Activity 5: Managing Forests for Change
Building a Forest Systems Diagram: Teacher Notes

Slide	Notes
1	In this presentation, we are going to develop a causal loop diagram (or systems diagram) to help us understand how forests behave under different environmental conditions. This presentation begins with an example of how to start developing a diagram of a system and then provides background information about forest growth. Note: The forest system presented in this activity represents one way of looking at the relationships between the variables. While we have done our best to provide accurate reasoning for our interpretation of the system, different people may "see" the system in different ways. These types of discussions are exactly what we hope the systems diagram exercise will evoke. If your students find different ways of viewing the relationship between the variables, ask them to explain and justify their ideas and alter the diagram accordingly.
2	A system is defined as a set of variables that interact with each other and with the environment.
3	You are already familiar with systems. Here are three examples. What are other examples of systems? Answers may include: digestive system, the human body, a cell, a city, a neighborhood, etc.
4	These systems all share certain characteristics. They all have parts that interact with each other and with the environment. Some of the relationships in a system seem simple and obvious, but because the system has a variety of relationships, there can also be surprises and interactions that we may miss. And they could be important.
5	It is so important to recognize and understand systems that teachers and schools are emphasizing "systems thinking" so that students get practice thinking about systems. Systems thinking helps us solve complex problems because we learn to better understand the way variables interact.
6	One way we do that is to draw a causal loop diagram of the system and the relationships between variables. That is what we are going to do today.
7	First, there are rules when making a systems diagram. To learn these rules, we'll start with something everyone is familiar with—studying and grades. We'll build a diagram to represent what we know about the relationship between studying for a test and the grade we are likely to make on that test. We are focused on that question mark–what is the impact of time spent studying on the grade that is earned? If there is no direct relationship between the amount of time studying for a test and the grade that's earned on that test, then we do not need to connect the two in our diagram. However, if you think there is a direct relationship, you will add an arrow to represent that relationship. How does a change in study time affect your grade?

	If increasing study time will increase the score we make on the test, we connect the two boxes with an S-arrow, showing that the variables represented in these two boxes increase or decrease together–they move in the SAME direction. An increase in one variable leads to an increase in the other. If we think that increasing our study time will decrease the score we earn on the test, then we can connect the boxes with an O-arrow, showing that the two variables move in OPPOSITE directions.
8	We can probably agree that, in general, studying more for a test will help you earn a higher grade on that test, so we should connect these two boxes with an S-arrow. Note that the S is written near the head of the arrow to clarify that it represents the impact of one variable on the other. Keep in mind that since this arrow signifies that the variables move in the same direction, it also implies that a decrease in study time will lead to a decrease in your grade on the test.
9	Now, let’s add another variable. This time, we are looking at the relationship between the **Amount of time watching television** and the **Amount of time studying** variables. Does the amount of time watching TV lead to an increase or decrease in time spent studying?
10	If increasing the time we spend watching TV will likely cause a decrease in the time spent studying, then we should put an O-arrow showing that those two variables will move in opposite directions. More TV time means we have less time to study and also less TV time means we have more time to study. Now we have three variables in our diagram. We can also see an indirect connection between watching television and our grade. The direct relationship is not between TV and grades, but TV affects grades through the variable of studying. Increasing time spent watching television leads to less studying, which leads to a lower grade. Or conversely, decreasing time spent watching television leads to an increase in time spent studying, which increases the grade. An important part of using these types of diagrams is being able to follow the cause/effect connections to identify the indirect connections. This is important because there might be other ways to affect studying time that just watching TV.
11	There is also the possibility of feedback in this system. What do you suppose would be the result of that higher grade? It could be that the satisfaction you get from doing well on the test feels so good that you decide to continue with the improved study habits and further increase the amount of time spent studying. We could show this in the model by adding an S-arrow from **Grade earned on a test** to **Amount of time studying.** This suggests that higher grades earned on tests will lead you to increase the amount of time you spend studying. Further, your increased study time suggests that you will also spend less time watching television. This is called a feedback loop, where our cause-effect chain closes on itself. In this case, an increase in the amount of time studying causes an increase in the grade earned on a test,

	which then causes a further increase in the amount of time studying. These types of reinforcing feedback loops are common and can play a significant role in the behavior of a system. Note to Teacher: *Students can add additional variables and arrows to the diagram, but we'll keep the explanation to a minimum for simplicity!*
12	Now let's shift our discussion to a forest. Of course, a forest is a system, and it is the focus of our activity today.
13	The decision about what variables to include in the diagram of a forest system depends on what we are trying to explore. The concepts listed here are helpful for understanding how climate change can affect forests and how forest managers can respond to those changes. At the top of the diagram is **Tree growth**, because many forest landowners want to maximize tree growth. The more trees grow, the more wood they can sell. [Note that **Tree growth** refers specifically to the growth of pine trees here, not other understory trees that need to be removed periodically.]
14	For the purpose of this activity, we will explore two factors that affect tree growth. First, there's the growth rate of each individual tree. We could measure growth in a forest by determining how much bigger each tree became over a year. But some trees might have died; and additional trees may have started to grow. So this is not the whole picture. So, to get an idea of how much tree biomass has increased in a forest over a year, we need to know both the change in the average size of the trees and the change in the number of trees. The variable **Tree growth** represents both of these aspects.
15	The variable **Forest density** refers to how many trees there are per acre. Here you can see the difference between a forest with high density and a forest with low density. When the density of a forest is high, trees compete with each other for limited resources, such as sunlight, water, and nutrients. The more trees there are in a given area, the more nutrients and water will be needed. If those factors are limited, tree growth may decline.
16	There are additional variables that affect a forest. Plants can succumb to disease much the way people do. If a plant is unable to fend off a disease, then it will likely die. High forest density can make it easier for disease to spread from one tree to another, in the same way that a simple cold can spread more quickly when people are packed in closely together, such as on an airplane.
17	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. This live and dead plant material is sometimes referred to as "fuel load" because it can become fuel for a wildfire. With enough fuel and the right weather conditions, a wildfire can reach the tree canopy and kill trees. In this mapping activity, we will call this type of wildfire a high-intensity wildfire.

18	Now let's link these variables together with S and O arrows.
19	First let's focus on the relationship between the **Risk of tree disease** and **Tree disease** variables in the middle of the diagram. If the risk of tree disease increases in a forest, perhaps due to high moisture causing additional fungal growth, what would likely happen to the amount of tree disease in the forest? [Wait for students to respond.]
20	Since an increase in the risk of tree disease would likely mean an increase in tree disease, and a decrease in the risk of tree disease would likely mean a decrease in tree disease, you should draw an S-arrow from **Risk of tree disease** to **Tree disease** showing that the risk of disease does affect disease and that the two boxes move in the same direction.
21	We can do the same test with two other boxes. Let's look at the **Understory fuel load** and **Risk of wildfire** variables. Remember that the fuel load is the amount of plant matter like shrubs and dead branches on the floor of a forest. How would an increase in fuel load affect the risk of wildfire? [Wait for response from students.]
22	Since an increase in fuel load would increase the risk of wildfire and a decrease in fuel load would decrease the risk of wildfire, we draw an S-arrow from **Understory fuel load to Risk of wildfire**.
23	What about the variable, **High-intensity wildfire**? Just like an increased risk of tree disease increased tree disease, an increased risk of wildfire will likely mean an increase in high-intensity wildfire if the conditions are right. And that means an S-arrow.
24	From the earlier description of fuel load, you know that high amounts of fuel load can often lead to wildfire. Therefore, you might be tempted to draw an S-arrow from **Understory fuel load** to **High-intensity wildfire**. But this is not a direct relationship. It is an indirect relationship in the diagram.
25	An increase in fuel load will not increase wildfire directly. The increased fuel load just means that if a fire does start and the weather conditions are right, a high-intensity wildfire may be more likely. This relationship is already shown in the cause/effect chain that we have here. An increase in understory fuel load increases the risk of wildfire, which likely leads to increased wildfire. By distinguishing between direct and indirect connections, we can learn to think more clearly about the system and avoid redundant arrows in our diagrams.
26	We have now identified three direct cause/effect relationships.
27	Let's focus on the **Tree growth** variable next. Remember that this box represents the combined growth of individual trees as well as the change in the number of trees in the forest. Which of the other variables we have looked at so far will directly affect tree growth? [Wait for student response.] Both tree disease and high-intensity wildfire will affect tree growth. Let's look at the effect of

	wildfire first. If wildfires increase in a forest, is tree growth going to increase or decrease? [Wait for student response.]
28	Since an increase in **High-intensity wildfire** could likely mean a decrease in **Tree growth**, the two variables move in opposite directions, which we can represent with an O-arrow How would an increase in tree disease affect tree growth? [Wait for student response.]
29	As with wildfire, an increase in tree disease will lead to the loss of trees or a decrease in tree growth. Again, we can represent this connection with an O-arrow. Let's take a moment to see how the indirect cause/effect relationships play out in what we have so far.
30	In terms of disease, we can see that if something increases the risk of disease, then it will likely increase the amount of tree disease.
31	This increase in tree disease can then cause a decrease in tree growth.
32	Also, we know that an increase in understory fuel load will increase the risk of wildfire.
33	And that increase in the risk of wildfire will likely mean an increase in high-intensity wildfire…
34	…which can decrease tree growth.
35	Now let's look at three more boxes in our diagram: **Tree stress from lack of nutrients/water**, **Available water**, and **Available nutrients**. Remember that each tree needs a certain amount of nutrients and water. If there are less nutrients and water available, trees can become stressed. We can represent these relationships by adding O-arrows to our diagram to show that decreases in available nutrients and available water will lead to an increase in tree stress.
36	Increasing tree stress can slow the growth of a tree and in severe cases can even lead to the loss of trees. Therefore, an increase in tree stress will lead to a decrease in tree growth. We can show these relationships by adding another O-arrow to our diagram. Increased tree stress also increases the risk of tree disease. We can show this relationship with an S-arrow from **Tree stress from lack of nutrients/water** to **Tree disease**.
37	Now we are ready to add the last box to our basic diagram: **Forest density**. Forest density will have a direct impact on four other variables. Can you identify those direct impacts? [Wait for student response.] Remember that we are looking only for direct connections. Once we have those, the indirect connections can be read by following the arrows. Note to Teacher: *The following four slides describe the direct connections for forest density. You can discuss them in any order you wish or in the order the students identify them.*
38	As the forest density increases, more trees are competing for the nutrients in the soil in that

	area. Therefore, less nutrients will be available for each tree. We can show this connection with an O-arrow from **Forest density** to **Available nutrients**.
39	As the forest density increases, more trees are competing for the water resources available in that area. Therefore, less water will be available for each tree. We can show this connection with an O-arrow from **Forest density** to **Available water**.
40	As the forest density increases, a fungus or disease can more easily spread from one tree to another. Therefore, as the forest density increases, the risk of disease also increases. We can show this connection with an S-arrow from **Forest density** to **Risk of tree disease**.
41	As the forest density increases, it becomes easier for fire to spread through the forest. Therefore, the risk of a damaging wildfire also increases. We can show this connection with an S-arrow from **Forest density** to **Risk of wildfire**.
42	We're almost done with our basic diagram, but we still have to add the feedback loops to the system. First, let's think about how tree growth affects the competition among the trees for water and nutrients. As trees grow, they absorb more and more water and nutrients from the soil. Eventually, that growth will significantly decrease the amount of water and nutrients available in the soil if additional water and nutrients are not added.
43	We can show this relationship by including O-arrows from **Tree growth** to **Available nutrients** and **Available water**. This suggests that an increase in tree growth may decrease the amount of nutrients and water available. Now we have a basic systems diagram of the forest system. We can use this diagram to understand how the forest responds to changes in climate and to management strategies. In this activity, you will be given a specific climate scenario. You can illustrate your scenario by adding variables and showing how they connect to the existing systems diagram.