest or natural area.
- Explore the purchasing process for the school (or another organization) and determine a set of criteria that emphasizes carbon sequestration and reductions. Present these criteria to the people who make purchasing decisions.

PLT *Greenworks!*

The PLT *Greenworks* program provides grants of up to $1,000 to schools and youth organizations to engage students in service learning projects. Applicants for this grant must have completed a PLT workshop and the grant must be completed in one year. The project should involve service learning, exemplify student voice, involve at least one community partner, and secure 50 percent matched funds (in-kind is acceptable). Check out the *Greenworks* webpage for tips and ideas for your project and to see examples of past projects. http://www.plt.org/greenworks. There are additional grants of up to $3,000 for register PLT Green Schools.

Getting Ready

Review the documents and websites in the Resources section before getting started so you know where to go for questions and assistance along the way.

Before selecting and launching a project, help your students consider the scope of the project and possible limitations of what they can do. If you are considering a school-based project, you may wish to talk to your administrator and maintenance staff about the types of projects that would be welcomed. Make sure the appropriate advisors are able to speak to the students and have their views incorporated into the discussion. It is helpful for students to understand their limits!

Doing the Activity

1. Ask students to brainstorm and list as many ideas as possible that describe potential environmental action projects in their school or community that build on the information they have just learned about forests in the future and climate change. What are the potential objectives for their project ideas? How would this project benefit the community? If they have a school forest, is there anything students can do to improve the area? Are all the projects feasible? What barriers might exist?

2. As a class, select a few of the best ideas to investigate further. Take your students to survey the proposed area; collect relevant data, or interview people about their project ideas. They should be seeking information and opinions how these environmental action plan ideas could be improved.

3. After the initial data collection, help students select the idea that has the most potential and then create a plan for their project. They may wish to divide into teams based on their interest to carry out specific components of the project.

4. Determine the ways in which this project will be connected to your curriculum and the learning objectives for students.

5. In teams, help students finalize the objectives for their action plan and evaluate the resources, approval, or support required for carrying out these objectives. To create an action plan, it will be helpful for students to write down:
   - Background Information (What is the area or audience identified for the project? What is the need for this project?)
   - Problem (What data has been collected? How do we know this is a problem?)
   - Recommendations (What actions could be taken to solve the problem? Which action do students recommend and why? What are possible future projects?)
   - Details of the Project (Who will be involved? How much will it cost? Where will the money come from? Who will do the work? What community partners can help? How does the project benefit the community?)
   - Expected Results (What results do students hope to achieve? How will students know whether the project was successful?)

6. When students have finished a draft of their plan, they should evaluate it using the following questions:
   - Is any additional information needed before they begin the project?
   - What alternative actions could be taken to solve the problem?
   - Is the action that students are proposing the best one? Why?
   - What are the ecological, social, and economic impacts of this project?
   - Do we have the skills, time, and materials needed for the project? If not, who can help?

7. Using the evaluation, students can make adjustments to their plan.

8. Depending on the project, you may wish to have students present their plan to administrators, community leaders, partners, or other parties that will be involved. If so, have students use presentation software to make a final version of the plan, and help them practice and present to this group.

9. Help students carry out the project as planned.

10. Provide adequate time throughout for students to reflect on their progress toward meeting the project objectives and to reflect on their learning and the personal impact that being involved in the project.

11. Decide with your students how they will share information about their project with the larger community. For example, this can be done by presenting to other schools or community organizations, having a media day at the school, writing news releases, or creating a video. Implement these ideas to showcase project accomplishments and lessons learned.

Enrichment

Have students write an environmental action project handbook for future students based on what they learned from their project. What works? What does not work? What did they wish they had known at the beginning?

Resources

Environmental Service-Learning
National Environmental Education Foundation
http://eeweek.org/resources/service_learning
This website has a comprehensive list of service learning and environmental service learning resources.

Environmental Service Learning
Treepeople Website
www.treepeople.org/environmental-service-learning
This website provides information about seven key elements for quality service learning and provides project examples.

Give Forests a Hand, Leader and Youth Action Guides, Circular 1269 and 1270
Janice Easton, Martha Monroe, Alison Bowers, and Lizzie Peme; University of Florida; 2009
http://edis.ifas.ufl.edu/fr118 and http://edis.ifas.ufl.edu/fr117
This resource includes a youth action guide and a leader guide to help students identify potential projects, select an idea that matches their abilities, create a plan, conduct the project, and celebrate their results. Reflection questions are built into the guide to encourage learning. Spanish versions are available.

GreenWorks!
Project Learning Tree
www.plt.org/greenworks
This webpage provides information on the service-learning, community action program of PLT that provides grant opportunities annually.

National Service-Learning Clearinghouse
Corporation for National and Community Service
www.servicelearning.org
This is comprehensive service-learning resource answers general questions about service learning and provides success stories. A subsection of this website focuses specifically on environmental issues.

Young Voices for the Planet, The Movies
Young Voices on Climate Change Website
www.youngvoicesonclimatechange.com/climate-change-videos.php
This series of short films presents replicable success stories of young people tackling climate change issues in their communities. Accompanying curriculum for each video is also available.

Appendices

A: Glossary
B: Website Overview
C: Additional Resources
D: Create Your Own LCA
E: Sample Assessment Tests
F: Subject Correlations
G: Next Generation Science Standards Correlations
H: PLT Conceptual Framework Correlations

A: Glossary

Many of the definitions listed in this section were taken from other Project Learning Tree materials, specifically the *PreK-8 Environmental Education Activity Guide*, *Focus on Forests, Exploring Environmental Issues: Biodiversity,* and the *Energy & Society Activity Guide*. Other definitions come directly from three sources available on the Internet: the U.S. Forest Service's *Climate Change Glossary*, and two documents from the U.S. Environmental Protection Agency: *Glossary of Climate Change Terms* and *A Student's Guide to Global Climate Change*. Please see the reference list at the end of this glossary for the full citations for these and other sources consulted and cited.

Note: The informal text citations (such as EPA, USFS CC, FoF, PreK-8) will be removed in final draft but have been left in this draft so reviewers can see where the definition came from. The informal citations refer to documents referenced above. The formal citations (e.g., McCall, 2012) will remain in text.

Adaptation: Adjustment in natural or human systems to a new or changing environment. Adaptation to climate change includes actions taken by humans 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. (USFS CC and EPA Kids)

Afforestation: The planting of new forests on lands that historically have not contained forests. (USFS CC)

Albedo: The fraction of incoming solar radiation that is reflected from an object or surface. (State Climate Office of North Carolina, n.d. and EPA)

Alleles: The alternative states of a particular gene. (McCall, 2012)

Atmosphere: The gaseous envelope surrounding the Earth. The dry atmosphere consists almost entirely of nitrogen and oxygen, together with a number of trace gases, such as argon, helium, carbon dioxide, and ozone. In addition the atmosphere contains water vapor, clouds, and aerosols. (EPA and USFS CC)

Biodiversity: The numbers and relative abundances of different genes, species, and ecosystems in a particular area. (USFS CC)

Biomass: The total weight of all living matter in a particular area at a given moment in time. Some kinds of biomass, such as wood and corn (in the form of ethanol), can be burned to produce energy. (PreK-8 and FoF; EPA and EPA Kids)

Carbon cycle: The movement of carbon, in its various forms, from one place (pool) to another through various chemical, physical, geological, and biological processes. (EPA Kids)

Carbon dioxide (CO_2): A naturally occurring greenhouse gas that is also a by-product of human activities, such as burning fossil fuels and biomass. (EPA/USFS CC)

Carbon dioxide equivalent: Basic unit for measuring the global warming potential of emissions that is expressed in terms of the amount of carbon dioxide that would cause the same amount of warming. For example, over a period of 100 years, 1 pound of methane will trap as much heat as 21 pounds of carbon dioxide. Thus, 1 pound of methane is equal to 21 pounds of carbon dioxide equivalents. (BBC, 2010 and EPA Kids)

Carbon flux: Process by which carbon moves from one pool to another.

Carbon footprint: A measure of how much carbon dioxide a person, organization, or product produces—directly or indirectly—in a certain amount of time (usually a year). (FoF)

Carbon pool: Any place where carbon can be found, such as plants, the atmosphere, or fossil fuels. Carbon pools can also be called stocks or reservoirs.

Carbon sequestration: Process of transferring atmospheric carbon dioxide into above- or below-ground carbon pools, such as plant biomass through photosynthesis or into soils by plant decomposition. (FoF)

Carbon sink: A carbon pool that absorbs and stores more carbon than it releases over some period of time, which helps to offset greenhouse gas emissions. Examples include the ocean, forests, and soil. (FoF)

Carbon source: A carbon pool that releases more carbon than it absorbs over some period of time. Examples include fossil fuels, forest fires, and livestock. (USFS CC)

Carbon storage: The amount of carbon that exists in a tree's leaves, wood, stem, and bark at a particular point in time. This is the total amount of carbon that is made during photosynthesis as well as the amount of carbon sequestered by the tree.

Chromosome: A rod-like body found in the cell nucleus that contains the genes. (McCall, 2012)

Climate: The average weather conditions in a particular location or region at a particular time of the year. Climate is not the same as weather. (EPA Kids and C2ES)

Climate change: Major changes in temperature, precipitation, or wind patterns, among others, that occur over several decades or longer as a result of changes in Earth's atmosphere. (EPA, PreK-8/FoF)

Clinometer: An instrument used to determine the height of a tree.

Conservation: The use of natural resources in a way that assures their continuing availability to future generations; the intelligent use of natural resources for long-term benefits. (PreK-8)

Decomposition: The chemical and mechanical breakdown of matter into simpler parts by plants, bacteria, fungi, and other organisms. (EPA Kids, PreK-8)

Diameter at breast height (DBH): The diameter of a tree as measured at breast height. Standard DBH is measured at 4.5 feet (approximately 135 cm) above the ground. (FoF)

Dry weight: The weight of the wood in the tree if it was dried in an oven and all water was taken out.

Ecosystem: A system of interacting living organisms together with their physical environment. The boundaries of what could be called an ecosystem are somewhat arbitrary, depending on the focus of interest or study. Thus, the extent of an ecosystem may range from very small spatial scales to, ultimately, the entire Earth. (USFS CC)

Emissions: In the climate change context, emissions refer to the release of greenhouse gases, the precursors of greenhouse gases, and aerosols into the atmosphere over a specified area and period of time. (USFS CC)

Evaporation: A physical change of state in which a liquid is transformed into a vapor or gas. (PreK-8)

Evapotranspiration: The transfer of water vapor to the atmosphere from soil and water surfaces (evaporation), and from living plant cells (transpiration). (USFS)

Externality: An impact on a third party caused by a decision made by a producer or consumer. Externalities can be social or environmental and either positive or negative. (Biz/ed, 2012)

Forest health: The ability of a forest ecosystem to remain productive, resilient, and stable over time and to withstand the effects of periodic natural or human-caused stresses such as climate changes, disease, drought, flood, insect attack, resource demands, and resource management practices. (FoF)

Forest management: The practical application of scientific, economic, and social principles to the administration of a forest. (PreK-8)

Forest product substitution: The practice of using wood instead of other products.

Forester: A person trained in and practicing forestry. (PreK-8)

Fossil fuel: Coal, oil, natural gas, and other energy sources that formed in the ground over millions of years from the remains of ancient plants and animals. (PreK-8)

Fusiform rust: A disease caused by a fungus that deforms and kills pine trees throughout the southern United States. (School of Forest Resources and Conservation, University of Florida, n.d.)

Genes: Small parts of DNA that carry the genetic code. (McCall, 2012)

Genetic diversity: The genetic variation present in a population or species. (Biod SM)

Global warming: An increase in the average surface temperature on Earth.

Global warming potential (GWP): A measure of how much heat a substance can trap in the atmosphere. GWP can be used to compare the effects of different greenhouse gases. For example, methane has a GWP of 21, which means over a period of 100 years, 1 pound of methane will trap 21 times more heat than 1 pound of carbon dioxide (which has a GWP of 1). (EPA Kids)

Grasslands: A vegetation community in which grasses are the dominant plants. (PreK-8)

Green weight: An estimate of the weight of the tree when it is alive. This weight includes all of the wood content and any water that is in the tree.

Greenhouse effect: The trapping of heat in Earth's atmosphere by gases, such as carbon dioxide, methane, nitrous oxide, and water vapor, that results in an increase in temperature at Earth's surface. (FoF)

Greenhouse gases: Gases in Earth's lower atmosphere that trap heat and affect the average temperature on Earth. Examples are carbon dioxide, chlorofluorocarbons, ozone, methane, water vapor, and nitrous oxide.

Groundwater: Water that infiltrates into the soil and is stored in slowly flowing and slowly renewed underground reservoirs called aquifers. (PreK-8)

Habitat: An area that provides an animal or plant with adequate food, water, shelter, and living space in a suitable arrangement. (PreK-8)

Harvest: To cut down trees for human consumption.

Hydrocarbons: Organic compounds that occur in fossil fuels that contain only hydrogen and carbon. (PreK-8/E&S)

Invasive species: A type of plant, animal, or other organism that does not naturally live in a certain area but has been introduced there, often by people. An invasive species can spread quickly, especially if it has no natural predators in its new habitat, and can cause harm to the economy, the environment, or human health. (EPA Kids and PreK-8)

Life cycle assessment: A technique to assess the environmental aspects and potential impacts associated with all life cycle stages of a product, process, or service. This information can be used by scientists, policy makers, and citizens to make decisions about which products to produce and purchase. (U.S. Environmental Protection Agency, 2006)

Limestone: A type of sedimentary rock that is composed mostly of calcium carbonate and is often formed when ocean sediments, containing the shells of marine animals, are compressed and buried under the ocean floor. Limestone is a long-term carbon sink that can store carbon for hundreds of millions of years. (Riebeek, 2011)

Long-lived wood product: Wood products, such as lumber used in housing, that store carbon for many years. The lifespan of lumber in housing is often estimated to be 80 years. (Lippke et al., 2012)

Mitigation: A human intervention to reduce the human impact on the climate system. Includes actions and strategies to reduce sources of greenhouse gases or increase the amount of carbon dioxide being removed from the atmosphere. (EPA)

Model: A quantitative tool that combines data from many variables and uses mathematical equations to approximate processes and systems over time. Climate models represent the interactions of the atmosphere, oceans, land surface, and ice; can range from relatively simple to quite comprehensive; and can be used to simulate climate and make climate predictions. (EPA, USFS CC)

Negative externality: A cost (harmful impact) incurred by a third party when a decision is made by a producer or consumer. (Biz/ed, 2012)

Non-timber forest products: All forest products except timber. Examples are resins, oils, leaves, bark, plants other than trees, fungi, and animals or animal products. (USFS)

Nonrenewable resource: A substance that once used, cannot be replaced in this geological age. Examples are such as oil, gas, coal, copper, and gold. (PreK-8)

Phenotype: A characteristic of an animal, plant, or other organism that can be seen or measured. Examples are eye color, birth weight, and tree height. (McCall, 2012)

Photosynthesis: The process by which green pants produce oxygen and glucose, a carbon-based molecule, in the presence of carbon dioxide, sunlight, and water. (PreK-8)

Plantation: A forest established by planting seeds or seedlings. (PreK-8/FoF)

Positive externality: A beneficial impact on a third party caused by a decision made by a producer or consumer. (Biz/ed, 2012)

Precipitation: Water from the atmosphere that falls to the ground. Examples include rain, mist, snow, sleet, and hail.

Prescribed fire: Any planned fire ignited in a natural area by trained professionals under appropriate weather and safety conditions to meet specific objectives including the reduction of wildfire risk and the maintenance or restoration of fire-dependent ecosystems. (PreK-8, USFS)

Product life cycle: The many steps that go into creating, using, and disposing of a product. Life cycle includes the acquisition of raw materials, bulk material processing, engineered materials production, manufacture and assembly, use, retirement, and disposal of residuals produced in each stage. (U.S. Environmental Protection Agency, 2006 and EPA Kids)

Projection: Description of how future climate is expected to respond to various scenarios of the factors that might affect climate change, such as population growth, greenhouse gas emissions, and land development patterns.

Ocean acidification: Increased concentrations of carbon dioxide in sea water causing a measurable increase in acidity (i.e., a reduction in ocean pH). This may lead to reduced calcification rates of calcifying organisms such as corals, mollusks, algae, and crustaceans. (EPA)

Recycle: To process waste materials (such as glass, plastic, newspaper, and cans) so that they can be used to make new products**.** (E&S)

Renewable resource: A naturally occurring raw material or form of energy which has the capacity to replenish itself through ecological cycles and sound management practices. The sun, wind, falling water, and trees are examples of renewable resources. (PreK-8)

Resilience: The ability of an ecosystem or species to remain whole and functioning as it copes with stress. (The Conservation Fund, 2013)

Respiration: The process whereby living organisms convert organic matter to carbon dioxide, releasing energy and consuming oxygen. (USFS CC)

Saltwater intrusion: Displacement of fresh or ground water by the advance of salt water due to its greater density, usually in coastal and estuarine areas. This can occur when sea levels rise. (EPA)

Sea level rise: An increase in the mean level of the ocean. (USFS CC)

Sediment: Solid mineral and organic material that is in suspension, is being transported, or has been moved from its site of origin by air, water, gravity, or ice. (USFS)

Service learning: A teaching strategy that integrates meaningful community activity with instruction and reflection to enrich the learning experience, teach civic responsibility, and strengthen communities.

Short-lived wood products: Wood products, such as paper, that store carbon for a relatively shorter time frame when compared to long-lived wood products like housing lumber. Carbon is returned to the atmosphere when the product decays or decomposes, which is often estimated to take 45 years. (Lippke et al., 2012)

Solar radiation: Energy emitted by the sun. It is also referred to as short-wave radiation. (EPA)

Species: A population of organisms composed of related individuals that resemble one another and are able to breed among themselves, but are not able to breed with members of another species. (PreK-8)

Thin: To remove small, deformed, or unwanted species to improve forest health, restore ecosystems, reduce wildfire risk, or improve economic viability. (Monroe, McDonell, & Oxarart, 2007)

Topography: The natural and manmade features and relief of Earth's surface. (State Climate Office of North Carolina, n.d.)

Transpiration: The process by which water evaporates from plant tissues. (PreK-8, FoF)

Understory: The layer of trees and plants beneath the forest canopy.

Vegetation: The mass of plants that covers a given area. (PreK-8)

Weather: Atmospheric conditions at any given time or place, measured in terms of such things as wind, temperature, humidity, atmospheric pressure, cloudiness, and precipitation. In most places, weather can change from hour-to-hour, day-to-day, and season-to-season. (EPA)

Wildfire: Any non-structural fire on wildlands other than one intentionally set for management purposes. (USFS)

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B: Module Website Overview

This section will explain the module website and resources available there.

C: Additional Resources

Climate Change

American Climate Attitudes
The Social Capital Project
http://www.thesocialcapitalproject.org/The-Social-Capital-Project/pubs/aca
This report provides review of public opinion research and polling data over the last few years and compared these findings with trends since 1997, and offers communication and engagement recommendations based on the data and our experience.

Climate.gov
NOAA
www.climate.gov
This website provides information, maps, educational resources, and videos to about climate science and climate change.

Climate Adaptation Knowledge Exchange (CAKE)
www.CAKEx.org
This joint project of Island Press and EcoAdapt is aimed at building a shared knowledge base for managing natural systems with regard to climate change. Their website has case studies profiles of on-the-ground adaptation projects, a directory of people and organizations engaged in adaptation, and tools and information related to climate change and adaptation.

Climate Connections Special Series
National Public Radio
http://www.npr.org/series/9657621/climate-connections
This NPR special species features videos, articles, and interactive maps to look at the causes and signs of climate change, along with stories about solutions and adaptation.

Climate Change: Evidence, Impacts, and Choices: Answers to Common Questions about the Science of Climate Change
National Research Council, 2012
http://nas-sites.org/americasclimatechoices/files/2012/06/19014_cvtx_R1.pdf
This booklet summarizes the current state of knowledge about climate change, explains some impacts expected in this century and beyond, and examines how science can help inform choices about managing and reducing the risks posed by climate change.

Climate Change Handbook: A Citizen's Guide to Thoughtful Action
Mark Apel, Lauren McDonell, Jay Moynihan, Darien Simon, and Viviane Simon-Brown, 2010
http://ir.library.oregonstate.edu/xmlui/handle/1957/20080
After providing an overview of climate change basics, this handbook focuses on how individuals can engage with their local government and how to take action.

Climate Change Information
US Environmental Protection Agency (EPA)
http://www.epa.gov/climatechange/
This is EPA's main climate change information page and is loaded with easy to understand information on the science behind global climate change, an award-winning kid's site, and carbon and water footprint calculators.

Climate Literacy Guidelines: The Essential Principles of Climate Science
US Global Change Research Program, 2009
www.globalchange.gov/resources/educators/climate-literacy
This guide presents information for individuals and communities who want to learn about climate, impacts of climate change, and approaches to mitigation and adaptation.

Earth Observatory
NASA Website
http://earthobservatory.nasa.gov/
This website features images, global maps, news, and data about climate and the environment that emerge from NASA research, including its satellite missions, in-the-field research, and climate models.

Global Climate Change
NASA Website
http://climate.nasa.gov
This website provides information on the evidence, causes, effects, and uncertainties of climate change. There is also recent data on Earth's "vital signs" including global temperature, carbon dioxide levels, and the rate of sea level rise.

Intergovernmental Panel on Climate Change (IPCC)
http://www.ipcc.ch/
IPCC is the primary source for many climate change publications. At their website, you'll find the 4th Assessment Report on Climate Change published in 2007, along with other reports, graphics, and news.

Preparing for Climate Change: A Guidebook for Local, Regional and State Government
Climate Impacts Group, King County, Washington, 2007
http://www.cses.washington.edu/db/pdf/snoveretalgb574.pdf
This guide provides a step-by-step guide to help decision makers identify and plan for climate change in their community.

Skeptical Science: Getting Skeptical about Global Warming Skepticism
John Cook, Global Change Institute at the University of Queensland
www.skepticalscience.com
This website reviews scientific, peer-reviewed literature to help explain climate change and to address common misconceptions about climate change.

Southeast Region Technical Report to the National Climate Assessment
Keith Ingram, Kirstin Dow, and Lynne Carter; 2012
http://downloads.usgcrp.gov/NCA/Activities/NCA_SE_Technical_Report_FINAL_7-23-12.pdf
This report summarizes the scientific literature that addresses climate impacts on the southeastern United States with a focus on literature published since 2004. Includes a chapter that specifically examines climate change and forests.

Teaching Controversy
Mark McCaffrey, 2012. The Earth Scientist 28(3): 25-29.
http://www.nestanet.org/cms/sites/default/files/journal/Fall12.pdf
The author discusses why teachers should not present climate change as a "theory" open for debate, but instead should focus on helping students understand climate change and the supporting scientific research. This article is part of a special issue on climate change education from the journal of the National Earth Science Teachers Association.

Understanding and Responding to Climate Change: Highlights of the National Academy Reports
The National Academies, 2008
http://dels-old.nas.edu/dels/rpt_briefs/climate_change_2008_final.pdf
This overview highlights findings and recommendations from National Academies' reports on climate change. It includes concise overviews of climate change science, impacts on ecosystems and human systems, and how science can inform decision making.

US Global Change Research Program
http://www.globalchange.gov/
The US Global Change Research integrates federal research on climate and global change, as sponsored by thirteen federal agencies. Their website provides access to reports, news, and other climate-related information and can be searched by region or by sector.

Yale Project on Climate Change Communication
Yale University
http://environment.yale.edu/climate
This website provides several reports, videos, and other resources that help explain research related to public knowledge and perceptions of climate change.

Young Voices for the Planet, The Movies
Young Voices on Climate Change Website
www.youngvoicesonclimatechange.com/climate-change-videos.php
This series of short films presents replicable success stories of young people tackling climate change issues in their communities. Accompanying curriculum for each video is also available.

Climate Change and Forests

Adapting to Climate Change: A Short Course for Land Managers
USDA Forest Service, Climate Change Resource Center, 2009
http://www.fs.fed.us/ccrc/hjar/index_st.html
A series of videos and graphics illustrating the key concepts of climate change, possible impacts on US forests and grasslands, and different strategies we can employ to adapt to climate change.

A Climate Change Atlas for 134 Forest Tree Species of the Eastern United States
Anantha Prasad, Louis Iverson, Stephen Matthews, and Matthew Peters; USDA Forest Service
http://www.nrs.fs.fed.us/atlas/tree
This searchable database provides information on 134 common trees in the eastern U.S. The key feature is the presentation of data for each species describing both the current distribution of that species and future suitable habitat based on climate change models.

Climate Change Resource Center
USDA Forest Service Website
http://www.fs.fed.us/ccrc/
The Climate Change Resource Center provides information about basic climate sciences and compiles knowledge resources and support for adaptation and mitigation strategies. The site offers educational information, including basic science modules that explain climate and climate impacts, decision-support models, maps, simulations, case studies, toolkits, and videos.

Forest Management Solutions for Mitigating Climate Change in the United States
Robert W. Malmsheimer, et al., 2008. Journal of Forestry 106(3): 115-171.
www.ntc.blm.gov/krc/uploads/399/Forest%20Management%20Solutions%20for%20Mitigating%20Climate%20Change.pdf
This report contains an executive summary and chapters related to preventing greenhouse gas emissions through wood substitution and biomass substitution, as well as reducing atmospheric greenhouse gases through sequestration in forests and storage in wood products.

PINEMAP
Pine Integrated Network: Education, Mitigation, and Adaptation Project
http://pinemap.org/
This website contains research summaries, newsletters, photos, webinars, and videos that describe current research related southern pine plantations and climate change.

Profile for Climate Change 2009
United Nations Food and Agriculture Organization (FAO)
ftp://ftp.fao.org/docrep/fao/012/i1323e/i1323e00.pdf
This document outlines how climate change will impact agricultural sectors and discusses priorities for adaptation and mitigation strategies for natural resources around the world, including forests.

Template for Assessing Climate Change Impacts and Management Options (TACCIMO)
USDA Forest Service
www.sgcp.ncsu.edu:8090
This web-based tool, intended for use by land managers, provides the most current climate change projections and research in an effort to link science to forest management and planning. Features include a geospatial mapping application, a searchable listing of peer-reviewed literature, and guides explaining how to use TACCIMO.

Forests and Forest Management

Eastern Forest Environmental Threat Assessment Center
USDA Forest Service
http://forestthreats.org/climate-change
The Eastern Forest Environmental Threat Assessment Center (EFETAC) is an interdisciplinary resource that is actively developing new technology and tools to anticipate and respond to emerging eastern forest threats. The site features resources about climate change and other significant threats.

FAO Forestry
Food and Agriculture Organization of the United Nations
http://www.fao.org/forestry/en/
This website provides access to publications, photos, videos, and other resources related to environmental, social, and economic aspects of Earth's forest resources. In particular, the *State of the World's Forests* and the *Global Forest Resources Assessments* reports provide a comprehensive look at the status, key issues, and trends of global forests.

Forest Encyclopedia Network
USDA Forest Service Southern Research Station and Southern Regional Extension Forestry Office
www.forestryencyclopedia.net
This website has several encyclopedias that provide scientific knowledge and tools related to forest ecosystems and management.

State Forestry Agencies in the Southeast

Alabama Forestry Commission
www.forestry.state.al.us

Arkansas Forestry Commission
forestry.arkansas.gov

Florida Forest Service
www.floridaforestservice.com

Georgia Forestry Commission
www.gfc.state.ga.us

Kentucky Division of Forestry
forestry.ky.gov

Louisiana Department of Agriculture & Forestry
www.ldaf.state.la.us

Mississippi Forestry Commission
www.mfc.ms.gov

North Carolina Division of Forest Resources
www.ncforestservice.gov

Oklahoma Forestry Services
www.forestry.ok.gov

South Carolina Forestry Commission
www.state.sc.us/forest

Tennessee Division of Forestry
www.tn.gov/agriculture/forestry

Texas Forest Service
txforestservice.tamu.edu

Virginia Department of Forestry
www.dof.virginia.gov

Stewardship Handbook for Family Forest Owners
National Association of State Foresters, 2005
www.stateforesters.org/stewardship_handbook
This handbook provides guidance for incorporating land management goals within a set of stewardship principles.

Southern Forest Futures Project
USDA Forest Service
www.srs.fs.usda.gov/futures
This website provides summary reports, a webinar, and other resources related to a multi-year research effort that forecasts changes in southern forests between 2010 and 2060.

Southern Forests for the Future
World Resources Institute
www.seesouthernforests.org
This website contains maps, photos, case studies, and other information to highlight key features and trends for southern forests.

Formal and Nonformal Education Programs/Lessons

Buy, Use, Toss? A Closer Look at the Things We Buy
Facing the Future
www.facingthefuture.org
This is a free interdisciplinary unit that includes ten fully-planned lessons that explore the system of producing and consuming goods that is called the materials economy. Students will learn about the five major steps of the materials economy; Extraction, Production, Distribution, Consumption, and Disposal. They will also be asked to analyze the sustainability of these steps, determining how consumption can benefit people, economies, and environments.

Climate Change: Connections and Solutions
Facing the Future
http://www.facingthefuture.org/Curriculum/BuyCurriculum/ClimateChangeGrades912/tabid/454/Default.aspx
This two-week curriculum unit for grades 9-12 encourages students to think critically about climate change and to collaborate to devise solutions. Students learn about climate change within a systems framework, examining interconnections among environmental, social, and economic issues.

Climate Change Wildlife, and Wildlands: A Toolkit for Formal and Informal Educators.
US Environmental Protection Agency
http://www.globalchange.gov/resources/educators/toolkit
The kit is designed for middle school classroom teachers and informal educators. The toolkit includes 11 case studies on US ecoregions, highlighting regional impacts and a 12-minute video introducing climate change issues as they affect wildlife and wildlands.

Climate Education for K-12
State Climate Office, North Carolina State University
http://www.nc-climate.ncsu.edu/edu/k12/
This website is designed to help educators understand climate and weather concepts and to be able to incorporate the learning material from this site into their course curriculum using examples as aids for learning.

Climate Literacy and Energy Awareness Network (CLEANET)
http://cleanet.org/index.html
The CLEAN collection is a small digital collection of teaching resources aligned with the Essential Principles of Climate Literacy Climate Literacy and the Energy Awareness Principles. Each teaching resource is reviewed by scientists and educators for alignment with these principles first, and then for scientific accuracy, pedagogic effectiveness and usability.

Coastal Areas Climate Change Education Partnership
http://www.cacce.net/index.html
This partnership of educators and scientists are creating innovative education programs for schools and organizations in Florida and the Caribbean to improve current and future generations' understanding of climate change and the local impacts.

EarthSky
http://earthsky.org/
EarthSky specializes in reporting timely and compelling science news and information through short, daily radio shows.

Educator Toolbox, Conservation Education
USDA Forest Service
http://www.fs.usda.gov/main/conservationeducation/educator-toolbox
Follow the "Climate Change" link to find a collection of resources provided by the Forest Service and by their partners and other trusted professionals.

Educational Global Climate Modeling (EdGCM)
http://edgcm.columbia.edu/
EdGCM provides a Global Climate Model with a user-friendly interface that allows students to explore the subject of climate change in the same way that actual research scientists do.

Environmental Literacy and Inquiry (ELI) Climate Change
http://www.ei.lehigh.edu/eli/cc/
In this middle school science inquiry curriculum, students use geospatial information technology tools, web-based tools and inquiry-based lab activities to investigate important climate change topics.

EE Link, Climate Change
North American Association for Environmental Education
http://eelink.net/pages/Climate+Change
Links on this page are for activities and materials dealing with climate change, global warming, and environmental policy.

Exploring Climate Change
NEED, 2010
http://www.need.org/needpdf/ExploringClimateChange.pdf
This set of nine activities is designed to teach students in grades 9 – 12 about the science behind climate change, the relationship between energy use and climate change, and personal choices that can be made to address climate change.

Forest Health Education
School of Forest Resources and Conservation, University of Florida
http://sfrc.ufl.edu/extension/ee/foresthealth.html
This site provides resources and information to help educators incorporate forest health into their lessons and activities. A middle school supplement, *What Is a Healthy Forests?*, contains 5 new activities and extensions to 13 Project Learning Tree PreK-8 activities. *Beyond the Trees* is a set of six lesson plans for high school educators to convey forest health concepts using a systems thinking framework. All the materials are available for free download.

i-Tree Learning Lab: Using i-Tree in the Classroom
Urban Natural Resources Institute, USDA Forest Service
http://www.unri.org/learninglab/
This curriculum uses urban forest inventory and assessment tools, developed through the USDA Forest Service i-Tree program, to teach students about ecosystem services of trees such as carbon sequestration, energy savings, and clean air and water benefits.

GLOBE Carbon Cycle
University of New Hampshire
http://globecarboncycle.unh.edu/index.shtml
This education unit focuses on bringing cutting edge research and research techniques in the field of terrestrial ecosystem carbon cycling into secondary classrooms. It includes several activities to help students understand the carbon cycle, including a "choose your own adventure story."

Job Corps Climate Change Curriculum
USDA Forest Service
http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5212126.pdf
The hands-on activities in this high school level curriculum were designed to introduce Job Corps students to the science and impacts of climate change.

MetEd
https://www.meted.ucar.edu/index.php
This free resource for atmospheric science education contains hundreds of formal sessions and offers distance education and continuing education credits.

Natural Inquirer Science Education Journal
USDA Forest Service
http://www.naturalinquirer.org/Natural-Inquirer-Climate-Change-Articles-v-80.html
The Natural Inquirer is a middle-school science education journal that is based on US Forest Service research. Many issues have articles related to climate change, and all resources are available for download or you can order free copies.

Teaching about Climate Change
National Science Teachers Association
http://learningcenter.nsta.org/products/symposia_archive_sponsor.aspx?page=USFS
This section of the NSTA Learning Center website archives forest-related climate change symposiums and webinars.

Will Steger Foundation Education Resources
http://willstegerfoundation.org/programs/k-12-education-program
The Will Steger Foundation offers lesson plans, videos, images, professional development opportunities, and other resources to support educators, students and the public with science-based interdisciplinary educational resources on climate change, its implications and solutions to achieve climate literacy.

D: Create Your Own LCA

The National Renewable Energy Laboratory's (NREL) database for life cycle assessment (LCA) calculations is open to anyone, which means that you can perform your own life cycle assessment using the same data that scientists use. Data for utilities, transportation, and basic mining and forestry materials are all included in this database. To use the database, you will need to know a few terms. LCA involves calculating the resources (or input streams) required for a process or product as well as the output streams that result from that process or product. A full life cycle assessment involves a "cradle-to-grave" calculation. This means accounting for all the inputs and outputs for a product involved at each step of production starting from raw materials, during the use of the product, and for disposal of the product. Product life cycles are generally split up into "unit processes." A unit process is one specific step in the product's life cycle.

The NREL database provides data sets for specific unit processes, which you can combine to analyze larger processes. Each unit process has its own set of data regarding necessary inputs from nature and from the technosphere (i.e., manufactured inputs), as well as outputs to nature in the form of solid, liquid, and gas emissions and co-products of the process. These spreadsheets can be combined to create analyses of more complex processes.

To begin, go to https://www.lcacommons.gov/nrel/search. Notice the data categories listed down the left side of the page. You can navigate through these to find the processes on which you would like to focus. For example, say that you how much electricity a particular process uses and you know that the electricity is produced using bituminous coal. You can use the NREL database to calculate the greenhouse gas emissions associated with that electricity consumption.

To do this, expand the "Utilities" category on the left side of the page and select "Fossil Fuel Electric Power Generation." This will change the list of datasets on the right side of the page. In that new list, find "Electricity, bituminous coal at power plant" and click on that selection. Go to the "Exchanges" tab of this new page to see the emissions associated with producing electricity using bituminous coal.

You can find data for the inputs and outputs associated with this process (Figure 1). The numbers are all based on one unit of product. Since we are looking at power production, these numbers are based on one kilowatt-hour of electricity. Let's focus first on the outputs. We can see quite a long list of outputs, but we are interested only in the most significant greenhouse gases (carbon dioxide, methane, and dinitrogen monoxide). Scanning down the list of outputs, we can see that producing one kilowatt-hour of electricity also produces 9.94e-01 kg of carbon dioxide, 2.42e-05kg of dinitrogen monoxide, and 8.31e-06 kg of methane. These are the greenhouse emissions associated with burning the coal at the power plant. However, to find ALL the emissions associated with coal-fired electricity, we must find the emissions associated with producing each of these inputs.

Activity | Modelling | Admin Info | Exchanges

Inputs

Flow	Category	Type	Unit	Amount
Bituminous coal, at mine	root/Flows	ProductFlow	kg	4.42e-01
Dummy_Disposal, ash and flue gas desulfurization sludge, to unspecified reuse	root/Flows	ProductFlow	kg	1.41e-02
Dummy_Disposal, solid waste, unspecified, to unspecified treatment	root/Flows	ProductFlow	kg	4.38e-02
Dummy_Transport, pipeline, coal slurry	root/Flows	ProductFlow	t*km	2.22e-03
Transport, barge, average fuel mix	root/Flows	ProductFlow	t*km	5.59e-02
transport, combination truck, diesel powered	root/Flows	ProductFlow	t*km	2.99e-03
transport, train, diesel powered	root/Flows	ProductFlow	t*km	4.61e-01

Outputs

Flow	Category	Type	Unit	Amount
Acenaphthene	air/unspecified	ElementaryFlow	kg	1.13e-10
Acenaphthylene	air/unspecified	ElementaryFlow	kg	5.52e-11
Acrolein	air/unspecified	ElementaryFlow	kg	6.41e-08
...				
Cadmium	air/unspecified	ElementaryFlow	kg	1.13e-08
Carbon dioxide, fossil	air/unspecified	ElementaryFlow	kg	9.94e-01
Carbon monoxide, fossil	air/unspecified	ElementaryFlow	kg	1.10e-04
...				
Cobalt	air/unspecified	ElementaryFlow	kg	2.21e-08
Dinitrogen monoxide	air/unspecified	ElementaryFlow	kg	2.42e-05
...				
Methane, fossil	air/unspecified	ElementaryFlow	kg	8.31e-06

Figure 1: NREL Data for "Electricity, Bituminous coal, at power plant"

Activity | Modelling | Admin Info | Exchanges

Inputs

Flow	Category	Type	Unit	Amount
Bituminous coal, combusted in industrial boiler	root/Flows	ProductFlow	kg	4.31e-04
Coal, bituminous, 24.8 MJ per kg	resource/ground-	ElementaryFlow	kg	1.24e+00
Diesel, combusted in industrial boiler	root/Flows	ProductFlow	l	8.80e-03
Dummy, Disposal, solid waste, unspecified, to underground deposit	root/Flows	ProductFlow	kg	2.35e-01
Electricity, at grid, US, 2000	root/Flows	ProductFlow	kWh	3.87e-02
Gasoline, combusted in equipment	root/Flows	ProductFlow	l	8.36e-04
Natural gas, combusted in industrial boiler	root/Flows	ProductFlow	m3	1.62e-04
Residual fuel oil, combusted in industrial boiler	root/Flows	ProductFlow	l	8.70e-04

Outputs

Flow	Category	Type	Unit	Amount
Bituminous coal, at mine	root/Flows	ProductFlow	kg	1.00e+00
Iron	water/unspecified	ElementaryFlow	kg	8.64e-06
Manganese	water/unspecified	ElementaryFlow	kg	5.76e-06
Methane	air/unspecified	ElementaryFlow	kg	3.99e-03
Particulates, unspecified	air/unspecified	ElementaryFlow	kg	1.63e-03
Suspended solids, unspecified	water/unspecified	ElementaryFlow	kg	1.00e-04
VOC, volatile organic compounds	air/unspecified	ElementaryFlow	kg	2.57e-05

Figure 2: NREL data for “Bituminous coal, at mine”

For example, looking at the list of inputs, we can see that 4.42e-01 kg of “Bituminous coal, at mine” are necessary to produce one kilowatt-hour of electricity. Returning to the categories list, we can expand the “Mining” category to find the link to the dataset for “Bituminous coal, at mine” and again go to the “Exchanges” tab to see the data. Again, we can see a list of outputs associated with this unit process along with the inputs necessary to produce one kilogram of bituminous coal (Figure 2). To find all the emissions associated with the production of electricity, we must follow each of these inputs back. The NREL data can be pieced together to construct a comprehensive view of the inputs and outputs associated with each unit process.

Figure 3 shows the unit processes we have identified so far. To complete this analysis, we would have to trace the other unit process in the same way that we have traced “Bituminous coal, at mine” and “Bituminous coal, combusted in industrial boiler.” Microsoft Excel can be used to build an account of emissions that incorporates all of the unit processes involved. To simplify calculations, we recommend not going following all the way through to the inputs associated with the transportation unit processes. For these, include only the emissions listed in the outputs. This will give a slightly lower estimate of emissions, but the difference will be minor.

As you can see, performing a complete life cycle assessment requires rather extensive accounting, even when focusing on seemingly simple products (such as electricity). Following through with these calculations can provide a student not only with a sense of the greenhouse gas emissions resulting from a particular product or process, but also a greater appreciation of the complex ecological and economic relationships involved with providing the things we use every day.

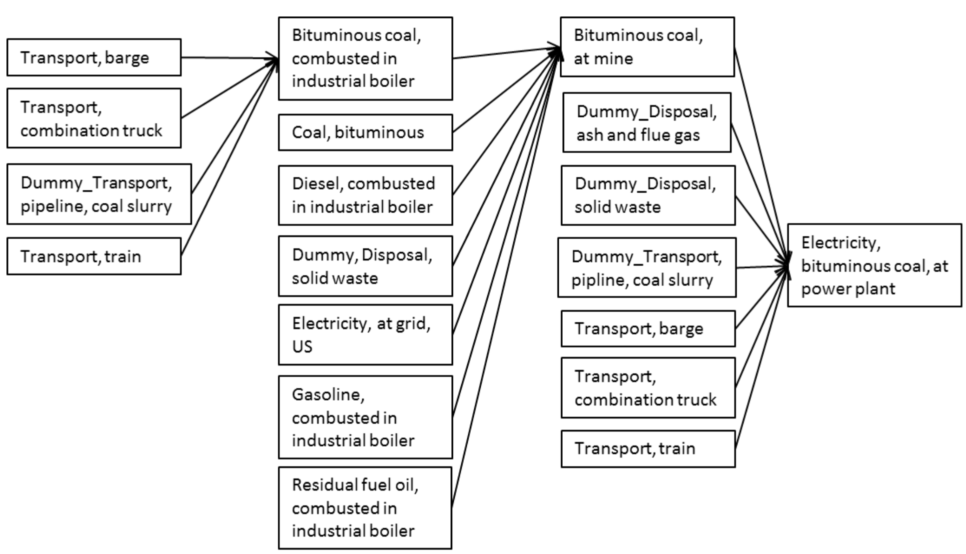

Figure 3: Partial map of unit processes associated with “Electricity, bituminous coal at power plant”

E: Sample Assessment Tests

This section will include sample student assessments (from Stephanie Hall's master's research and from our evaluation)

F: Subject Correlations

Subject	1	2	3	4	5	6	7	8	9	10	11	12	13
Agriculture Education	X	X	X	X	X		X				X	X	X
Biology and AP Biology	X	X	X	X	X	X	X	X	X	X	X	X	X
Biotechnology					X								
Chemistry and AP Chemistry		X				X							
Earth Science		X				X							
Economics								X	X	X			
Environmental Issues / Ecology	X	X	X	X	X	X	X	X	X	X	X	X	X
Environmental Science and AP Environmental Science	X	X	X	X	X	X	X	X	X	X	X	X	X
Forestry / Natural Resource Management	X	X	X	X	X		X				X	X	X
Government / Politics		X						X					X
Integrated Science	X	X	X	X	X	X	X	X	X	X	X	X	X
Language Arts	X		X					X				X	
Life Science	X	X	X	X	X	X	X	X	X	X	X	X	X
Mathematics							X				X		

G: Next Generation Science Standards Correlations

	Activity												
Standards	1	2	3	4	5	6	7	8	9	10	11	12	13

To be added when standards are finalized.

H: PLT Conceptual Framework Correlations

Theme: Diversity

PLT Concept		Activity												
		1	2	3	4	5	6	7	8	9	10	11	12	13
1.0	Throughout the world, there is a great diversity of habitats, organisms, societies, technologies, and cultures.	?												
Diversity in Environments														
1.1	Biodiversity results from the interaction of living and nonliving environmental components such as air, water, climate, and geologic features.		X	?		?								
1.2	Forests, as well as other ecosystems, contain numerous habitats that support diverse populations of organisms.			X										
1.3	The Earth's atmosphere, water, soil, climate, and geology vary from region to region, thus creating a wide diversity of biological communities.		X	X		?								
Diversity of Resources and Technologies														
1.4	Humans use tools and technologies to adapt and alter environments and resources to meet their physical, social, and cultural needs.				?	?				?				
1.5	Technologies vary from simple hand tools to large-scale and complex machinery, mechanisms, and systems.				?	?								
1.6	Successful technologies are those that are appropriate to the efficient and sustainable use of resources, and to the preservation and enhancement of environmental quality.		X		?	?								
Diversity Among and Within Societies and Cultures														
1.7	Human societies vary greatly and inhabit many land forms and climates throughout the world.													
1.8	Humans throughout the world create differing social, cultural, and economic systems and organizations to help them meet their physical and spiritual needs.													
1.9	The standard of living of various peoples throughout the world is dependent on environmental quality; the availability, utilization, and distribution of resources; the government; and culture of its inhabitants.													
1.10	Natural beauty, as experienced in forests and other habitats, enhances the quality of human life by providing artistic and spiritual inspiration, as well as recreational and intellectual opportunities.													

Theme: Interrelationships

PLT Concept		Activity												
		1	2	3	4	5	6	7	8	9	10	11	12	13
2.0	The ecological, technological, and socio-cultural systems are interactive and interdependent.				?							?	?	
Environmental Interrelationships														
2.1	Organisms are interdependent, and depend on nonliving components of the Earth.				X		X							
2.2	Altering the environment affects all life forms, including humans, and the interrelationships that link them.	?	X	?									?	
2.3	Organisms adapt to changes in the environment according to the genetic and behavioral capacity of their species.		X	X		X							?	
Resource and Technological Interrelationships														
2.4	Resource management technologies interact and influence environmental quality; the acquisition, extraction, and transportation of natural resources; all life forms; and each other.				X				X	X	X	X	X	
2.5	While technological advances decrease the incidence of disease and death, the ever increasing world population is placing heavy demands on the finite resources of the Earth.								?					
2.6	International cooperation directed toward conserving resources and protecting environmental quality is beneficial to human health and the well-being of other life forms.													
2.7	By reducing waste and recycling materials, individuals and societies can extend the value and utility of resources and also promote environmental quality.								X	X	X			
Societal and Cultural Interrelationships														
2.8	Human societies and cultures throughout the world interact with each other and affect natural systems upon which they depend.								X	X	X			
2.9	The quantity and quality of resources and their use—or misuse—by humans affect the standard of living of societies.								?			?		
2.10	Cultural and societal perspectives influence the attitudes, beliefs, and biases of people toward the use of resources and environmental protection.	?												
2.11	All humans consume products and thereby affect the availability of renewable and nonrenewable natural resources.								X	X	X			
2.12	The extracting, processing, transporting, and marketing of natural resources provide employment opportunities for many people.													

Theme: Systems

PLT Concept		Activity												
		1	2	3	4	5	6	7	8	9	10	11	12	13
3.0	Environmental, technological, and social systems are interconnected and interacting.	?			X							X	X	
Environmental Systems														
3.1	In biological systems, energy flows and materials continually cycle in predictable and measurable patterns.						X	X				?		
3.2	Plant and animal populations exhibit interrelated cycles of growth and decline.		X	X										
3.3	Pollutants are harmful by-products of human and natural systems which can enter ecosystems in various ways.													
3.4	Ecosystems possess measurable indicators of environmental health.		X		?									
Resource Management and Technological Systems														
3.5	The application of scientific knowledge and technological systems can have positive or negative effects on the environment.	X				?						?		
3.6	Resource management and technological systems can help societies meet, within limits, the needs of a growing human population.				?	?				?		?		
3.7	Conservation technology enables humans to maintain and extend the productivity of vital resources.				?					?	?	?		
Systems in Society and Culture														
3.8	Most cultures have beliefs, values, and traditions that shape human interactions with the environment and its resources.													
3.9	In democratic societies, citizens have a voice in shaping resource and environmental management policies. They also share in the responsibility of conserving resources and behaving in an environmentally responsible manner.										?		?	X
3.10	In democratic societies, individuals and groups, working through governmental channels, can influence the way public and private lands and resources are managed.				?									?
3.11	Effective citizen involvement in the environmental decision-making process involves a careful study of all sides of the issues, along with the ability to differentiate between honest, factually accurate information and propaganda.	X												X

Theme: Structure and Scale

PLT Concept		Activity												
		1	2	3	4	5	6	7	8	9	10	11	12	13
4.0	Technologies, societal institutions, and components of natural and human-built environments vary in structure and scale.													
Structures and Scale in Environments														
4.1	Populations of organisms exhibit variations in size and structure as a result of their adaptation to their habitats.		X			X								
4.2	The structure and scale of an ecosystem are influenced by factors such as soil type, climate, availability of water, and human activities.			X										
4.3	When the Earth is studied as an interacting ecological system, every action, regardless of its scale, affects the biosphere in some way.	X			X		X	X						X
Structure and Scale in Resources and Technology														
4.4	Technologies vary in size, structure, and complexity and in their positive and negative effects on the environment.				?				X	X	X	?		
4.5	Conservation and management technologies, when appropriately applied to the use or preservation of natural resources, can enhance and extend the usefulness of the resource, as well as the quality of the environment.		X		X							X	X	
4.6	Human-built environments, if planned, constructed, and landscaped to be compatible with the environment in which they will be located, can conserve resources, enhance environmental quality, and promote the comfort and well-being of those who will live within them.													
4.7	International cooperation on resource management and environmental improvement programs can be beneficial to people in many parts of the world.	?												
Structure and Scale in Societies and Cultures														
4.8	The structure and scale of the natural resources in a given area shape the economy upon which the society and its culture is based. Cultural structures and actions affect the management of resources and environmental quality.				?								?	
4.9	Governmental, social, and cultural structures and actions affect the management of resources and environmental quality.								?				?	
4.10	Demographics influence environmental quality, government policy, and resource use.								?	?	?			

Theme: Patterns of Change

PLT Concept		Activity												
		1	2	3	4	5	6	7	8	9	10	11	12	13
5.0	Structure and systems change over various periods of time.													
Patterns of Change in the Environment														
5.1	Organisms change throughout their lifetimes. Species of organisms change over long periods of time.			?	?	?								
5.2	Although species become extinct naturally, the increasing number of extinctions in recent history may be linked to the rapid increase in human population.			?										
5.3	As organisms go through their life cycle of growth, maturity, decline, and death, their role in the ecosystem also changes.			?										
5.4	Ecosystems change over time through patterns of growth and succession. They are also affected by other phenomena such as disease, insects, fire, weather, climate, and human intervention.			X	X	X	X	X	X				X	
Patterns of Change in Resources & Technologies														
5.5	Our increasing knowledge of the Earth's ecosystems influences strategies used for resource management and environmental stewardship.	X			X	X						X	X	X
5.6	Technologies that are developed to meet the needs of an increasing world population should also be environmentally sound.				?	?								
5.7	To be effective, new technologies require well-informed and highly skilled workers.													
Patterns of Change in Society and Culture														
5.8	Governments change and evolve over the years. Such changes affect the lives of its citizens, as well as resource management and environmental policies.												?	
5.9	Consumers "drive" the marketplace with their demands for goods and services. Such demands shift with time and may have positive or negative effects on the resource base and environmental quality.								X	X	X	?		
5.10	Industries usually respond to consumer demand for recyclable, recycled, or otherwise environmentally friendly products.								?	?	?	?		
5.11	Leisure and recreational pursuits can have an impact on forests and other resource producing areas.													
5.12	Increased public knowledge of the environment and the need for conservation of natural resources have resulted in lifestyle changes in many cultures.	?												