GLOBE Educator One-Week Pacing Guide: *Trees and the Carbon Cycle*

Phenomenon: Trees and the Carbon Cycle	**Guiding Question:** How are trees related to the carbon cycle?	**Contact:** Reach out to Brian Campbell (brian.a.campbell@nasa.gov), if you have questions.
Grade Level: 6-12		
Further Investigation: Trees Around the GLOBE Student Research Campaign		
Optional: Become a GLOBE Trained Teacher: GLOBE Biosphere Protocol Training		
Access GLOBE Pacing Guides: https://www.globe.gov/web/nasa-langley-research-center/home/resources		
Revision Date: 2-24-2022		

Standards - These standards are supported by the activities in this guide but not completely covered.		
Middle	**Performance Expectations:** • MS-ESS2-1 Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process. • MS-LS1-5 Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms • MS-LS1-6 Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms.	**Disciplinary Core Ideas:** • ESS2.A Earth's Materials and Systems • LS1.B Growth and /development of Organisms • LS1.C Organization for Matter and Energy Flow in Organisms • PS3.D Energy in Chemical Processes and Everyday Life
	Science and Engineering Practices: • Constructing Explanations and Designing Solutions • Developing and Using Models	**Crosscutting Concepts:** • Cause and Effect • Energy and Matter

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		• Stability and Change
High School	**Performance Expectations:** • HS-LS2-5 Ecosystems: Interactions, Energy, and Dynamics Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.	**Disciplinary Core Ideas:** • LS2.B Cycles of Matter and Energy Transfer in Ecosystems • PS3.D Energy in Chemical Processes
	Science and Engineering Practices: • Developing and Using Models	**Crosscutting Concepts:** • Systems and System Models

Background Information and NASA Connection

The Carbon Cycle

All living things on Earth contain carbon. Even you contain carbon. Lots of it. If you weigh 100 pounds, 18 pounds of you is pure carbon! And plants are almost half carbon! With so much carbon, why isn't everything black and sooty? How can dogs be white and trees green? Because carbon, an element, combines easily with other elements to form new materials. The new stuff, called compounds, are quite different from pure carbon.

Carbon is also present in the Earth's atmosphere, soils, oceans, and crust. When viewing the Earth as a system, these components can be referred to as carbon pools (sometimes also called stocks or reservoirs) because they act as storage houses for large amounts of carbon. Any movement of carbon between these reservoirs is called a flux. In any integrated system, fluxes connect reservoirs together to create cycles and feedbacks. An example of such a cycle is seen in Figure 1 where, carbon in the atmosphere is used in photosynthesis to create new plant material. On a global basis, this process transfers large amounts of carbon from one pool (the atmosphere) to another (plants). Over time, these plants die and decay, are harvested by humans, or are burned either for energy or in wildfires. All of these processes

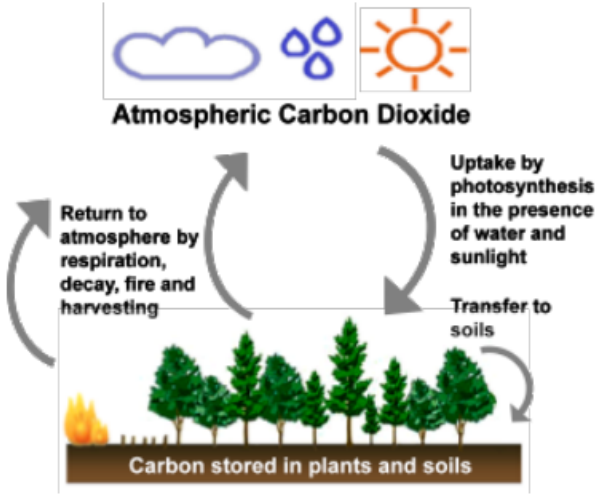


Figure 1. *A sub-cycle within the global carbon cycle. Carbon continuously moves between the atmosphere, plants and soils through photosynthesis, plant respiration, harvesting, fire and decomposition.*

are fluxes that can cycle carbon among various pools within ecosystems and eventually release it back to the atmosphere.
On the shortest time scales, of seconds to minutes, plants take in carbon dioxide (CO_2) from the atmosphere and produce oxygen. On longer time scales, carbon from dead plant material can be incorporated into soils, where it might reside for years, decades or centuries before being broken down by soil microbes and released back to the atmosphere. On still longer time scales, organic matter that became buried in deep sediments (and protected from decay) was slowly transformed into deposits of coal, oil and natural gas, the fossil fuels we use today. When we burn these substances, carbon that has been stored for millions of years is released once again to the atmosphere in the form of carbon dioxide (CO_2). The carbon cycle has a large effect on the function and well being of our planet. Globally, the carbon cycle plays a key role in regulating the Earth's climate by controlling the concentration of carbon dioxide in the atmosphere. Carbon dioxide (CO_2) is important because it contributes to the greenhouse effect, in which heat generated from sunlight at the Earth's surface is trapped by certain gasses and prevented from escaping through the atmosphere. The greenhouse effect itself is a perfectly natural phenomenon and, without it, the Earth would be a much colder place. But as is often the case, too much of a good thing can have negative consequences, and an unnatural buildup of greenhouse gasses can lead to a planet that gets unnaturally hot.

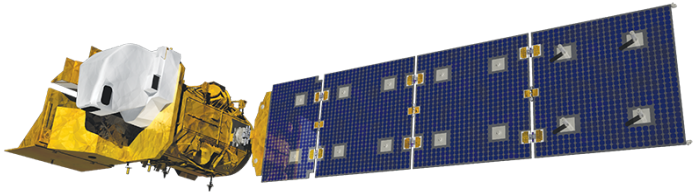
In recent years CO_2 has received much attention because its concentration in the atmosphere has risen to approximately 45% (as of 2017) above natural background levels and will continue to rise into the near future. Scientists have shown that this increase is a result of human activities that have occurred over the last 150 years, including the burning of fossil fuels and deforestation. Because CO_2 is a greenhouse gas, this increase is causing a rise in global temperatures. This is the primary cause of climate change and is the main reason for increasing interest in the carbon cycle.
Source: GLOBE: An Introduction to the Global Carbon Cycle

Trees and Carbon

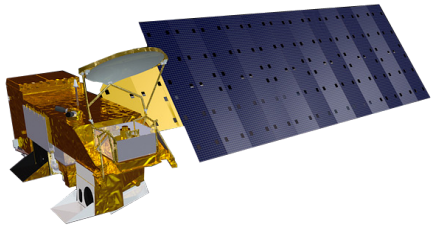
Tree height is the most widely used indicator of an ecosystem's ability to grow trees, so tracking tree height over time can help us to assess the ecological health and carbon storage of a given area. Changes in trees and tree height are greatly affected by the changing climate, with a tie-in to a changing land cover. Some types of land cover absorb carbon from the atmosphere, and when subject to changes, such as a forest burned in a wildfire, result in more carbon entering the atmosphere.

How NASA Studies Trees and Land Cover

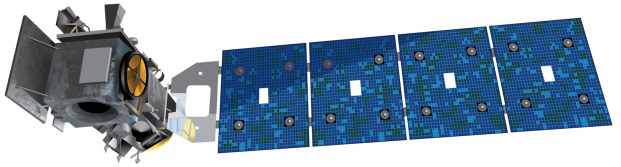
NASA satellites, instruments, and sensors can be used for monitoring global land cover and tree height patterns. Missions like Landsat 9, Terra MODIS, ICESat-2, GEDI, and others use technologically-sophisticated, onboard instruments to observe and measure parts of the Earth synoptically, and allow researchers to see global scale changes through remote sensing techniques.



Landsat 9



Terra MODIS



ICESat-2

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The GLOBE Program is NASA's largest and longest lasting citizen science program about the Earth. Through the program's GLOBE Observer app, you can submit tree height and land cover observations and photograph what you see. Because ecosystems across the land surface store as much carbon as the atmosphere, carbon taken up by plants and soils plays an important role in regulating the climate. Students involved can both contribute to our current state of scientific knowledge while filling society's growing need for informed citizens, environmental stewards, and trained professionals for future generations.

Activities		**Assessment Options**
Day 1: Tree Growth Game **Materials:** listed in activity	 Image Credit: My Tree	Completed tree posters. ***Connection to guiding question:*** *What happens to carbon as a tree grows?* ***Answer:*** *It is stored in the tree.*

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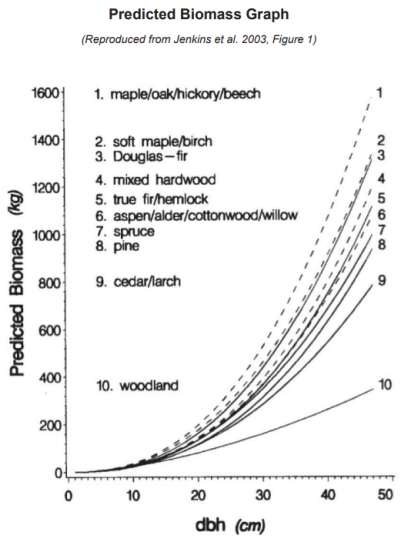
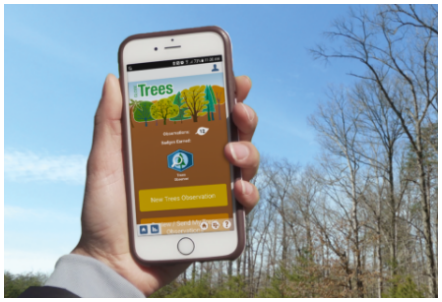
<table>
<tr><th colspan="2">Activities</th><th>Assessment Options</th></tr>
<tr><td>Day 2: Allometry - Not a Llama Tree
This can be modified to do only one section to meet time constraints.

Materials: Listed in activity.</td><td> 
</td><td>Activity questions.

Connection to guiding question: Typically, half the biomass of a tree is carbon. How much carbon is your tree storing?
Answer: Answers will vary.</td></tr>
<tr><td rowspan="2">Day 3: GLOBE Observations
● The GLOBE Program’s GLOBE Observer Tree Height and/or Land Cover Tools
● Measure the circumference of the tree as well
● If you are not using the GLOBE Observer tools, you may use the following protocols.
○ Biometry Including Tree Height
○ Land Cover Classification

Materials: Online activity, tape measure

Only make observations if you can do so safely and legally.</td><td rowspan="2"> 
</td><td>Develop consensus as a class and discuss observations.

Connection to guiding question: Does the area around your tree have many other trees? What does this indicate about the land cover?
Answer: Answers will vary.</td></tr>
<tr><td>Optional Instructional Videos:
● GLOBE Observer Trees Introduction
● How to Take a NASA GO Tree Observation
● GLOBE Observer: Land Cover - Getting Started</td></tr>
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Activities		Assessment Options
Day 4: My NASA Data Carbon Dioxide Production and Sequestration **Materials:** Listed in activities		Completed activities answer key. ***Connection to guiding question:*** *How does the carbon stored in a wooded area differ from the carbon stored in a barren area?* ***Answer:*** *The wooded area stores much more carbon.*
Day 5: Carbon Around Me **Materials:** Listed in activity.		Completed models. ***Connection to guiding question:*** *What role do trees play in the carbon cycle around you?* ***Answer:*** *Answers will vary. Trees store carbon. Loss of trees will lead to release of carbon. Areas with little to no trees will not have carbon stored in them.* ***Connection TO NASA:*** *Why does NASA study tree height?* ***Answer:*** *It helps determine the amount of carbon stored or being lost. That helps determine changes that may be occurring which can impact climate and land cover.*

Additional Resources		
Online Activities	Audience	Description
Mission Biomes	Ages 9-14	Investigate different biomes and test your knowledge.
Hands-On Activities	Audience	Description
Paper Clip Simulation A Simple System	Middle and High School	Through a simulation activity in which students act out the paper clip distribution system, students will take part in a simple system. As a result of the simulation, students will identify and analyze the basic parts of systems including input flows, output flows, and stocks.
Carbon Cycle Adventure Story	Middle and High School	This activity provides an introduction to the carbon cycle and systems thinking. It also could be used, more broadly, to introduce biogeochemical cycling, the greenhouse effect and climate change. During the activity, students read about a carbon atom that begins in the atmosphere as part of carbon dioxide. Students choose where the atom will travel next, i.e. into a leaf via photosynthesis or dissolve into the ocean. Students keep track of the carbon pools they visit, and the process that takes their carbon atom on to the next pool.
Carbon Travels Game	Middle and High School	During the activity, students research one carbon pool in depth, share their knowledge with peers and then see how carbon pools are connected by fluxes as they roll game dice to move from station to station around the classroom. Students keep track of the carbon pools they visit, and the process that takes them to the next carbon pool.
Getting to Know Global Carbon	Middle and High School	This activity provides an introduction to the carbon cycle and, more broadly, to biogeochemical cycling, the greenhouse effect and climate change. During this activity, students compare a carbon cycle diagram they develop to one developed by scientists.
A Beginning Look at Photosynthesis	Elementary and Middle School	Simple investigation to see how plants respond to light.

Additional Resources (continued)		
Hands-On Activities	Audience	Description
Tree Health Check-up	All	Just like people can be healthy or sick, so can trees! Experts who study trees (called arborists) look for symptoms in trees to determine whether they are healthy or not. In this activity, learners will look for some of these indicators in a tree nearby.
Videos and Reading	Audience	Description
GMS: GLOBE Observer Why Observe: Tree Height?	All	*Why Observe?: Tree Height* explores surface height measurement missions and the role that citizen science can play within the scientific community. Credit: NASA's Goddard Space Flight Center Additional footage provided by MOSAiC/Alfred-Wegener Institute, Artbeats and Pond5
Global Carbon Dioxide 2020-2021	All	Data visualization featuring volumetric carbon dioxide on a global scale for the period June 1, 2020 - July 31, 2021. Credit: NASA's Scientific Visualization Studio
Plants are Struggling to Keep Up with Rising Carbon Dioxide Concentrations	All	Plants play a key role in mitigating climate change. The more carbon dioxide they absorb during photosynthesis, the less carbon dioxide remains trapped in the atmosphere where it can cause temperatures to rise. But scientists have identified an unsettling trend – 86% of land ecosystems globally are becoming progressively less efficient at absorbing the increasing levels of CO2 from the atmosphere. Credit: NASA's Scientific Visualization Studio
Trees Around the GLOBE	All	Join the Trees Around the GLOBE Campaign video clip. Credit: NASA's Scientific Visualization Studio
GLOBE Carbon Cycle	Middle and High School	This project is focused on incorporating the most cutting-edge research and data collection techniques within the field of terrestrial ecosystem carbon cycling into various classroom activities. To accomplish this goal, the GLOBE Carbon Cycle Project uses a systems-level approach to establish foundational knowledge of how carbon flows through our ecosystems and its relationship to climate and energy. The included materials incorporate a diverse set of activities focused on upper-middle and high school students.

Additional Resources (continued)		
Videos and Reading	Audience	Description
GMS: GEDI Overview	All	The GEDI instrument was built at NASA's Goddard Space Flight Center, and has the highest resolution and densest sampling of any lidar every put in orbit. The mission is led by the University of Maryland and is designed to help researchers understand how ecosystems are storing carbon. Credit: NASA's Scientific Visualization Studio
NASA: Keeping Up with Carbon	All	Climate change refers to long-term shifts in temperatures and weather patterns, mainly caused by human activities, especially the burning of fossil fuels.
NASA eClips Real World: The Carbon Cycle - Essential for Life on Earth	Middle School	Carbon is an essential building block for life. Learning how carbon is converted through slow- and fast-moving cycles helps us understand how this life-sustaining element moves through the environment. Discover how NASA measures carbon through both field work and satellite imagery keeping watch through its eyes on the sky, on Earth, and in space.
Breaking Down the Big Questions at NASA	All	Brian Campbell describes how to answer big questions by breaking it down into smaller questions.

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