ACTIVITY 5

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 draw these connections in a systems diagram, a tool that helps them see the system.

Subjects
Agriculture, Biology, Environmental Science

Skills
Determining Cause and Effect, Diagramming Systems, Identifying Relationships and Patterns, Predicting

Materials
Student pages, answer keys, and presentations (see Activity Webpage link below). Optional: colored pens or markers, large pieces of paper, yarn, tape

Time Considerations
Two to three 50-minute periods

Related Activities
Students should have an understanding of climate change (Activity 2) and the relationship between forests and climate (Activities 1 and 3). This activity can be followed with additional activities that show how forest managers can address climate change (Activities 4, 6, or 8).

Research Connection
Forestry research in the Southeast explores strategies that can create profit from resilient forest plantations. The management strategies included in this activity are based on research findings from comparison plots across the Southeast. Family landowners may have additional management objectives for their property, such as wildlife habitat and a legacy for their family.

Activity Webpage
Find online materials for this activity at https://sfcc.plt.org/section2/activity5

Objectives

By the end of this activity, students will be able to

- explain how forest managers can manage forest plantations to thrive in a changing climate,
- create a systems diagram to explain forest health and productivity, and
- predict how changes in climatic conditions and management strategies might affect forest health and productivity.

Assessment

- Use students' answers on the student page 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

Good ***forest management*** practices are important to ensure the health and stability of forests. To achieve a landowner's objectives, ***foresters*** develop management plans that detail the practices and activities they will apply to the forested land. These activities may include replanting practices, ***species selection***, tree ***harvesting*** and ***thinning*** schedules, fertilizer applications, steps to enhance wildlife ***habitat*** or ***biodiversity***, actions to protect water quality, strategies to protect trees from insect pests and disease, and ***vegetation*** management to reduce ***wildfire*** risk and competition with the trees. Most of the forests in the Southeast are privately owned and many are managed for ***timber*** or pulp production.

The management activities described in this activity are based on techniques that are commonly used by forest landowners who wish to harvest trees for income. Most of these strategies also can be used in ***naturally regenerated forests*** that are managed for biological diversity and recreation.

Additional background information can be found in the **Section 2 Overview** and in **Activity 4**.

Forests as a System

When thinking about the forest as a ***system***, it is easy to see why management strategies might be needed to maximize the landowner's objectives. This activity begins by helping students generate a systems diagram of a forest. Specifically, students create a ***causal loop diagram***, which is a tool to visualize and better understand the cause-effect relationships between parts of a system. The presentation, Building a Forest Systems Diagram, is available on the activity webpage to help you teach this important skill. The teacher notes in the presentation include a script that will guide you and your students through this process. In this diagram, tree growth is the landowner's objective, so that is at the top. The diagram includes several variables the landowner can manage to affect tree growth.

Systems diagrams are useful for picturing how different aspects of a system, such as a forest, are connected through cause-effect relationships. John Muir famously said, "When we try to pick out anything by itself, we find it hitched to

LARRY KORHNAK, UNIVERSITY OF FLORIDA

Many pine forests in Southeast, such as this loblolly pine plantation, are managed to produce wood products such as paper and timber.

everything else in the Universe." Of course, he didn't necessarily mean that everything is *directly* linked to everything else. He was referring the web of relationships in which things are connected indirectly to each other. These indirect connections matter a great deal in the behavior of an ***ecosystem***.

In this activity, students learn how to create and use a simple systems diagram to track the cause-effect relationships in a forest and predict how that system would likely change in the face of environmental changes and management measures. They learn how changes can ripple through a system through indirect connections in the web of cause-effect relationships. When decisions are made without considering the web of relationships, we may fail to anticipate the undesirable side effects of our actions. A forest system can include many more variables and relationships than we have used here. We have included the key elements for this activity.

In addition, students are introduced to the concept of feedback loops. In teaching, we use feedback to direct student behavior. If a student behaves in a desirable way (completing homework), we reward that behavior in hopes of fostering continued efforts in that direction. Conversely, if a student behaves in an undesirable way (skipping class), we take measures to change that behavior.

We can see a similar pattern in complex systems when two or more parts of a system are connected to each other so that a change in one variable ripples through the system and comes back to affect that variable. There are two different types of feedback loops. ***Reinforcing feedback loops*** (also called positive feedback loops) can turn small changes into larger changes. Fads are an example of a reinforcing feedback loop. When a television show or a product becomes popular with a few people, other people hear about it and become interested. As this larger group experiences the show or product, even more people hear about it, so it becomes even more popular. As more people watch the show and talk about it, more people watch the show. This is what happens when a YouTube video goes viral (figure 1). A reinforcing or positive feedback loop (called positive even when the outcome is not good) that causes rapid change in an undesirable direction is referred to as a vicious cycle. For example, in the vicious cycle of poverty and environmental degradation, an increase in one causes an increase in the other, which loops back and amplifies the first change. This cycle continues until the situation spirals out of control. Of course, this same feedback loop could reinforce continuing *decreases* in poverty and environmental degradation. Part of being a systems thinker is looking for ways to use reinforcing feedback loops to create desirable change.

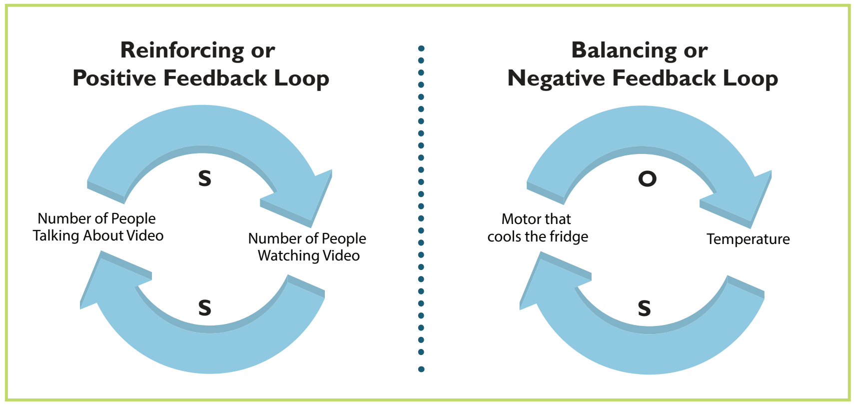


Figure 1. Systems can have reinforcing (or positive) feedback loops, where the cause-effect sequence tends to amplify change (left). Systems can also have balancing (or negative) feedback loops, where the cause-effect sequence tends to resist change (right).

Systems also have ***balancing feedback loops*** (also called negative feedback loops)—the most common example is the thermostat in your refrigerator. If the temperature in the fridge gets too warm, the motor comes on to cool things off. Once the fridge has cooled to the desired temperature, the motor turns off. In other words, any major change in the system evokes a response to reverse that change. Populations are often balanced by constraints in food supply. In our forest systems diagram, there is an example of a balancing (or negative) feedback loop as tree growth affects competition for water and nutrients. The terminology positive and negative does not refer to beneficial or detrimental outcomes, but to the way that positive feedback reinforces or compounds an action and to the way that negative feedback balances or maintains a system.

In this systems diagramming activity, in addition to placing the arrows and understanding the relationships, students will label the arrows to indicate how a change in one variable affects the variable on the receiving end of the arrow. The presentation, Building a Forest Systems Diagram, provides examples and explanation for helping students add an S when the two variables change in the SAME direction and an O when the change is in OPPOSITE direction. (AP Environmental Science teachers may prefer to use a + for the same direction and a - for opposite. An odd number of minus signs in a loop will indicate a negative feedback loop.)

Climate Change Impacts

In many areas of the Southeast, it is increasingly important for forest managers to consider ***climate change*** when choosing management strategies, as variations in ***climate*** will likely affect pine forest ***productivity*** and ***forest health*** over the life cycle of the trees. The importance of these management activities can be seen in the forest system diagram 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 ***plant and animal*** migration. ***Precipitation*** patterns may 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 unusually strong storm events. When large storms produce torrential rain, much of the water runs into surface drainage areas rather than filtering into the ground. Impacts on southeastern pine forests will vary. For those places that experience warm and moist conditions, growing seasons could become longer, which could increase tree productivity. Alternatively, prolonged droughts could stress trees, decrease productivity, and impact tree survival. For a good introduction to visualizations of climate models, see **Activity 3: Atlas of Change.**

Increased atmospheric carbon dioxide (a cause of climate change rather than an impact) may also influence tree growth. Most experiments show that trees initially grow faster when the atmosphere has higher levels of carbon dioxide. At some point, this increase slows or disappears as growth becomes limited by other factors such as reduced soil nutrients or water availability.

Additional factors influenced by climate change, such as soil moisture, wildfire, insects, and diseases, also impact pine forests. Changes in precipitation and temperature influence ***evaporation*** and ***groundwater*** levels, both of which affect the amount of water stored in soils and trees. Longer periods of hot, dry

DAVID GODWIN, SOUTHERN FIRE EXCHANGE

Prescribed fire is used in southeastern forests to reduce wildfire risk and to maintain or restore fire-dependent ecosystems.

conditions could increase the frequency and severity of wildfires. Increased temperature across the region and a greater increase in hurricanes could also enable forest insects, such as bark beetles, to expand their range. When the population of these insects peaks, they can be enormously destructive, especially when trees are stressed by drought, overstocking, or extreme ***weather*** events. ***Invasive species*** from tropical areas are also likely to increase their ranges. Climate conditions, tree growth, and forest stressors are interrelated. For example, reduced summer precipitation and increased temperature during the growing season lead to increased moisture stress, as less water is available for the trees. This in turn could reduce growth rates and increase the risk of disturbance by fire, insects, and disease. Conversely, increased precipitation could decrease competition for water and increase tree growth. Of course, if precipitation remained high, flooding could occur, which would reduce tree growth. The Suggested Solution Diagrams presentation found online shows how to discuss these possibilities in the context of the systems diagrams.

Forest Management

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***, many 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 to meet the new conditions. ***Adaptation*** to climate change includes actions taken by humans to avoid, benefit from, deal with actual, or plan for expected climate change impacts. These include some management options that may enhance the ability of forests to adapt to climate change such as the following:

- **Thin crowded forests:** As trees grow, forests can become increasingly crowded and competition between trees can become intense. While overcrowding often happens in naturally regenerated forests, tree seedlings in a ***plantation*** forest are usually planted at a high density to ensure that trees grow straight with fewer branches. Once the trees reach a certain size, they begin competing for resources such as light, water, and nutrients. When these factors are limited, the trees can become stressed, making them more susceptible to disease and insect attack. In addition, overcrowded forests are more susceptible to mortality from wildfire. Removing some trees from the forest reduces tree stress and enhances the growth of the remaining trees. It also decreases the risk of wildfire, insect attack, and disease. Even though removing trees from a forest sounds like it will reduce income to the landowner, in most cases the remaining trees will be larger and will sell for more money than the smaller trees from an unthinned forest.
- **Promote genetic diversity:** Forests with some variation in genetic diversity (different species or different ***families*** of a single species) may be better able to withstand uncertain environmental changes than forests with little genetic diversity because they might be more resilient. Species and families differ in their ability to grow under different climate conditions. For example, longleaf

Systems Thinking Connection

THROUGH THIS ACTIVITY, students see that cause-effect relationships in a forest look something like a web. This weblike structure is typical in complex systems as are the feedback loops described in the background section of this activity. Feedback loops play a large role in the stability (and instability) of complex systems. Indeed, the enormous web of cause-effect relationships and the prevalence of numerous feedback loops are the major reasons why making precise predictions about climate behavior is so difficult. Two additional Systems Enrichment Exercises help students practice making systems diagrams.

(*Pinus palustris*), sand (*P. clausa*), and shortleaf (*P. echinata*) pines are more drought tolerant than loblolly (*P. taeda*) and slash (*P. elliottii*). Even within a species, some trees are better able to tolerate certain environments than others. Planting a variety of improved genotypes may enable some trees to thrive even in great uncertainty about climatic conditions. See **Activity 6: Mapping Seed Sources** for more information on genetic diversity within a species.

- **Use prescribed fire:** Many southeastern forest ecosystems are adapted to the periodic, low-intensity fires that historically have occurred naturally. Without periodic fire in the ecosystem, the forest ***understory*** can become filled with fast-growing vegetation and dead organic matter. Over time, the absence of fire changes the makeup 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 conduct ***prescribed fires*** in natural areas under appropriate weather and safety conditions.
- **Using improved fertilizers:** Many pine plantations grow on nutrient-poor sandy soil. If forest landowners are able to supplement soil nutrients with fertilizer once or twice during the life span of their trees (roughly every 8–10 years), the trees grow faster and sequester more carbon. Maintaining vigorous growth of the trees can make them less susceptible to insect attacks and drought. Researchers are developing specialized fertilizer that is taken up by trees more efficiently, allowing foresters to apply less fertilizer to get similar increases in growth.

Teaching This Content

This activity engages students in systems thinking. If you have not been using the Systems Enrichment Exercises, you may wish to use the **Dynamic Systems Dance** exercise on the Activity 1 webpage to help explain the concept of a system. Being able to draw a system by identifying components and their relationships may be a new skill, and it is a helpful step to understanding and thinking about systems. Pilot testers who were unfamiliar with this concept found that reviewing the slide presentations and slowly explaining the relationships helped their students better draw diagrams and understand them. The Suggested Solution Diagrams presentation is available if you wish to work through one example with students.

Some students may think that forests will die because of climate change, particularly if a recent drought or wildfire has occurred nearby. Such severe and direct impacts are not typical, though they might occur in some places. It is more likely that trees will be stressed and vulnerable during one season. During the period of drought, for instance, trees may not grow much and may be susceptible to other stressors, but they are not likely to die in one year. In this way forests are more resilient than corn and other crops. However, long term drought and other stressors have the ability to weaken trees to the point where beetles or disease could kill them.

TEACHERS SAY ...

My students (and I) were unfamiliar with the modeling activity, but, after slow, careful explanation, they were able to understand and process the information.

—AP Environmental Science Teacher, Florida

Getting Ready

The Activity 5 webpage provides **Teacher Tools** that you can use to become more familiar with this activity's background and procedure (https://sfcc.plt.org/ section2/activity5).

A background in local forest management practices will help students with this exercise. You can use the Introduction to Southeastern Forests presentation on the Activity 5 webpage to introduce students to this topic. In addition to the background and resources provided here, a guest speaker from your state forest or Extension agency could help explain the management terms and answer questions about nearby forests.

Download the Building a Forest Systems Diagram presentation from the Activity 5 webpage and review it to determine how you wish to present the information to students. Even if students have experience making causal loop diagrams, this activity will be more successful if all students use the same framework for understanding the system's variables and relationship, which is the system they will create using the Forest Diagram student page.

Make copies of the Forest Diagram student page so students can add the arrows as you explain the system. It is possible, of course, to design many forest systems diagrams with many relationships; this abbreviated version helps students consider climate impacts and management options. The video on the activity webpage provides a brief explanation of systems by Dr. Richard Plate.

Decide whether you will have students watch the Private Family Landowner video or read the student page, which has been adapted from the video. Make copies if necessary. Make a copy of the Management Cards for each group.

Review the Suggested Solution Diagrams presentation to decide which climate scenarios to give students and how to discuss their responses. The presentation provides potential answers that students may generate as they add variables and relationships to their diagrams in Part B of the activity. Then copy and cut apart the Climate Scenario Cards you chose and give one or two to each group.

Doing the Activity

Part A: Visualizing the Forest Connections

1. Begin the activity by asking students to describe nearby forests that are harvested for wood products. These are likely privately owned forests (either by individuals or corporations) and in many areas of the Southeast are probably pine plantations. In this activity, your students will provide advice to Doug Moore, the landowner featured in the video and student page, who is wondering how to best manage his forest for future climate conditions. Introduce Mr. Moore and his forest with either the video or student page to help students visualize his forest.

2. Explain that a systems diagram of a forest helps people see the connections and relationships in a forest ecosystem, and through those relationships, predict how changes could affect the forest. This is an important strategy for providing Mr. Moore with good advice. Students need to see the whole forest (and its ecosystem) not just the trees! Distribute the Forest Systems Diagram student page and ask students to follow along with your presentation of Building a Forest Systems Diagram by adding the arrows and S for SAME or O for OPPOSITE to designate the relationships between variables that you introduce. You may wish to demonstrate the first few relationships and then call on students to explain the next relationship or set of relationships (both options are available in the presentation). This may be helpful in conveying the relationships: "When forest density is *increased*, competition is *increased*, and nutrient availability is *decreased* (O), which *increases* stress (O) and *reduces* tree growth (O). If forest density is *reduced*, competition is less severe, so trees obtain more nutrients

TEACHERS SAY ...

I had the most response and most active learning in my classroom with this two-day activity. The conversations in the groups the second day when we added the management squares to the forest systems model were engaging and lively. The discussions about climate change for the forest landowner went well.

—Biology Teacher, Florida

(O), are less stressed (O), and grow more." If students use the diagram with one initial condition (forest density is increasing) to insert the symbols, they can check their symbols with the opposite condition (forest density is decreasing). The symbols should stay the same. Only some variables and connections are illustrated to emphasize the relationships that play particularly important roles in the context of this exercise. A complete diagram of this system is included in the presentation.

3. Check that the class understands how to use the diagram to track cause-effect relationships by asking them to draw an additional arrow to show how more frequent wildfires might affect understory vegetation *(An O feedback arrow between High-intensity wildfire and Understory fuel load will make this a balancing or negative feedback loop).*

Part B: Making Management Decisions

1. During the second part of the exercise, students use their basic forest systems diagram to decide how Mr. Moore could manage his forest in a future with changing climatic conditions.

2. Divide the class into small groups and give each group one or two climate scenario cards and the page of management cards. Ask them to draw, on their forest systems diagram, the additional variables listed on the cards to show how climate change might affect this forest. Then ask them to select one or two management activities and show on the diagram how these strategies could reduce those potential climate impacts. It might help for students to use different colored pens or markers when adding these variables and arrows. The Suggested Solution Diagrams presentation and teacher notes provide ideas about how to explain this task.

3. Give the groups 15 minutes to add the climate and appropriate management variables, draw the changes on their Forest Systems Diagram student page, and discuss the following questions in the group:

- How might climate change affect this forest?
  Each climate card specifies one possible change and suggests new variables that should be added.
- Which management strategies might become important to enable the forest to thrive with this possible climate change?
  Several management strategies may be helpful in response to each potential climate change (see Suggested Solution Diagrams presentation).

4. Ask each group to present one diagram, explaining the group's ideas about how the forest might be affected by change and the management strategies they chose to address these changes. The Suggested Solution Diagrams presentation includes some sample results for these scenarios; others are possible.

5. After all groups have presented, discuss the following questions as a class:

- What are some general trends for how climate change might affect forests?
  Small changes in temperature and precipitation can improve growing conditions; large changes may add stress to trees by increasing the possibility of disease and severe fires.
- Which management practices could help landowners increase forest resilience?
  Thinning forests can help keep trees from becoming stressed by competition or disease. Planting superior seedlings can improve tree growth. Maintaining genetic diversity by planting multiple families of improved seedlings can help some trees survive a variety of conditions.
- What is an example of an indirect relationship on your diagram?
  Drought indirectly affects tree growth. Rather than having an arrow that goes directly from drought to tree growth, notice that the arrow goes from drought to water availability, from water availability to tree stress, and finally from tree stress to tree growth.

TEACHERS SAY ...

The assessment was very helpful. I like hearing students explain the concepts to each other.

—Sixth Grade Science Teacher, Kentucky

TEACHERS SAY …

I needed to work more closely with the students and we did the model together. I enlarged and cut out each of the components and laminated the cards so students could place them on a larger piece of paper and draw the arrows as we completed the model together.

— Ecology Teacher, Virginia

- Your diagram helps you see the relationships in a forest at one particular time. Pretend it is ten years later and the trees are all larger. Where on your diagram would you see feedback loops indicating how the larger trees affect some of these variables?
  Water and nutrient availability will decrease.
- Under which climate scenarios might wildfire occur? What management strategies could reduce the risk of wildfire?
  Wildfire may be more likely in climate scenarios that involve drought. Both prescribed fire (if done with care) and thinning could reduce this risk.
- If increased atmospheric carbon increases tree growth, which variables on your diagram might limit tree growth? Could a forest landowner change those limiting variables?
  Water and nutrients will likely limit tree growth; nutrients could be added through fertilizer, but forest landowners do not have the capacity to irrigate their forests like a farmer might. Thinning should make more water available to remaining trees.

6. Systems Reflection: Summarize the activity by reminding students that a systems diagram is one tool for visualizing a complex system and predicting how the system might respond to change. As your students become more familiar with system modeling, they may see systems in lots of places, such as the school bus routes and school schedule, baggage handling in an airport, or dinner preparations at home. Similar to these other systems, forests will be subjected to many possible conditions and variations over time. Putting the system on paper helps to simplify it and allows students to see how the relationships can be used to attain the intended objectives.

Modifications

Teachers can simplify this activity by keeping the class together and making a large systems diagram on the chalkboard or bulletin board rather than dividing into small groups and using individual student pages. Colored yarn can be used to designate relationships.

Grouping sets of variables together may make it easier to explain the diagram.

Using only a few of the climate scenarios and working together to alter the large diagram may be a useful strategy for Part B.

Students will know from common sense that if there is less rain, trees will not grow as much, so you can ask them to check their diagrams to make sure that is conveyed. Then select a less obvious change and ask student what the diagram predicts could happen.

Review any unfamiliar forestry terms prior to beginning the activity.

Enrichment

If your students already know something about forest management, you may wish to distribute the forest diagram variables cards and ask groups to create their own diagrams (without using the Forest Diagram student page).

Ask your students to make a forest system diagram for a public forest. A description of a public land agency forest is available on the Activity 5 webpage in the optional Public Land Agency student page. This information can be supplemented with information from your state's forest agency. Instead of using tree growth as the ultimate goal for forest management, students may use forest health or biodiversity for the key variable at the top of their diagram. Students can also work through more climate scenarios. Information from Activity 3 can be used to develop climate scenarios for your region.

After working through the various scenarios in this exercise, instructors may want to make a more thorough systems diagram 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 diagram, containing many variables and a tangle of connections. While the predictive capability of such a map is limited, it may help students to understand that there are truly a multitude of connections in a 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. Alternatively, instructors may want to encourage students to focus on a limited set of variables in order to keep the systems diagrams from becoming overwhelming.

Additional Resources

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

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

Forestry Instructional Film - It's Time to Thin!
School of Forest Resources and Conservation, University of Florida
http://www.youtube.com/watch?v=dBxGxeAagtE
This short video explains the forestry practice of thinning to improve forest health, resilience, and profits on timberland.

If you wish to explore additional strategies for explaining systems, check the Sustainable Tomorrow Teacher's Guide or the Systems Thinking in Action website.

Systems Enrichment Exercises

SOME OF THE MOST IMPORTANT FEEDBACK LOOPS regarding forests and climate are not included in Activity 5 because they are occurring on a global scale rather than on the scale of a single forest. In the systems enrichment options for this activity, students can explore these broad-scale feedback loops in more detail.

In **Feedback Loops in the News** students read a *New York Times* article in which writer Justin Gillis identifies feedback loops on a global scale. After reading the article, students draw a systems diagram, showing the relationships suggested in the article, and use that article to discuss the role that feedback loops play in the behavior of the system. See the instructions on the Activity 5 webpage for more details.

In **How Earthworms Got Me into College** students read a story that exemplifies a recurring lesson in systems thinking: how seemingly small changes can turn into large changes as they ripple through an entire system. In this story the narrator learns about the broad impacts that seemingly unimportant species—earthworms—can have on an entire forest ecosystem. Students use a causal loop diagram to understand the web of cause-effect relationships in the forest ecosystem. Other links are provided for instructors who wish to pursue these examples further. See the instructions on the Activity 5 webpage for more details.

In the **PINEMAP Focus on Research** video on the Activity 5 webpage, you can learn about a study exploring the interactions between fertilization, water flow in loblolly pine trees, and reduced rainfall (manipulated by throughfall exclusion structures, shown here).

ANDY LAVINER, VIRGINIA TECH

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

Protecting Your Forest Asset: Managing Risks in Changing Times
Southern Regional Extension Forestry, 2013
http://sref.info/resources/publications/protecting-your-forest-asset
This pamphlet reviews healthy forest strategies and approaches to decrease the risks associated with projected climate change impacts.

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

Sustainable Tomorrow: A Teacher's Guidebook for Applying Systems Thinking to Environmental Education Curricula for Grades 9-12
Association of Fish and Wildlife, 2011
http://www.fishwildlife.org/files/ConEd-Sustainable-Tomorrow-Systems-Thinking-Guidebook.pdf
This guidebook provides descriptions of systems concepts and tools to help teachers in-tegrate systems thinking into their instruction.

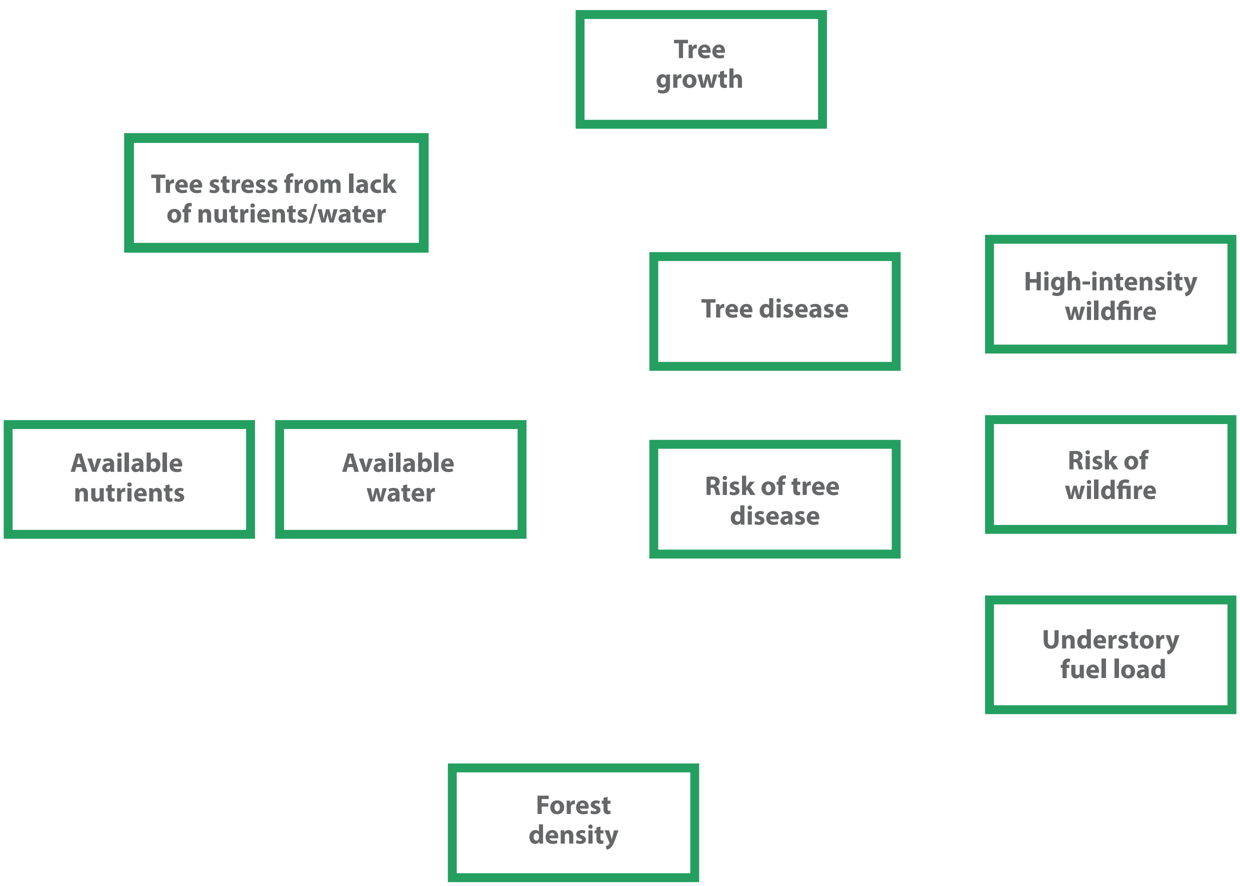
Systems Thinking Essay
The Center for Ecoliteracy
www.ecoliteracy.org/essays/systems-thinking
A short essay that describes how ecological understanding requires shifting to a new way of thinking.

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.

Forest Systems Diagram

NAME DATE

Use these variables to create a forest systems diagram by adding arrows to depict direct effects. Label the arrows with an S for SAME or an O for OPPOSITE to describe how one variable changes another. Only some variables and connections are illustrated here to emphasize relationships that play particularly important roles by influencing tree growth.



Private Family Landowner

SHELBY KRANTZ, UNIVERSITY OF FLORIDA

DOUG MOORE IS A LIFE-LONG RESIDENT OF JACKSONVILLE, Florida, and was a third generation dairy farmer until 2004. He phased out of the dairy business because of the urban development in his area. He wanted to stay in agriculture and had always wanted a big piece of timberland. There was a lot of timberland being sold by the forest companies in Baker County, and he purchased 2,400 acres in 2002.

Mr. Moore wants to balance the benefits of both forestry and wildlife on the land he purchased. He is interested in both wildlife and timber management because his family needs the timber income, and he also loves to hunt. While it would be nice to have plenty of money and manage the forest only for wildlife, the timber income allows him to pay for the property, taxes, and necessary management practices. He thinks landowners can manage for both objectives without sacrificing either one of them very much.

Landowner Doug Moore manages his forest for both timber and wildlife.

Prescribed burning is one of the most beneficial management treatments for wildlife, and it also lowers his risk for wildfires and reduces the understory competition that impacts tree growth. As a certified prescribed burn manager, Mr. Moore has established a regular burning schedule on the property.

Since he acquired the property, he has had the opportunity to harvest trees. As soon as he started cutting timber, he planted food plots to attract wildlife. In the open areas where trees were piled during the harvest, he removed the stumps and added lime to improve the soil nutrients. He used his farming background to create 40 different food plots on about 50 acres. When he replants trees, Mr. Moore uses a range of genetically diverse seedlings.

He also thins the forest, which is beneficial for wildlife and timber. He typically removes the slow growing and diseased trees and never lets the forest get too crowded or stressed. He conducts the first thinning when the trees are about 17 years old. In addition, three to four years later, he comes back and takes out trees that he can sell for pulpwood. He cuts the forest back from 400 trees per acre to about 250 trees per acre. This allows the remaining trees to grow larger and produce more timber. Simultaneously, he does some additional burning, which benefits the wildlife.

Thanks to Doug Moore, landowner, for sharing this information about his forestland in Northeast Florida.

Climate Scenario Cards

Use these variables to modify your a forest systems diagram by adding arrows to depict direct effects. Label the arrows with an S for SAME or an O for OPPOSITE to describe how one variable changes another. Only some variables and connections are illustrated in the Forest Systems Diagram to emphasize relationships that play particularly important roles in influencing pine tree growth.

	Climate Scenarios	Variables for Your Forest Systems Diagram
1	Increased carbon dioxide in the atmosphere enables Mr. Moore's trees to grow faster until other factors limit growth. What should Mr. Moore do to adjust to this change?	CARBON DIOXIDE
2	A decrease in summer rainfall has reduced the amount of groundwater available for the trees in Mr. Moore's forest. How should he respond?	PRECIPITATION; GROUNDWATER
3	Less rain has fallen recently, but the understory of Mr. Moore's forest is thick and tall. What should Mr. Moore do?	PRECIPITATION
4	Increased temperatures have resulted in a longer growing season with high precipitation. How should Mr. Moore respond to these changes?	PRECIPITATION; TEMPERATURE; LENGTH OF GROWING SEASON
5	There have been more severe storms. These storms have damaged trees in Mr. Moore's forest, and the weakened trees could attract pests that carry disease.	SEVERE STORMS
6	Mr. Moore has been observing warmer winter temperatures this year, which have caused an increase in tree fungi that cause disease. How are these changes likely to impact the forest? What should Mr. Moore do?	TEMPERATURE; FUNGI
7	Rapid changes to climate patterns have caused increased uncertainty regarding the amount of precipitation each year. What can Mr. Moore do to adjust to this increased uncertainty?	PRECIPITATION; GROUNDWATER

Management Cards

Use these variables to modify your a forest systems diagram by adding arrows to depict direct effects. Label the arrows with an S for SAME or an O for OPPOSITE to describe how one variable changes another. Only some variables and connections are illustrated in the Forest Systems Diagram to emphasize relationships that play particularly important roles in influencing pine tree growth.

THINNING helps reduce competition between trees and promotes growth of the remaining trees by increasing the light and nutrients they receive. Thinning can also increase the amount of water that each tree obtains. As a result, reducing forest density reduces the risk of insects, disease, and wildfires. Properly managing forest density through thinning is critical for maintaining the health of our forests.	THINNING
PRESCRIBED FIRE is an important tool to reduce fuels and the risk of wildfire, reduce invasive plants and insects, improve wildlife habitat, and maintain native forest ecosystem health. However, changes in temperature, precipitation, and storm events may reduce opportunities to use prescribed fire safely. Wildfire risk increases with elevated summer temperatures and reduced rainfall during the growing season.	PRESCRIBED FIRE
INCREASING GENETIC DIVERSITY by planting seedlings from different species or different families of a single species may help forest owners prepare for uncertainty. In some situations, forests with some variation in genetic diversity may be more resilient and better able to withstand uncertain environmental changes than forests with little genetic diversity. Species and families differ in their ability to grow under different climate conditions. Species with larger geographic ranges, and therefore with the genetic potential to tolerate a wider variety of conditions, may offer less risk than species with narrowly defined ranges.	GENETIC DIVERSITY
FERTILIZING a forest once or twice in the lifetime of the trees encourages more rapid tree growth in places where nutrients such as nitrogen and phosphorus are naturally limiting in the soil. Landowners must be careful to only apply minimal amounts of fertilizer and not let it drift into streams or wetlands. Maintaining vigorous growth of the trees makes them less susceptible to insect attacks and drought. Prices of fertilizer may increase as fossil fuel prices climb, making it more costly to manage for proper tree nutrition.	APPLY FERTILIZER