“Solutions-Oriented Learning” Storyline

HS-Forests: Carbon Sequestration

Storyline introduction and overview:

The goal of the high school carbon sequestration in forests storyline is to build on the science of carbon sequestration from the middle school storyline. In this storyline, **carbon sequestration** refers to the removal of **carbon** (**in the** form of **carbon** dioxide) from the atmosphere through the process of photosynthesis. **Carbon storage** refers to the amount of **carbon** bound up in woody material above and below ground. High school students will develop an understanding of the variables and considerations that arise from managing forests for different purposes including carbon sequestration and other ecosystem services.

NGSS Learning Progression for this Storyline: The high school storyline is part of a larger learning progression that includes students mastering standards pre-K to 12th grade. Take a look at how the high school performance expectations fit in a continuum of learning for your students.

Placemaking:	**Anchoring phenomena:**	**Drawdown:**
Over half of the land in Washington State is forested. These 22 million acres are managed by federal and state agencies as well as private owners for many different goals. Tipping the balance to more carbon storage in Pacific Northwest forests.	Examine your relationship with a piece of lumber and a living tree.	Temperate Forests Afforestation (depending on the site) Forest Restoration Indigenous People's Land Management
Indigenous and other relevant cultural connections: Worldview of trees as sovereign living beings with whom humans have a relationship versus trees as “resources” for human use.	**NGSS PEs (progress towards):** HS-LS2-4. Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem. HS-LS2-7. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity HS-ESS3-6. Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.	

Estimated time required to implement this storyline: Eight or more 50-minute class periods. Teachers who choose to do an action-oriented project will need to allot more time based on the activity they choose.

NGSS PEs:

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HS-LS2-4. Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.

HS-LS2-7. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity

HS-ESS3-6. Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.

Disciplinary Core Idea (DCI)	Science & Engineering Practice (SEP)	Cross Cutting Concept (CCC)
For HS-LS2-4. **LS2.A Interdependent relationships in ecosystems** Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem.	**Using Mathematical and Computational Thinking** Mathematical and computational thinking in 9-12 builds on K-8 experiences and progresses to using algebraic thinking and analysis; a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms; and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. Use mathematical representations of phenomena or design solutions to support claims.	**Energy and Matter** Energy cannot be created or destroyed; it only moves between one place and another place, between objects and/or fields, or between systems.
For LS2-7 **LS2.C: Ecosystem Dynamics, Functioning, and Resilience** Anthropogenic changes (induced by human activity) in the environment — including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change — can disrupt an ecosystem and threaten the survival of some species. **LS4.D: Biodiversity and Humans** Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. **ETS1.B: Developing Possible Solutions** When evaluating solutions it is important to take into account a range of constraints including cost, safety, reliability and aesthetics and to consider social, cultural and environmental impacts.	**Constructing Explanations and Designing Solutions** Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. Design, evaluate, and refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.	**Stability and Change** Much of science deals with constructing explanations of how things change and how they remain stable
For ESS3-6 **ESS3.D: Global Climate Change** Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in	**Using Mathematics and Computational Thinking** Mathematical and computational thinking in 9–12 builds on K–8 experiences and progresses to using algebraic thinking and analysis; a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms; and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical	**Systems and System Models** When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models

response to human activities.	models of basic assumptions. Use a computational representation of phenomena or design solutions to describe and/or support claims and/or explanations.	

Learning Sessions

Learning Session:	**Materials List**
2 **4** **4**	Piece of wood (lumber) Class set of tape measures and meter sticks Supplies to make clinometers (protractors, string, plastic straws)

1.	**Grounding Native Ways of Knowing:**	
	Worldview of trees as sovereign living beings with whom humans have a relationship versus trees as "resources" for human use. Watch The Story of Cedar. Students write down all the ways the tree is used as a resource. At the end of the video, as a class, discuss how the indigenous people *have a relationship* with the cedar tree.	

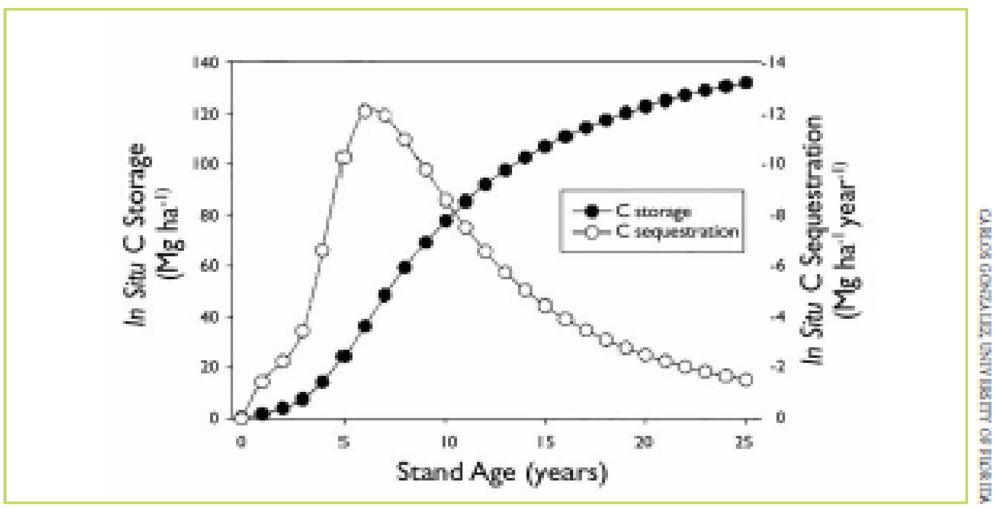
2.	**Examine phenomena: Examine your relationship with a living tree and a piece of lumber.**	Estimated time: 30-minutes
	Present students with a piece of lumber and a living tree. How do you use/enjoy/think about these things? In no particular order, write down every way you use/enjoy/think about these items. How long is the carbon stored in the various products that you use/enjoy/think about in your life? *Expected answers: recreation (tree swing, climbing trees) lumber for building houses and furniture, paper; burning for heat; cultural significance, etc. The carbon is stored in living trees until they die and decompose. The carbon is stored in wood products until they are burned and/or disintegrate/decompose.*	

2.	**Pre Assessment:**	
	HS- Forests: Carbon Sequestration Pre Assessment **HS- Forests: Carbon Sequestration Assessment Rubric**	

3.	**Guiding Question: What ecosystem services does a forest provide? What happens to these services if the trees are cut down?**	Estimated time: 50-minutes

1. Provide the definition of ecosystem services to students: '*Ecosystem services are the benefits that humans gain from a properly functioning ecosystem*.' Students brainstorm the ecosystem services provided by a forest.
2. Students use Ecosystem Services for research.
3. Students refer back to the list they made when they watched The Story of Cedar and consider what ecosystem services the cedar tree provided to the indigenous people.
4. Students create a bubble map of the types of ecosystem services that fall under the categories 1) provisioning, 2) regulating, 3) cultural, and 4) supporting.
5. Students consider what will happen to each of these ecosystem services if a forest were to be cut down. Indicate on their map who might be impacted if any ecosystem services were lost.

4.	**Guiding question: How is carbon stored in a forest?**	Estimated time: Three 50-minute periods



Carlos Gonzales, University of Florida

1. Using this graph from Project Learning Tree - Southern Forest and Climate Change (page 140), students:
   a. Make a claim about the relationship between the age of the forest and the amount of carbon stored
   b. Provide evidence
   c. Give a scientific reason for your claim
   d. Students use evidence from the graph to describe how human activity could affect the amount of carbon sequestered and the amount of carbon stored. (For example, what would the impact be on carbon storage if an old growth forest was cut down to make room for more houses?)

	2. Students use the Carbon Cycle and the role of photosynthesis/respiration (including soil respiration as well as human respiration), students draw a flow chart of carbon. Use Ecological Cycles Carbon Cycle Photosynthesis & Respiration.pptx and Dead stuff: The secret ingredient in our food chain as resources. 3. **Counting Carbon** (PLT SFCC page 139) – Students measure trees near their school and calculate the amount of carbon stored in individual trees. Students then compare the carbon sequestration potential for land-use types in their state, compare this to the estimated amount of carbon released by human activities, and discuss forests' ability to sequester atmospheric carbon

5.	**Guiding question: How can forests impact climate change?**	Estimated time Four 50 minute periods
	1. Students build a model to recreate the greenhouse effect and make observations of global warming during experiments using It's Really Heating Up in Here 2. Students read the Project Drawdown Forest Protection. 3. Using Forests and Climate Change as a resource, students develop a mathematical representation of relative amounts of carbon stored in the living biomass of a forest and the soil in a forest. Explore the question of how those amounts can be impacted by human activity. 4. **The Carbon Puzzle** (PLT SFCC page 215) – Students use a series of facts to realize how forest plantations, wood products, and wood substitution can reduce atmospheric carbon, and then interpret a graph published by the researchers who explored this concept. 5. Students study Dr.Ganguly's paper Global Warming Mitigating Role of Wood Products from Washington State's Private Forests. This paper may be difficult for students to read. Students can concentrate on the abstract, Figure 4 graph, and the conclusion in order to gain an understanding of the information provided.	

6.	**Guiding question: Who are the stakeholders that must be considered in forest management?**	Estimated time: 50-minutes Extension: one to two 50-minute periods
	1. Students identify the stakeholders that must be considered in forest management. *Expected answers: forestry industry, people that live near forest, people that use wood products, people around the world impacted by increased CO_2/climate change, etc.* 2. Assign a stakeholder role to each student. Students should be able to identify their	

	stakeholder's connection to the forest. There can be more than one student for each stakeholder role. Role-play the impact on each stakeholder as different decisions about forest management are made. This activity is designed to introduce the interconnectedness and far reaching consequences of decision making without yet being exposed to the evidence of the impacts. It is a brainstorming activity. Be sure to have some students recording the stakeholders' comments.

7.	**Guiding question: What happens to carbon sequestration when there is a forest fire? Do all of the forest ecosystem services disappear? Should we log forests to prevent forest fires? What might be some positive and/or negative consequences of logging for fire prevention?**	Estimated time Two 50-minute periods
	1. Washington state is currently considering using controlled burns for reducing wildfire. The Indigenous people used controlled burns to reduce fire and promote understory growth. There is already a state law that requires the Dept of Natural Resources to thin 1 million acres by 2033. These are both tools used for reducing wildfires. Discuss pros and cons of each of these tools. 2. **The Changing Forests** (PLT SFCC page 85) – Students review how scientists are monitoring forest changes and exploring adaptive strategies to keep forests healthy.	

8.	**Guiding question: How can consumers play a role in reducing and preventing greenhouse gas emissions that contribute to climate change?**	Estimated time 30-minutes:
	1. Students brainstorm how they might be able to contribute to reducing greenhouse gas emissions. *Expected answers: Consumers can play an active role in reducing and preventing greenhouse gas emissions by examining the environmental costs of their choices.* 2. **Activity 9: The Real Cost** (PLT SFCC page 165) – Through a simulated shopping activity, students learn about the impact, or externalities, of consumer choices on the environment. 3. **Activity 10: Adventures in Life Cycle Assessment** (PLT SFCC page 179) – Students investigate life cycle assessment data for three types of outdoor dining furniture to determine which type would generate the lowest amount of greenhouse gases. Using the data, students design a solution.	

9.	Guiding question: What are some solutions using forests and/or wood products that will sequester and store more carbon thereby reducing human impact on the environment?	Estimated time Three 50-minutes periods

1. Using the knowledge gained from all the above activities (especially those in sessions 5-8), students prepare a final project. This could be used as a performance assessment as well.

2. Students design a solution to the guiding question. To focus students on a more specific solution, have students brainstorm some more specific questions. Below is a list of a few example questions:
    a. What products that are currently made out of paper could either be made of something else that is not a one use item or not used at all (another product is substituted)?
    b. What product could be made of wood that is currently NOT being made of wood?
    c. How can a small forest plot be managed to sequester the MOST carbon for the longest time?

3. Students describe the ways the proposed solution decreases the negative effects of human activity on the environment (sequesters and stores more carbon).

4. As part of their solution, students will explain how they will evaluate the effectiveness of their solution to a real-world problem, based on scientific knowledge.

5. These solutions can be presented by students to the class using any format they choose (video, paper, audio, etc.). Each presentation should include
    i. A clear solution
    ii. The ways the solution sequesters/stores more carbon
    iii. A method to evaluate the effectiveness of their solution

10.	Possible next steps/off-ramps/actions:	Estimated time:

Career connections: What kind of jobs work to support healthy forests? Using the resources below, explore possible forest related careers with students:
- PEI Career Card: Assistant Forester
- PEI Career Card: Land Steward
- PEI Career Card: Senior Resource Information Forester
- PEI Career Card: Silviculture Forester
- Natural Inquirer: Forest and Plants Scientist Cards

Use the following activities from Project Learning Tree to augment this storyline. These activities help teachers summarize the concepts in this module. These can be adapted to

	reflect the learning sessions above that teachers selected. **Life Cycle Assessment Debate** (PLT SFCC page 199) – Students debate four pairs of similar products to develop their own sets of questions about product life cycles that can help guide consumer choices. **Future of Our Forests (**PLT SFCC page 227) – Student teams review information from the module and share their knowledge with an appropriate audience. **Starting a Climate Service-Learning Project** (PLT SFCC page 235) – Students select and complete an action project to mitigate climate change or help their communities adapt to projected changes.

11.	**Post Assessment:**	Estimated time 20-minutes:
	HS-Forests: Carbon Sequestration Post Assessment **HS-Forests: Carbon Sequestration Assessment Rubric**	

OER Tracker - HS Forests: Carbon Sequestration

Definitions:

Carbon flux: Transfer of carbon from one carbon pool to another in units of measurement of mass per unit area and time (e.g., t C ha^{-1} yr^{-1})

Carbon pool: A reservoir of carbon. A system which has the capacity to accumulate or release carbon.

Carbon sink: Any process or mechanism which removes a greenhouse gas, an aerosol or a precursor of a greenhouse gas from the atmosphere. A given pool (reservoir) can be a sink for atmospheric carbon if, during a given time interval, more carbon is flowing into it than is flowing out.

Carbon stock: The absolute quantity of carbon held within a pool at a specified time. The units of measurement are mass.

Sequestration (uptake):The process of increasing the carbon content of a carbon pool other than the atmosphere. (IPCC, 2000).

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