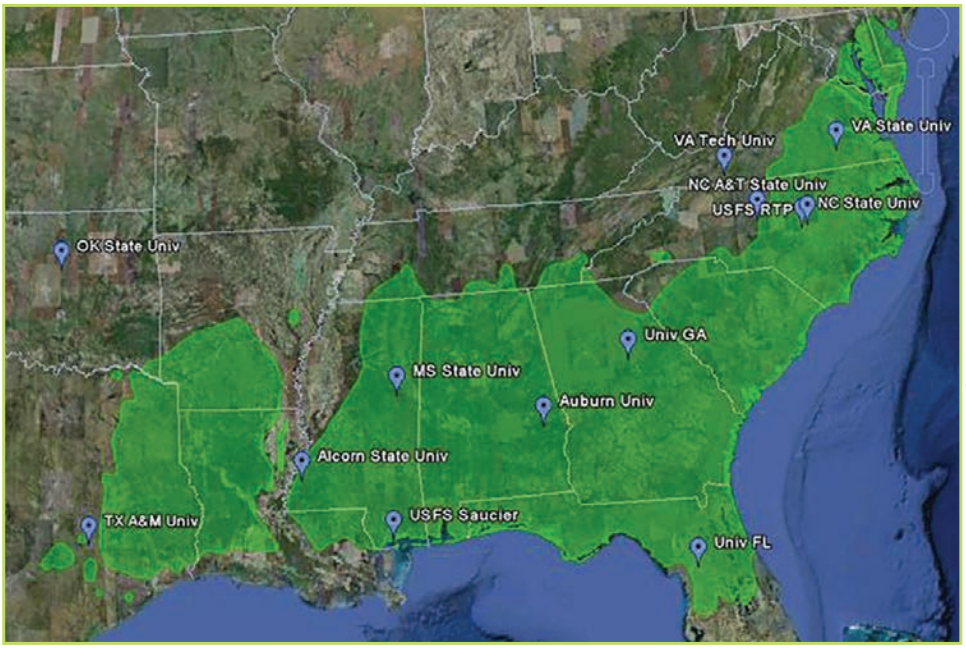
BACKGROUND

Southeastern Forests and Climate Change

About PINEMAP

THE PINE INTEGRATED NETWORK: EDUCATION, MITIGATION, AND ADAPTATION PROJECT (PINEMAP) is one of three Coordinated Agriculture Projects (CAP) awarded by the United States Department of Agriculture (USDA), National Institute of Food and Agriculture (NIFA) 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 anticipated climate variation. These initiatives have created opportunities for the development of new insights and solutions to the challenges of climate change. PINEMAP focuses on planted pine forests in the Atlantic and Gulf coastal states that are managed by ***industrial*** and ***non-industrial*** private landowners (figure 1). Loblolly pine (*Pinus taeda*) accounts for 80 percent of the planted forests in the Southeast United States (U.S.). PINEMAP integrates research, Extension, and education to enable landowners to 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. Eleven land-grant universities, the U.S. Forest



REMOTE SENSING IMAGE FROM GOOGLE EARTH; RANGE MAP FROM U.S. FOREST SERVICE.

Figure 1. PINEMAP focuses on the native range of loblolly pine (shown in green) and includes thirteen collaborating institutions (shown in blue).

Service, state climatologists, and Project Learning Tree® (PLT) are collaborating in PINEMAP activities.

Rather than research that focuses on a small or theoretical question, PINEMAP research is focused on an applied question: how can we continue to grow pine trees in the face of climatic change, and in a way that mitigates climate changes? There are many ways to answer that question, and they are all linked together. For example, if tree breeding results in shuffling the genetic makeup of trees, a new generation might thrive in the changing environment. This will depend upon many things, such as how the forests are managed, when fertilizer is applied, and how much rainfall arrives. Researchers have amassed additional climate data and created a new computer-based climate model that is able to downscale regional projections to the county level, allowing landowners to think about the range of realistic possibilities for the future. But climate change models also depend on the level of carbon emissions and the ways we choose to sequester carbon, so exact forecasts are not possible. The sequestration power of trees is not limited to merely planting them, but also to using them in long-lived wood products. These interconnected questions and answers have their roots in tree physiology, economics, genetics, and ecology. Over 100 faculty, staff, and student researchers investigated aspects of these questions as part of PINEMAP from 2011-2016, working toward the following outcomes:

- Increased carbon (C) sequestration from silvicultural and genetic enhancement of productivity and efficiency of fertilizer use, and resilience to climate variability and disturbance.
- A more robust and resilient forest-based economy in the Southeast U.S.
- Enhanced connections between corporate and noncorporate forest landowners and forestry and climate researchers and education and outreach professionals.
- Enhanced capacity for regional, interdisciplinary collaboration among climate and forest scientists and Extension and education professionals.
- Public policy that supports sustainable management of planted pine under future climate scenarios.
- Engaged and literate public with the capacity to make informed, practical decisions related to climate, forest ecosystems, and forest management.

One way PINEMAP accomplishes its education-related outcomes is to work closely with Project Learning Tree to develop, test,

Over 100 faculty, staff, and student researchers are helping to achieve PINEMAP's outcomes by integrating research, extension, and education programs.

U.S. FOREST SERVICE

Project Learning Tree uses the forest as a "window on the world."

and implement this module. Forest researchers have helped develop and review these activities to reflect concepts they are currently exploring. Although some examples relate to loblolly pine, the activities and concepts can be easily applied to forests across the continent. Teachers who use this material will be able to help their students gain the foundational concepts that underpin current climate science and forestry research.

Visit www.pinemap.org for project updates, annual reports with research results, publications, and more.

About Project Learning Tree

Project Learning Tree® (PLT) is widely recognized as one of the premier environmental education programs in the world. Through hands-on, interdisciplinary activities, PLT provides students with opportunities to investigate environmental issues and encourages them to make informed, responsible decisions.

PLT provides educators the tools they need to bring the environment into classrooms and students into the environment. Developed to meet state and national academic standards, PLT activities can be integrated into lesson plans for all grades and subject areas.

All PLT programs are directed and implemented locally, which facilitates adaptations to meet local needs. The programs also provide opportunities for local investigations and service-learning projects, plus the involvement of community-based resource professionals.

Project Learning Tree is a program of the American Forest Foundation. PLT materials are used in all 50 states, the District of Columbia, the U.S. territories, and many other nations. Each year in the U.S., around 30,000 educators attend PLT professional development workshops to learn how to integrate environmental education into their teaching.

What Is Environmental Education?

Environmental education is a process that increases the learner's awareness and knowledge about the environment and related issues. Environmental education enhances critical-thinking, problem-solving, and decision-making skills by teaching individuals to understand various sides of an environmental issue and to make informed and responsible decisions concerning the environment and related issues (UNESCO, 1978). Environmental education does not advocate a particular viewpoint or course of action (U.S. EPA, 1997).

The three objectives of environmental education as they are written in the Tbilisi Declaration, one of the founding documents of the environmental education field, are to (1) foster clear awareness of and concern about economic, social, political, and ecological interdependence in urban and rural areas; (2) provide every person with opportunities to acquire the knowledge, values, attitudes, commitment, and skills needed to protect and improve the environment; and (3) create new patterns of behavior of individuals, groups, and society as a whole toward the environment.

PLT Mission, Vision, and Goals

Mission: PLT advances environmental literacy and promotes stewardship through excellence in environmental education,

professional development, and curriculum resources that use trees and forests as windows on the world.

Vision: PLT is committed to creating a future where the next generation values the natural world and has the knowledge and skills necessary to make informed decisions and take responsible actions to sustain forests and the broader environment.

PLT uses the forest as a "window on the world" to increase students' understanding of our complex environment, to stimulate critical and creative thinking, to develop the ability to make informed decisions on environmental issues, and to instill the confidence and commitment to take responsible action on behalf of the environment.

The goals of PLT are to

1. provide students with awareness, appreciation, understanding, skills, and commitment to address environmental issues;
2. enable students to apply scientific processes and higher-order thinking skills to resolve environmental problems;
3. help students acquire an appreciation for and tolerance of diverse viewpoints on environmental issues and develop attitudes and actions based on analysis and evaluation of the available information;
4. encourage creativity, originality, and flexibility to resolve environmental problems and issues; and
5. inspire and empower students to become responsible, productive, and participatory members of society.

How PLT Works

PLT produces high-quality environmental education curriculum materials to help educators teach about natural and built environments. Topics include forests, wildlife, water, air, energy, waste, climate change, invasive species, biotechnology, biodiversity, and community planning. PLT materials are intended to supplement, not replace, existing curricula. PLT has a comprehensive system of delivering these materials to educators that ensures effective use with students. The PLT program consists of three essential elements:

- High-quality curriculum materials
- Diverse network of professional educators and natural resource specialists
- Professional development delivery system

PLT Materials

PLT materials and programs include the following:

- *PreK–8 Environmental Education Activity Guide*, with 96 engaging, hands-on lessons that use trees and forests to introduce ecological and social concepts.
- *Environmental Experiences for Early Childhood* guide integrates nature-based exploration, art, literature, math, music and movement, and outdoor play into early childhood education programs.
- Secondary modules focus on environmental issues and decision-making skills. Topics include:
  - *Exploring Environmental Issues: Focus on Forests*
  - *Global Connections: Forests of the World*
  - *Exploring Environmental Issues: Places We Live*
  - *Exploring Environmental Issues: Municipal Solid Waste*
  - *Exploring Environmental Issues: Focus on Risk*
  - *–Biotechnology* Supplement (available online)
  - *Exploring Environmental Issues: Biodiversity* (available online)
- *Energy & Society* kit, designed for best use with grades 4-8, helps students investigate environmental issues related to energy's role in society. In addition to hands-on activities, the program integrates music and dance to enhance learning.

Environmental education enhances critical-thinking, problem-solving, and decision-making skills.

- GreenSchools! service-learning program engages students, teachers, school administrators and maintenance staff, parents, and community members in investigating and improving environmental conditions at their schools to create a more green and healthy learning environment.
- GreenWorks! service-learning grants support student-led environmental projects.

See the module website (http://sfrc.ufl.edu/extension/ee/climate/wp-content/uploads/PLT_activities.pdf) for ideas about PLT activities you can use to introduce or expand concepts covered in this secondary module.

Correlations to National and State Standards

PLT activities address national standards, including Common Core and Next Generation Science Standards, as well as state academic standards. In many states, PLT activities are correlated with state science, social studies, language arts, mathematics, and environmental education standards and assessments. Visit PLT's website (http://www.plt.org) for details about the correlations between PLT activities and your state's academic standards.

Project Learning Tree produces high-quality environmental education materials to help educators teach about natural and built environments.

PLT Professional Development

PLT curriculum materials are available through professional development workshops. PLT was one of the first environmental education programs in the U.S. to establish a protocol of professional development as part of its methodology. By participating in a PLT workshop, educators join a network that includes more than 650,000 trained educators who use PLT with more than 100 million students nationwide.

PLT Network

PLT curriculum materials and professional development are delivered to educators via a vast network of international, national, state, and local partners. In each state, sponsoring organizations (state natural resource and education agencies, universities, and nonprofit organizations) identify PLT state coordinators to carry out PLT programs and recruit and train facilitators to lead workshops in their states. Hundreds of people work together to help students learn. PLT also has agreements with sponsoring organizations in other countries and a partnership with the U.S. Peace Corps that trains volunteers to use PLT activities with youth around the world. PLT collaborates with its partners on an ongoing basis to develop new curriculum materials, provide educator training, reach diverse communities, and create new initiatives for innovative teaching and learning opportunities.

Through this vast network, PLT delivers professional development programs to teachers, offers an array of resources, and creates new initiatives for quality environmental education.

For more information and resources, visit www.plt.org; sign up to receive PLT's quarterly e-newsletter, *The Branch*; and join PLT on Facebook.

LARRY KORINIAK, UNIVERSITY OF FLORIDA

Pine forests in the Southeast play an important role in the region by providing both environmental and economic benefits.

Why Focus on Southeastern Forests and Climate Change?

Climate change has been identified as the single biggest challenge that faces the planet today, but not everyone is aware of that and some people don't agree. Perhaps more than any other environmental issue, the topic of climate change challenges science teachers to accurately 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.

Elected officials, businesses, and citizens in many nations 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 or more variable growing seasons. Many communities in the United States are also exploring ways to reduce greenhouse gas emissions or respond to sea level rise too. We believe that students and their parents need to acquire 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 may generate.

While a global issue, with many examples of change occurring at the poles, in the oceans, and on mountaintops, climate change is more meaningful to students when examples of impacts are local. Because the impacts of climate change will be different throughout the world, we provide information in this module about the southeastern United States and forest ecosystems to help make the materials

relevant. In addition, unique characteristics of specific geographic locations can affect climate change. For example, weather patterns in the Southeast are strongly influenced by the Atlantic Ocean, the Gulf of Mexico, and the El Niño-Southern Oscillation (ENSO), making specific impacts of climate change challenging to project. Unfortunately, most climate models cannot provide exact answers to the simple question about what will happen at a specific place.

The module activities build on basic concepts about climate, forest carbon cycle, forest ecosystems, and genetics.

Although there are many resources available to teach students about the physics of climate change, they are best suited to Earth science courses. This module has been created 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 human beings 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, such as crops that no longer thrive in changing plant zones or an increase in the frequency and severity of wildfires. These and other possible effects make the concepts presented in this module relevant to students and educators.

Pine forests in the Southeast provide critical economic and ecological services to U.S. citizens. Forests in this region contain one-third of the contiguous U.S. forest carbon (Jose, 2007). Since 1986, southeastern forests have produced more timber than any other country in the world, and in 2009 more than 1 million jobs and $51 billion in employee compensation were attributed to the Southeast's wood-related industries (Wear & Greis, 2012). 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 landowners might consider as they plant and manage their forests.

Students in our pilot tests and teachers responding to our needs assessment have made it clear that 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 are useful to mitigate climate change. Since this module focuses on forests, we provide information about life cycle assessment and the opportunities for consumers to use wood products in order to reduce carbon in the atmosphere. Our pilot tests also suggest that this combination of research-based information and strategies to approach challenges help empower students with knowledge, skills, and a hopeful outlook for their futures.

Purpose of This Module

This module is based on the interdisciplinary research that is conducted through PINEMAP to help understand how forest management can mitigate climate change and adapt to potential changes in temperature, precipitation, and other variables. Activities in this module provide examples that build on basic concepts about climate, forest carbon cycle, forest ecosystems, and genetics. In addition, it introduces computer modeling and life cycle assessment to help students build a sufficiently complex mental model to see the connections between economic, biological, and physical systems. Faculty and graduate students at land-grant universities across the Southeast have contributed to and reviewed these activities, and they have even created videos about their research findings that teachers can download from the module website (http://sfrc.ufl.edu/extension/ee/climate). Although we have emphasized southeastern forest species and silviculture, the concepts conveyed through these lessons are true in other areas of the United States and across the globe.

The complexity of climate change suggests an opportunity for science teachers to

MORGAN CHEEK, NORTH CAROLINA STATE UNIVERSITY

Teachers at a workshop use science and math skills to complete calculations to determine the amount of carbon stored in a tree, one of the many activities that support STEM education.

emphasize systems thinking skills and STEM (science, technology, engineering, and math) subjects. Systems thinking refers to a set of critical-thinking skills that helps students understand complex phenomena. Teaching students to see systems and the relationships between elements can enable them to understand the interactions among items that at first blush might not be obviously related, such as wildfire and climate change. Systems thinking skills include recognizing complex relationships, identifying feedback, understanding dynamic behavior, and differentiating stocks and flows. These skills can be extremely helpful to students not only for understanding the behavior of the complex systems covered in this module, but for making the cross-disciplinary connections necessary for students to understand the ecological, economic, and social impacts of most environmental issues. Evidence of the importance of systems thinking skills can be seen in the crosscutting concepts included in the Next Generation Science Standards (NGSS). While only one of the seven crosscutting concepts—system and system models—refers specifically to systems, the other six concepts are commonly covered in systems thinking literature and curricula. On the module website, we provide a table that links the module activities to the NGSS crosscutting concept and its corresponding systems thinking concept (http://sfrc.ufl.edu/extension/ee/climate/wp-content/uploads/CCNGSS.pdf).

This module includes several tools for instructors interested in encouraging students to apply systems thinking to these activities. In each activity, a **Systems Thinking Connection** box and systems reflection questions help instructors emphasize and reinforce systems concepts. In addition, Activities 1, 2, 3, 5, and 10 include descriptions of **Systems Enrichment Exercises** that are available on the module website. These supplemental exercises provide opportunities to explore systems thinking tools and concepts in more depth. Each systems thinking component is marked with the systems icon.

Similarly, these activities support STEM education by linking closely with principles that underpin science and technology. From the carbon cycle to genetic breeding trials, students learn to apply science to current

By clicking on the Explore Module Activities tab on the module website, you can find slide presentations, handouts, videos, and answer keys to enhance the activities (http://sfrc.ufl.edu/extension/ee/climate).

challenges and explore potential solutions to mitigate or adapt to climate change. Computer models and databases can be accessed through websites that bring the technology used by researchers into your classrooms. Processes from the world of production, from cracking hydrocarbons to casting aluminum, introduce engineering concepts through life cycle assessments. And challenges requiring students to make sense out of data, from measuring trees to interpreting a graph, help students improve skills in mathematics. In support of Common Core standards, these activities also enable students to practice critical thinking and writing skills.

This module provides educators with a great deal of background information and resources to teach about climate change and forests. The accompanying website provides slide presentations, handouts, videos, and answer keys that enhance each of these activities. In addition, the website includes online training components, such as short introductions to each activity, videos explaining key concepts, and quizzes for teachers to check their understanding. These items are designed to increase educators' confidence in using these materials and can be found on each activity webpage in the **Teacher Tools** section.

Throughout the module, look for this icon which indicates that the supplemental activity materials are available on the module website (http://sfrc.ufl.edu/extension/ee/climate).

This module is designed to help students

- understand how climate change could impact forests in the southeastern U.S.;
- understand how forests can be managed to address changing climate conditions and to reduce greenhouse gas emissions;
- enhance decision-making skills to make informed choices as consumers to mitigate climate change;
- develop systems thinking skills to understand connections between climate change, forests, and people;
- recognize that individual and community actions can help mitigate and adapt to climate change; and
- become part of future community conversations about climate change and potential solutions.

Module Overview

This module is designed for educators of students in grades 9–12, both standard and advanced placement classes. All of the activities include a section describing strategies to adapt the activities to grades 6–8 or basic high school classes. Teachers of introductory biology and environmental science classes in colleges may find these activities helpful as well. The fourteen activities build on each other to create a unit that applies what we know about climate change to forest ecosystems and forest management, making this module most appropriate for teachers of life science, biology, agriculture, and environmental science. We do not include Earth science content focused on atmospheric, hydrologic, and meteorological sciences, expect for a brief introduction in **Activity 2: Clearing the Air**. Because complex societal problems weave together science, policy, and human behavior, these activities blur the boundaries between biology, environmental science, social studies, and civics courses. As a result, teachers of government, economics, math, and language arts classes may enjoy using some of these activities too. The module website includes a subject correlations chart that may help educators choose appropriate activities for their courses (http://sfrc.ufl.edu/extension/ee/climate/wp-content/uploads/Subjects.pdf).

To help educators address curriculum and content standards, the website also includes correlations for the Next Generation Science Standards (http://sfrc.ufl.edu/extension/ee/climate/wp-content/uploads/NGSS.pdf) and the PLT Conceptual Framework (http://sfrc.ufl.edu/extension/ee/climate/wp-content/uploads/PLT_Concepts.pdf). 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.

Several learning theories and a variety of teaching strategies form the basis of these activities to help educators actively engage students in learning about a controversial, social, and scientific issue. We provide activities that help students gain scientific literacy, understand the nature of science, and apply this to climate change scenarios (Zilder et al., 2005). Our partnership with researchers enables us to design activities that use datasets and models that duplicate the ongoing work to understand climate change and forest management options. Videos on the module website (http://sfrc.ufl.edu/extension/ee/climate) allow students to hear from these PINEMAP researchers and may spark interesting discussions about career opportunities in science and forest management. The process of resolving climate change does not have a single correct solution, and will likely require that people use skills of systems thinking, critical thinking, and group process as they work together. Many of the following activities follow a problem-based learning approach with small group exercises designed to elicit skills in collaboration and higher order thinking (Barrows & Kelson, 1995). Each activity is designed to guide learners through an experience and reflection cycle where they process, generalize, and apply the key concepts (Kolb, 1984).

The fourteen activities are organized by themes into five sections. The first activity in each section introduces basic concepts; subsequent activities extend and apply those concepts. The first section introduces climate science and climate change, why people might disagree about the scientific evidence, and how climate models can be used to project impacts to forests. The second section focuses on strategies that scientists and forest landowners are using to understand and adapt to an uncertain climate future. The third section introduces the strategy of carbon sequestration as one tool forest managers can use to mitigate climate change. The fourth section offers a different strategy by teaching students about life cycle assessment, which is a tool that consumers can use to select products that reduce atmospheric carbon dioxide. The final section of the module includes three activities that help summarize the themes of the module and connect ideas about carbon sequestration from Section 3 to life cycle assessment from Section 4.

Each section contains an overview to provide background information common to those activities. Based on literature and the module pilot test, we also provide a list of concepts that are likely to be student misconceptions or may generate confusion (National Research Council, 2005). This information will help educators prepare for the types of questions their students may or may not ask and address them appropriately.

Depending on the amount of available time, teachers may choose the activities in one section to supplement an important concept in their course curriculum, or they may select activities from each section to provide a reasonable overview of the module concepts. Whether additional activities are needed to introduce a concept is a function of the subject area, curriculum, and student age; therefore, individual teachers must use their discretion in making choices. In the Activity Overview, we suggest related activities in this module that are reasonable to consider using before and after each activity.

Videos on the module website allow students to hear from PINEMAP researchers about ongoing studies to understand climate change and forest management.

How to Use This Module

First, select a theme, a section, or an activity that you wish to use in your classroom. We recommend reading the relevant section overview before reading the activities to help set the stage and obtain background information that

Section	Theme	Activity
1. Climate Change and Forests	Three activities introduce the module theme by conveying how scientists currently understand observed changes in weather and climate that are impacting forest ecosystems.	**1. Stepping through Climate Science** – Students walk along a timeline of climate science and policy initiatives and then explore connections between forests and climate. **2. Clearing the Air** – After an introduction to the evidence of climate change, students explore common confusions and role-play a community discussion with the goal to reach consensus on strategies to reduce greenhouse gas emissions. **3. Atlas of Change** – Students are introduced to climate modeling to understand past changes and project future possibilities, and then use Web resources to consider how forest ecosystems might change over the next 100 years.
2. Forest Management and Adaptation	Climate changes are projected to affect surface temperature, precipitation patterns, and frequency of storm events. As scientists study how forests might change as a result, forest managers can be encouraged to alter management practices to help create resilient forests that will survive these challenges.	**4. The Changing Forests** – Students review how scientists are monitoring forest changes and exploring adaptive strategies to keep forests healthy. **5. Managing Forests for Change** – Students develop and use a systems diagram to model a forest so they can advise a forest landowner how to manage a pine plantation in light of climate projections. **6. Mapping Seed Sources** – Across the native range of loblolly pine, variations in genotype create trees that may do better under new climatic conditions. This activity helps students analyze data from three trials to determine the origin of the seeds.
3. Carbon Sequestration	Sequestering carbon in trees, soil, and wood products keeps it out of the atmosphere. Scientists are exploring if we can sequester more carbon in these carbon pools.	**7. Carbon on the Move** – Students become familiar with the carbon cycle and pathways that increase and decrease atmospheric carbon. **8. Counting Carbon** – Students measure trees near their schools and calculate the amount of carbon stored in individual trees. Students then compare the carbon sequestration potential for land-use types in their state, compare this to the estimated amount of carbon released by human activities, and discuss forests' ability to sequester atmospheric carbon.
4. Life Cycle Assessment	Consumer choices can play a role in reducing and preventing greenhouse gas emissions. These activities introduce the concept of externalities to consider the environmental problems that can occur from the production, shipping, and disposal of various products. Greenhouse gas emissions are one of the many criteria that students can use to assess products as they develop their own personal code for deciding what to purchase.	**9. The Real Cost** – Through a simulated shopping activity, students learn about the impact, or externalities, of consumer choices on the environment. **10. Adventures in Life Cycle Assessment** – Students investigate life cycle assessment data for three types of outdoor dining furniture to determine which type would generate the lowest amount of greenhouse gases. This detailed analysis of inputs and outputs is another tool for systems thinking. **11. Life Cycle Assessment Debate** – Students debate four pairs of similar products to develop their own sets of questions about product life cycles that can help guide consumer choices.
5. Solutions for Change	Three activities that help teachers summarize the concepts in this module. These can be adapted to reflect the activities that teachers selected. Students can be empowered with the knowledge and hope that all of us can help work toward healthy, sustainable forests and communities.	**12. The Carbon Puzzle** – Students use a series of facts to realize how forest plantations, wood products, and wood substitution can reduce atmospheric carbon, and then interpret a graph published by the researchers who explored this concept. **13. Future of Our Forests** – Student teams review information from the module and share their knowledge with an appropriate audience. **14. Starting a Climate Service-Learning Project** – Students select and complete an action project to mitigate climate change or help their communities adapt to projected changes.

is common to activities in that section. Consider what your students already know about this topic and consult the activity webpage to explore the additional information, videos, and systems thinking exercises.

Each activity contains the following sections:

- **Activity Overview.** Brief activity description, objectives, assessment suggestions including a student writing prompt, related subjects, skills that are practiced, materials that are needed, estimated time, connections to current scientific research, and related module activities.
- **Background.** Information about the activity topic for the teacher, with bolded and italicized words defined in the glossary.
- **Systems Thinking Connection.** Ideas for emphasizing and applying systems thinking skills.
- **Teaching This Content.** Key ideas and tips to help teachers succeed with these particular teaching strategies and content.
- **Getting Ready.** Suggestions for preparing to lead the activity.
- **Doing the Activity.** Step-by-step suggestions for how to conduct the activity, with appropriate, italicized answers to discussion questions.
- **Modifications.** Suggestions for how to modify an activity for middle school or basic science classes.
- **Enrichment.** Suggestions of ways to extend the activity.
- **Additional Resources.** Websites, readings, and reports for both teachers and students that relate to this topic.
- **References Cited.** Citations for referenced information in the background or student pages.
- **Student Pages.** Handouts and worksheets for students.
- **Teacher Comments.** Tips and suggestions from other teachers who have used this activity.

In addition, activity webpages contain the following items:

- A recorded "tour" to introduce teachers to the activity and tips for using the activity in the classroom.
- A short online quiz for teachers that covers the content in the activity and includes explanations and pointers to additional resources.
- Videos that introduce concepts or explain how researchers are exploring important questions related to this topic.
- Supplemental support for teachers on certain topics or strategies, such as graphing or creating informative posters.
- Supplemental activity materials, such as signs or cards.
- Slide presentations with teacher notes that can be adapted and used with students to explain concepts.
- Student pages in an easy-to-modify format.
- Answer keys for student pages.
- Bank of multiple-choice assessment items.

The Development Process

Several sources informed the development of this module, and additional input from content reviewers and pilot-test educators improved it. We began with a review of the existing literature and curriculum that addresses climate change education and discovered a range of informative materials. The framework of the PINEMAP project helped us develop the structure for the module, and access to the expertise of the PINEMAP researchers enabled us to generate interesting, current, and meaningful activities related to their research. The following sources were also utilized in the initial development process:

- Wise's (2010) findings from a survey of Colorado science teachers about climate change instruction
- National Center on Science Education (NCSE) Climate Change Education website (http://ncse.com/climate)

Each activity webpage contains **Teacher Tools**, which include a tour of the activity, a short online quiz, and videos to provide extra background information.

More than 175 people helped with the module development through writing and reviewing activities, or participating in the advisory committee, expert content review, pilot test, or summative evaluation.

- Climate Literacy and Energy Awareness Network (CLEAN) website (http://cleanet.org)
- Global Learning and Observation to Benefit the Environment (GLOBE) website (http://www.globe.gov)

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 how students can become engaged in this issue (Monroe, Oxarart, & Plate, 2013). 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 North American Association for Environmental Education (NAAEE) and EECapacity Climate Change Education Professional Learning Community for 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's Center for Precollegiate Education and Training to determine which version might be more effective. We also tested several activities with teachers at the Climate Change Symposium organized at the University of Florida in May 2013. All of these resources helped us assemble a draft module that was reviewed by 33 forestry, climate, and education experts in spring 2013.

The revised module was used in a pilot test with more than 40 teachers in the Southeast in fall 2013. Their experiences with using the activities helped us revise the materials with clarifying explanations and examples. Their observations are sprinkled throughout the activities and on the website to provide insight that may help other teachers use these materials. We specifically asked middle school teachers to provide suggestions for younger students, and their ideas have been added to each activity in the Modifications section. From the pilot test, we learned that the activities effectively engage students in exploring and discussing issues of interest, that teachers and students can use these activities successfully, and that students improve their knowledge of climate and forests.

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

Addressing Climate in the Classroom

Public opinion polls suggest that Americans 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 that all of these varying opinions should be framed in the classroom as a "scientific controversy" (McCaffrey, 2012). Although there are scientific uncertainties associated with climate change, there are not competing *scientific views* on the basic fundamentals of climate change. The controversies lie in how to apply these findings to our society, which policies to implement, and what investments to make. This module rests on the scientific conclusions that recent observations of changes in our global climate are influenced, in large part, by human activity (IPCC, 2013).

In a survey that was conducted to learn more about how to frame this module for southeastern secondary science teachers (Monroe, Oxarart, & Plate, 2013), we learned that many teachers use the topic of climate change to teach students about the nature of science. The process of making observations, forming hypotheses, collecting data, and searching for patterns and explanations is going on right

now around the world. The researchers working with PINEMAP are conducting projects that answer questions about the impact of climate changes on southeastern forests: How does drought change sap flow in pine trees? How do forests respond to less frequent precipitation? What incentives will help landowners make suggested changes? Which trees have the genetic traits to thrive in future climates? This module provides opportunities for students to understand how scientists approach this complex topic (Activities 3, 4, 6) and to understand the implications of their data (Activities 5, 8, 12, 13).

In Activity 2, we focus on helping 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. While this activity helps students understand why people hold different ideas about climate change, it does not provide guidelines for changing those opinions. If the students (or their parents) present alternate ideas in your classroom, it may be helpful to have a careful, deliberate discussion about what lies at the root of those ideas. For some, there may be concepts that you can help clarify. For others, there may be deeply held values or attitudes that suggest that the climate change is not caused by human activities. Such a position does not negate the importance of planning for how to cope with projected changes; so you might focus your discussion on adaptation strategies, such as creating healthy, resilient forests through forest management strategies.

A focus on science, the nature of science, and the interpretation of data tends to be comfortable for science teachers and will be less likely to result in classroom conflict. It is in the implication of these findings where disagreement occurs, as well it should. Policymakers must understand the science and then balance economic tradeoffs, culture, ethics, and preferences. Activities 9 and 11 give students a chance to experience that balance in a relevant context, for example, by considering what type of shirt to buy. How much does the environmental impact matter? What else matters? What questions should they ask before purchasing something? What else do they need to know? These activities allow students to assess and compare information and to explore the values that they use to guide their consumer decision making. And this process mirrors what decision makers must do every day.

ANNIE OXARART, UNIVERSITY OF FLORIDA

This module provides opportunities for students to learn how scientists are studying topics related to forests and climate change.

Some educators hesitate to embark on the topic of climate change because it is so complex and current that it is a challenge to be able to answer students' questions. While we have provided explanations and slide presentations to cover the most obvious points, perhaps the better strategy is to ask students

This module can assist you in helping students understand the following:

- Why a variety of perspectives of climate change exist.
- How to build consensus with people who represent a variety of perspectives.
- How to explore underlying beliefs and address missing information.
- How to respect differences of opinion.
- How to find common ground of agreement.
- The scientific evidence for climate change.
- Potential impacts of climate change on ecosystems.
- The limitations and purpose of climate models and projections.
- The nature of science.
- How data are analyzed and used for inferences.
- Why policy recommendations can be sources of controversy.
- Where to find accurate answers to questions about climate change.

to find the answers to their questions! We have provided links to additional resources on the Internet in each activity. Of course, new information and research findings will be available every year so helping students find and assess the most current information is an important skill to teach too.

Climate change is a complicated environmental issue. There are deep political and religious divides across the nation and at the same time nearly unanimous agreement among climatologists. We believe this module makes an important contribution to science education in the Southeast by providing activities based on current scientific research. The most important action that educators can take is to help students build the knowledge and skills to have reasoned conversations about climate change in their communities. We are not likely to ever have all the answers, but we all need to be able to understand and discuss the risks, tradeoffs, and potential impacts of our actions.

References Cited

Barrows, H. S., & Kelson, A. C. (1995). *Problem-based learning in secondary education and the problem-based learning institute* (Monograph 1). Springfield, IL: Problem-Based Learning Institute.

Intergovernmental Panel on Climate Change (IPCC). (2013). *Climate change 2013: The physical science basis. Contribution of working group I to the fifth assessment report of the Intergovernmental Panel on Climate Change*. [Stocker, T. F., D. Qin, G. K. Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex & P.M. Midgley (Eds.)]. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

Jose, S. (2007, May). *Carbon sequestration and intensive silviculture: The southern US experience.* Paper presented at the Fall Meeting of the American Geophysical Union, Abstract #B53A-03. Retrieved from http://adsabs.harvard.edu/abs/2006AGUSM.B53A..03J

Kolb, D. (1984). *Experiential learning as the science of learning and development.* Englewood Cliffs, NJ: Prentice Hall.

McCaffrey, M. (2012). Teaching controversy. *The Earth Scientist 28*(3), 25–29. Retrieved from http://www.nestanet.org/cms/sites/default/files/journal/Fall12.pdf

Monroe, M. C., Oxarart, A. & Plate, R. (2013). A role for environmental education in climate change for secondary science educators. *Applied Environmental Education and Communication, 12*(1), 4–18.

National Research Council. (2005). How students learn: Science in the classroom. Committee on How People Learn, A Targeted Report for Teachers. [Donovan, M. S. & Bransford, J. D. (Eds.)]. Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

UNESCO. (1978). *Final report: Intergovernmental conference on environmental education*. United Nations Educational, Scientific, and Cultural Organization with United Nations Environment Programme in Tbilisi, Georgia, USSR, 14–26 October 1977. Paris: UNESCOED/MD/49. Retrieved from http://unesdoc.unesco.org/images/0003/000327/032763eo.pdf

U.S. Environmental Protection Agency. (1997, August 22). Solicitation notice, environmental education grants program, fiscal year, 1998. *Federal Register 62*(163), 44860. Retrieved from http://www.gpo.gov/fdsys/pkg/FR-1997-08-22/pdf/97-22365.pdf

Wear, D. N., & Greis, J. G., eds. (2012). *The Southern Forest Futures Project: Summary report.* (General Technical Report SRS–168). Asheville, NC: USDA Forest Service.

Wise, S. B. (2010). Climate change in the classroom: Patterns, motivations, and barriers to instruction among Colorado science teachers. *Journal of Geoscience Education, 58*(5), 297–309.

Zeidler, D. L., Sadler, T. D. Simmons, M. L. & Howes, E. V. (2005). Beyond STS: A research-based framework for socioscientific issues education. *Science Education, 89*(3), 357–377.