CHICAGO BOTANIC GARDEN

Activity 3.3: Climate and Forest Ecosystem Services

Grades 10 – 12

Description: This activity ties the concepts of ecosystem services and climate change to the forest succession activity. Students will learn about carbon sequestration and brainstorm what types of trees can sequester the most carbon.

Time: One class period

Materials:
- Student journals
- "Ecosystem Services in the Forest" handout
- NASA reading

National Science Education Standards:

D2.a The Earth is a system containing essentially a fixed amount of each stable element. Each element can exist in several different chemical reservoirs. Each element on Earth moves among reservoirs in the solid earth, oceans, atmosphere, and organisms as part of geochemical cycles.

D2.b Movement of matter between reservoirs is driven by the Earth's internal and external sources of energy…Carbon, for example, occurs in carbonate rocks, in the atmosphere as CO_2, and in all organisms as complex molecules that control the chemistry of life.

AAAS Benchmarks:

5E/M1c Plants can use the food they make immediately or store it for later use.

8C/M11 By burning fuels, people are releasing large amounts of carbon dioxide into the atmosphere and transforming chemical energy into thermal energy, which spreads throughout the environment.

4C/H1 Plants on land and under water alter the Earth's atmosphere by removing carbon dioxide from it, using the carbon to make sugars and releasing oxygen. This process is responsible for the oxygen content of the air.

Guiding Questions:
- What ecosystem services do forests provide?
- What is carbon sequestration? Why is it important?
- What are the effects of climate change on forest ecosystems?

Notes: For more information about the financial estimates of ecosystem services please see: *Costanza, R., d'Arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., et al. (1997). The value of the world's ecosystem services and natural capital. Nature, 387(6630), 253-260. The article can be downloaded at: www.esd.ornl.gov/benefits_conference/nature_paper.pdf*

Part 1: Ecosystem Services in the Forest

Procedure

1. Class opener: Pass out the student handout, "Ecosystem Services in the Forest." Give students a few minutes to answer question 1 on their own.

2. Begin the class with a review of ecosystem services from Activity 1.4 (If you have not yet done activity 1.4, you may want to begin with that activity, and use this as part 2). *Ecosystem services* are ways in which healthy ecosystems benefit humans. A prior lesson divided ecosystem services into these main categories:
    - Provisioning services: food, water, and other necessities to sustain life.
    - Regulating and supporting services: things that keep our Earth systems running as they should.
    - Cultural services: spiritual, religious, and recreational uses of ecosystems.

3. Students should think back to their time in the forest, and brainstorm at least three ecosystem services performed by healthy forests. (Examples: Forest trees perform photosynthesis and provide us with oxygen (1) while taking carbon dioxide out of the air (2). Forests can provide humans with food (3) and timber (4). Forests help keep water clean and prevent soil erosion (5). Forests are peaceful places for recreation and exercise (6). See "Benefits of trees in urban areas" for more information: http://www.actrees.org/files/Research/benefits_of_trees.pdf. List student answers on the board.

    Remind students that at this point, photosynthesis is the only process that actually removes carbon dioxide from the atmosphere. Plants sequester the carbon dioxide in their tissues as they grow. Climate regulating services performed by forests are extremely important.

    Ask students: What types of trees do you think would sequester the most carbon? (You do not need to list individual species here, but do list properties of tree species that you would expect to sequester more carbon).

    This is an opinion question, and answers will vary, but in general a fast-growing tree species will sequester more carbon in a given amount of time than a slow-growing tree species.

4. Ask students: Think back to the forest succession study you performed. Which trees do you think sequester the most carbon – seedlings, saplings, or canopy trees?

    The answer to this question is somewhat complicated. Trees sequester carbon as they grow, so a canopy tree would have sequestered a large amount of carbon over the course of its lifetime, but if it is no longer growing, will not sequester much additional carbon. On the other hand, a seedling or sapling has the potential to sequester large amounts of carbon dioxide that is currently in the atmosphere.

5. Ask students: How do you think carbon that is sequestered in a forest tree can be released?

The carbon sequestered in a tree can be released when a tree is burned. This is an important opportunity to talk to your students about deforestation. When trees are cut down, they can no longer provide the climate-regulating service of carbon sequestration. In addition, if trees are burned, the carbon stored in their tissues is released back into the atmosphere as carbon dioxide, where it can once again contribute to the greenhouse effect and climate change.

6. Question six is an opinion question on "carbon-neutral" concerts and events. As an extension, students can research what goes into making an event "carbon neutral," and describe how they would plan a carbon-neutral event.

Part 2: Remote Sensing of Forest Cover, and the Effects of Climate Change on Forests

Procedure (this section can be done in class or as a homework assignment):

1. Have students answer the two pre-reading questions. You may have them discuss their predictions with a partner, or with the class as a whole.

2. Have students read the article "NASA Satellites Can See How Climate Change Affects Forests" about a NASA program that can remotely estimate forest cover. The article is included at the end of this activity guide, but can also be downloaded from: http://www.nasa.gov/centers/goddard/news/topstory/2006/forest_changes.html. You may have students practice any reading strategies you have been using in class, or have them read through the article either in class or for homework. Have them note anything interesting or confusing as they read. They can discuss what they found with a partner or with the class.

3. After students finish reading the article, have them answer the post-reading questions. In the post-reading questions, students compare this program to the forest succession field study they performed (if students did not complete this study, you may have them skip those questions, or have them answer the questions to the best of their ability). Students will also read about two possible outcomes of climate change on forests.

CHICAGO BOTANIC GARDEN

Climate and Forest Ecosystem Services

Name_______________________________ Date_____________ Class_____________

Part 1: Ecosystem Services in the Forest

1. In your own words, define *ecosystem services*:

2. Give at least three examples of ecosystem services provided by forest ecosystems:

Ecosystem service	Description
1.	
2.	
3.	

3. Forests, more than any other habitat type, provide climate-regulation services. As trees perform photosynthesis, they take up carbon dioxide from the atmosphere. As trees grow, they *sequester* the carbon for long-term storage. In fact, the climate-regulation services of an acre of deciduous forest are estimated at $220 per year. This might not seem like much, but when you recognize that there are more than 7×10^9 acres of deciduous forest in the world, this number becomes pretty large! (Costanza et al. 1997). What types of trees do you think would sequester the most carbon? *(You do not need to list individual species here, but do list properties of tree species that you would expect would sequester more carbon.)*

4. Think back to the forest succession study you performed. Which trees do you think sequester the most carbon – seedlings, saplings, or canopy trees?

5. How do you think carbon that is sequestered in a forest tree can be released?

6. Sometimes an event or concert will say that it is "carbon neutral." To *mitigate* the carbon dioxide released to set up and run the event, trees are often planted in an area far away. Explain how this would make the event "carbon neutral." What is your opinion of this practice? Explain.

Part 2: Remote Sensing and the Effects of Climate on Forests

Read the article "NASA Satellites Can See How Climate Change Affects Forests"

Before you read:

1. Predict how NASA satellites can "see" the effects of climate change on forests:

2. What do you think the effects of climate change on forests will be?

As you are reading:

Note anything that is interesting or confusing in the chart below. Be sure to describe why you find this idea to be interesting or confusing.

Interesting	Confusing

After you have finished reading:

3. How does the MODUS program compare to your method of data collection during the forest succession activity?
   - What are the pros and cons of using MODUS?
   - What are the pros and cons of visiting the forests and measuring the trees?
   - Is there any information that you obtained in your study that cannot be collected by MODUS?

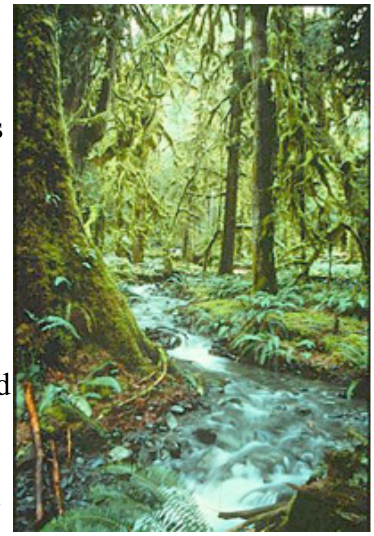
4. What are possible effects of climate change on forests as described in the article?

5. The article describes a "positive feedback loop" where climate change increases tree numbers, which actually accelerates climate change in that particular region. Describe this process in your own words.

NASA Satellites Can See How Climate Change Affects Forests

Mike Bettwy 08.29.06

A NASA-funded study shows that satellites can track the growth and health of forests and detect the impact of a changing climate on them.



Although predicting how future climate change will affect forests remains uncertain, new tools, including satellite data, are giving scientists the information they need to better understand the various factors at play and how they may change forest composition and health.

Image right: *A rain forest in the U.S. Pacific Northwest. Credit: National Park Service*

Scientists have found that satellite measurements of tree species and growth in forested regions across the United States were often equivalent to those taken directly on the ground. The study relied on a sophisticated data product from NASA's MODerate-resolution Imaging Spectroradiometer (MODIS) aboard the Terra and Aqua satellites called the "enhanced vegetation index," a measure of forest productivity that can also be used to gauge the total number of tree species in a region. The data was found to be highly successful in indicating the number of tree species when compared against data compiled, for the first time, in a country-wide survey of tree species by the U.S. Department of Agriculture Forest Service.

The MODIS data also shows that the overall productivity or growth of a forest in response to weather and seasonal conditions was closely linked to the number of different tree species it contains, allowing scientists to more readily infer the effects of climate change. “In anticipation of shifts in climate, accurate measurements of forest growth and composition are becoming more important,” said Richard Waring, professor emeritus of forest science at Oregon State University, Corvallis, Ore., and lead author of the study. "These new data help us better predict how forests may change so officials can implement environmental plans or regulations to lessen the impact in advance."

Image above: *An image of evergreen conifers, a species common in the U.S. Pacific Northwest.*

Woody Turner, Program Scientist at NASA Headquarters, Washington, said "this research confirms that MODIS can provide detailed, accurate information on forests over vast regions in a simple, straightforward manner, essential for forest managers in a period of changing climate."

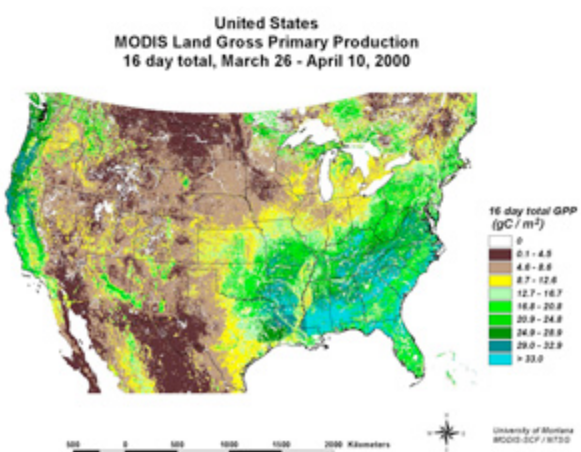
In the past, scientists predicted the productivity of forests from computer models using climate data. Gross primary productivity is a measure of plant photosynthesis and the ability of forests to “inhale” carbon dioxide. Net productivity is the amount of energy left for plant growth following the conversion of carbon dioxide into new plant tissue.

"Such methods relied heavily on costly ground measurements and on mathematical computer models that require extensive soil and climate data, which is often imprecise," said Waring. "The data from MODIS used here may also be helpful in sorting out changes in forest health caused by land conversion or pollution rather than climate change."

The MODIS data was highly accurate in confirming the number of tree species in many regions across the United States, but it predicted more than the number currently present in the Pacific Northwest. This finding is not unexpected given the region's climate history.

***Image right:** Global tree cover as measured by the NASA's MODerate Imaging Spectroradiometer (MODIS) instrument aboard NASA's Terra and Aqua satellites, showing areas with little or no tree cover (white shades) to considerable tree cover (green shades). Credit: NASA/University of Maryland*

A look at the area's evolutionary past suggests that about two to three million years ago, during a period known at the late Pliocene, the region rather suddenly turned cooler and drier, leading to a major die-off of many species, many of which still have not recovered. "Overall, the Pacific Northwest now supports about 60 tree species, but if not for the abrupt climate shift millions of years ago, it is likely the region's current climate would support twice that number," Waring said.



Although forests appear to be adapting to changes in today's climate, prehistoric records indicate that climate change tends to destroy established vegetation patterns and causes new ones to be formed. "It is unclear how forests will respond in the future, when climate change is likely to accelerate," said Waring.

***Image left:** A false-color image of global primary productivity, as measured by the NASA's MODerate Imaging Spectroradiometer (MODIS) instrument* *aboard NASA's Terra and Aqua satellites. Blue-shaded areas show where plants absorbed as much as 60 grams of carbon per square meter. Areas shaded green and yellow indicate 40 to 20 grams of carbon absorbed per square meter. Red pixels show absorption of less than 10 grams of carbon per square meter and white pixels show little or no absorption. Credit: NASA/GSFC*

But researchers are fairly certain there will be both winners and losers among tree species. New patterns of tree growth will emerge, some species may die but others may simply migrate and thrive.

Such shifts in the forest landscape may in turn cause more climate changes. For instance, additional warming could result if tree species like evergreen conifers move into areas that were previously treeless or snow-covered since evergreens would reflect less of the sun's energy, causing temperatures near the surface to increase.

Image above: *An image of "enhanced vegetation index" as measured by the NASA's MODerate Imaging Spectroradiometer (MODIS) instrument aboard NASA's Terra and Aqua satellites in June 2001, during vegetation's summer peak. Vegetation ranges from 0, indicating no vegetation, to nearly 1, indicating rich vegetation. Credit: NASA/University of Arizona*

Under another possible scenario, climate change might allow a greater number of tree species to grow in some forests, providing a natural defense against insect and disease attacks. But some of the new species could be "invasive" and threaten the overall health of the forests. Unexpected fire, insect and disease outbreaks can also further disturb forests, making them more vulnerable to invasive species. NASA's research tools like MODIS are giving scientists the detailed information they need to better understand such possibilities, vital for improving predictions and preparedness.

The study appears in the July 2006 issue of the journal *Remote Sensing of Environment.*

Find this article at:

http://www.nasa.gov/centers/goddard/news/topstory/2006/forest_changes.html