Lesson Overview:
Students will investigate forest species and characteristics in an outdoor setting through various activities to learn about forest composition, forest health, ecosystem services, forest products, carbon cycling, and ecological footprints. This unit connects to my current curriculum by expanding my ecology unit and offering a case study approach to learning. My AP Biology students now spend a few weeks studying the major themes of ecology, at the organism, population, community, and ecosystem levels, through a combination of lecture and outdoor and indoor laboratories. These additional activities will provide a more focused investigation of forest ecology and resources to allow students to explore the wood lot of our school to analyze the complex biotic and abiotic associations occurring therein. It is my hope that my students will gain increased confidence and skill when performing tree identification and forest measurements, and will also learn to critically analyze the data collected to ascertain forest health, ecosystem services, and carbon cycling of their local school forest.

Sources Consulted/References:


Tree Factory Cards provided at Forest Ecology and Resources Teacher Institute (on CD) (handout provided below)

Tree carbon activity provided by Maria Janowiak at Forest Ecology and Resources Teacher Institute (on CD) (handout provided below)
Teaching and Learning Objectives:

At the end of this unit, students will be able to:

1. Identify common tree species in the school forest using a dichotomous key.
2. Quantify tree/forest characteristics (DBH, height, tree condition, forest diversity, soil quality, regeneration, wildlife, etc) using appropriate measuring tools.
3. Analyze data from tree/forest measurements to assess the health/quality of a forest ecosystem and be able to effectively communicate results within a group discussion format.
4. Evaluate ecosystem services such as ecological and economic benefits of tree species in the school forest.
5. Calculate the quantity of carbon contained within a tree using species identification, DBH and height measurements.
6. Estimate carbon footprints and analyze methods to reduce human impacts on forest ecosystems.

Michigan High School Content Expectations for Science

B1.1 Scientific Inquiry
   B1.1C Conduct scientific investigations using appropriate tools and techniques (e.g., selecting an instrument that measures the desired quantity—length, volume, weight, time interval, temperature—with the appropriate level of precision). (Objectives A, B, E from above)
   B1.1E Describe a reason for a given conclusion using evidence from an investigation. (Objective C)

B1.2 Scientific Reflection and Social Implications
   B1.2D Evaluate scientific explanations in a peer review process or discussion format. (Objectives C, D, F)

B3.3 Element Recombination
   B3.3b Describe environmental processes (e.g., the carbon and nitrogen cycles) and their role in processing matter crucial for sustaining life. (Objectives E, F)

B3.4 Changes in Ecosystems
   B3.4B Recognize and describe that a great diversity of species increases the chance that at least some living organisms will survive in the face of cataclysmic changes in the environment. (Objectives C, D)
   B3.4C Examine the negative impact of human activities. (Objective F)

Materials Needed:

Day 1—Introduction to Forest Health and Resources: Copies of Forest Ecology Pretest, Smartboard with internet access or computer/projector setup, Tree cookies, whiteboards, markers, Tree Factory cards, open space in classroom, hallway, or common area, copies of student handouts “Forests Are More Than Trees”

Day 2—Tree Identification & Measurement Field Work: Michigan Trees books for student groups to use dichotomous keys, copies of student data sheets “Evaluating Tree Benefits”, tape measures or DBH tape, clinometers or rulers

Day 3—Smartboard or whiteboard, Monitoring Forest Health Field Work: Michigan Trees books for student groups to use dichotomous keys, copies of seven different student data sheets “Forest Health Indicators”, flag markers, clipboards, tape measures or DBH tape, clinometers or rulers, colored chalk, string, compasses, 100-circle grid transparency, spade or trowel, cups or plastic bags, distilled water, eyedropper, Petri dishes or plastic containers, pH paper, white paper

Day 4—Monitoring Forest Health Summary and Presentations: Smartboard or projector, document reader, whiteboard and markers, copies of student data sheets “Forest Health Summary”
Day 5—Climate Change and Forests: copies of student data sheets “The Carbon in Trees”, tape measures or DBH tape, clinometers or rulers, copies of student data sheets “Carbon Footprint Calculator Homework”

Classroom/Field Activities

Day 1—Introduction to Forest Health and Resources:

Opener: Students take Forest Health and Resources Pretest. Once all students have pretest complete, exchange papers with a partner and grade/discuss each question as a class.

Podcast: Students listen to the 8 minute podcast—“Monitoring Earth’s Forests from Space” an interview with Dr. Curtis Woodcock from Boston University found at http://earthsky.org/earth/curtis-woodcock-earths-forests-from-space. Discuss the main concepts of the interview as a whole class discussion. Focus Questions: What can we learn about forests from space? What are ecosystem services? What connection is there between forest health and ecosystem services?

Tree Cookies Stories: Pass out a tree cookie to each group of two students. Students investigate the cross section of the tree for plant anatomy/vocabulary with which they are familiar (plant structure and growth has been previously studied in a former unit during the year). Students should identify structures such as bark, xylem, phloem, heartwood, sapwood, etc., and make conjectures about tree growth based on the rings. Each student pair will write a short story/paragraph about the life story of their particular tree based on observation of the tree cookie on large whiteboards using markers. These can be easily accessed by the instructor and students can share their stories orally.

Tree Factory Activity: Divide students into groups based on the parts of the tree by handing out tree factory cards to each student: heartwood (1 student), xylem (2 students), phloem (4 students), cambium (6 students), bark (8 students) roots (4 students), and leaves (5 students). Numbers are approximate for a class of 30 students, and can be easily adapted to the size of the particular class. List the parts of the tree on the smartboard or whiteboard and have students arrange themselves in the appropriate order to represent the tree in an open area of the classroom or hallway. Once everyone is assembled, have each group chant their mantra for their tree structure, one group at a time, them all together. (This is a simple activity normally reserved for younger students, but will also be enjoyed by my eleventh and twelfth graders as a short kinesthetic interest grabber.)

Independent Work: Pass out a copy of the handout “Forests Are More Than Trees” to each student. Students independently read this article found in the Project Learning Tree book: Exploring Environmental Issues: Focus on Forests Secondary Environmental Education Module, pages 17-29. Students should “Talk to the Text” as they read by underlining or highlighting key ideas, writing comments and reactions in the margins, and overall interacting with the content on the page. This active reading technique allows students to engage with the text and better comprehend it through meta-cognition. Student questions at the end of the article can be assigned for homework if students do not finish them in class.
Day 2—Tree Identification and Measurement Field Work:

Opener: Discuss the main concepts of yesterday’s independent reading as a whole class discussion. Focus Questions: What are some ecosystem services provided by forests? What are the four pressing issues that North American forests face today? What is the relationship between forests and climate change? What is forest sustainability?

Tree Identification and Measurement: Take students into the school forest to practice using dichotomous keys from the Michigan Trees books to identify local tree species. Model the technique using a few sample trees. Also model for students how to measure diameter at breast height (DBH) using a tape measure or DBH tape and how to measure tree height using a ruler or clinometer (whatever is available).

Evaluating Tree Benefits Activity: Students collect data for this activity using the skills just practiced for identifying and quantifying trees on the “Evaluating Tree Benefits” datasheet located in the Project Learning Tree book: Exploring Environmental Issues: Focus on Forests Secondary Environmental Education Module, pages 52-53. Each student group will need to select a tree to study, identify its species, determine the tree’s diameter at breast height, and measure the tree’s height. For homework, students will visit the Tree Benefits website (www.treebenefits.com) to determine the ecological services provided by their selected tree and complete the data sheet.

Day 3—Monitoring Forest Health Field Work:

Opener: Begin by asking students the following questions: What do you think forest health means? Why should we care whether forests are healthy or not? What factors do you think might promote or diminish forest health? Generate a list of ideas on the smartboard/whiteboard.

Monitoring Forest Health Activity: Explain to students that they will conduct a forest health checkup of the school forest area, will take forestry measurements, and will evaluate the ecological services provided by trees and forests much like a doctor accesses a human patient’s health. Divide students into seven groups to each collect data on one of the following forest health indicators: tree and crown condition, forest diversity, lichen abundance, soil quality, regeneration, snags and coarse woody debris, and wildlife. Student datasheets are located in the Project Learning Tree book: Exploring Environmental Issues: Focus on Forests Secondary Environmental Education Module, pages 38-50. To increase data validity, have two teams do each of the seven indicators (each student group would get two data sheets). Compare this list of forest health indicators to the one prepared by the class during the opener before going outside. As a class (or prepare ahead of time) mark off a 0.1 acre plot in which to sample. A circular plot can be made by using a flag to mark the center followed by using a tape measure to measure 37.2 feet (11.34 meters) from the center. Use flags to mark the circumference of the circle. Alternatively, multiple study plots could be marked off depending on class size or sampling needs. Each group should collect their relevant data in the field. Depending on student proficiency with data collection, this activity may need to be spread over two or more days.
Day 4—Monitoring Forest Health Summary and Presentations

Opener: Have students discuss the following questions with their groups from the previous day’s field work: What was your group’s assessment of the health of the forest plot? Do you think your results are representative of the overall forest health of the plot?

Monitoring Forest Health Summary and Presentations: Each student group will prepare a short presentation on the forest health indicator that they investigated to share with the class. During the presentation the type of data collected and the methods used for collecting the data should be explained, key observations should be noted, the overall point value (3, 2, or 1) and overall rating (good, fair, or poor) for that indicator should be shared. Students can show the class their group’s data using the document reader, or they could prepare a presentation poster on a large size individual whiteboard using markers. During the presentations, students will complete the “Forest Health Summary” handout found in the Project Learning Tree book: Exploring Environmental Issues: Focus on Forests Secondary Environmental Education Module, page 51. After the presentations, discuss the following questions as a class: What is the overall health assessment for your study plot? Which results were most important in making your assessment? Do the results represent the entire forested area? How might a more accurate assessment be obtained? How do human activities with degrade or enhance the health of this forest? What could humans do to improve it?

Day 5—Climate Change and Forests

Opener: Begin by asking students the following questions: Do you think the Earth’s climate is changing? Why or why not? What is global climate change? What human activities are contributing to global climate change? What is carbon sequestration? How much carbon can a tree hold?

Carbon in Trees Activity: Review the carbon cycle with students, noting how carbon is gained by trees through photosynthesis and released by all living things through respiration and decomposition. Ask students how they might calculate the amount of carbon that a tree can hold. Discuss factors contributing to the amount of carbon in a tree such as size, species, age, growth rate, etc. Divide students into small groups to collect data in the forest plot used previously. Using the “Carbon in Trees” data sheet, each student group will select a specific tree and will determine the approximate amount of carbon stored within it by measuring the diameter at breast height (DBH) and height and then completing the calculations.

Carbon Footprint Activity: Once back inside, ask students if they have heard the term carbon footprint. Work through the definition as a class discussion. Also brainstorm ways that human activities produce CO₂ and list them on the Smartboard or whiteboard. Pass out the “Carbon Footprint Calculator Homework” handout to students, review its contents, and have students work with their family at home to complete the questions. After the homework handout is complete, students should use an online carbon footprint calculator, such as the EPA Household Emissions Calculator (www.epa.gov/climatechange/ emissions/ind_calculator.html) to calculate their family’s carbon footprint. A summary of results should be printed or recorded on the back of the student handout. Encourage students to experiment with the calculator to determine what factors have the greatest
impact on their final footprint. During the next class period, discuss the following questions with students: How does CO₂—as a greenhouse gas—affect the Earth’s climate? How does energy use affect CO₂ levels in the atmosphere? What factors most affected our carbon footprints? What actions can individuals take to reduce their carbon footprints? What about your family and your school? How do trees and forests affect the amount of CO₂ in the atmosphere?

Unit Assessment:

Formative Assessment: Pretest scores can be analyzed to determine the level of prior knowledge students bring into this unit. During the discussions and time devoted to analyzing and summarizing data, the instructor should be assessing the knowledge of students and their grasp of the concepts as the lesson activities progress. It is important to offer insight and feedback to students as they develop a working knowledge of the topics investigated. By mentoring students and pointing them in the right direction, they will gain confidence with the concepts and be ready to discuss their ideas with their peers. Accurate completion of the independent reading comprehension questions, the Evaluating Tree Benefits datasheet, the Forest Health Summary handout, and the Carbon Footprint Calculator Homework can be assessed for graded points during the lesson activities.

Summative Assessment: Following the lesson activities, student answers on the posttest can be analyzed and compared to the pretest to determine how much students have learned from the unit’s activities, field work, presentations, and discussions.
True or False? (Circle T or F to mark your answer.)

1. T or F—Forests provide ecosystem services such as nutrient cycling, oxygen uptake, carbon release, clean water, and temperature regulation.
2. T or F—Forest resources are used to produce more than 5,000 commercial products, such as charcoal, firewood, fruits, nuts, lumber, medicines, paper, and turpentine.
3. T or F—It is possible to measure the height of a tree using a ruler while standing on the ground.
4. T or F—A carbon footprint is a measure of how much glucose (C₆H₁₂O₆) a person, organization, or product produces, directly or indirectly, in a certain amount of time (usually a year).
5. T or F—Forest regeneration is measured by the number of tree seedlings present.
6. T or F—Lichen growing on the bark of a tree is an indicator of an unhealthy forest.
7. T or F—Forest tree species prefer acidic (pH of 4 or less) soil.
8. T or F—Loam, sandy loam, or clay loam is the preferred soil type for forest tree species.
9. T or F—In forest ecosystems, the presence of snags (standing dead trees) and coarse woody debris (dead logs and large branches on the ground) are indicators of a healthy forest.
10. T or F—Carbon naturally cycles between the animals, atmosphere, oceans, plants, and soils. Carbon sequestration is the process through which CO₂ from trees is absorbed by the atmosphere through photosynthesis.
**Tree Factory Cards**

**Heartwood = strength**
- Stand tall and tighten muscles
- Chant: *I support! I support!*

**Phloem = transports food from leaves to rest of tree**
- Join hands and form large circle around tree. Reach above heads & grab food from leaves.
- Chant: *Food to the tree! Food to the tree!*

**Xylem (sapwood) = transports water and nutrients up from roots to leaves**
- Join hands to form small circle around heartwood.
- Chant: *Gurgle, slurp! Gurgle, slurp!*

**Cambium = thin layer of growing tissue that becomes new xylem, phloem or cambium to keep tree growing**
- Form circle between phloem and heartwood. Sway from side to side.
- Chant: *New phloem, sapwood and cambium!*

**Roots = absorbs water from soil for sapwood**
- Lie down with feet next to sapwood. Spread out fingers & hands to represent root hairs.
- Make sucking noises!

**Bark = protects the tree**
- Lock arms around tree, and face outward. Look tough!
- Chant: *We are bark! Please keep out!*

**Leaves = make food through photosynthesis**
- Hold string attached to heartwood. Flutter hands.
- Chant: *We make food; We make food!*

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The Carbon in Trees

**Description:** Recent interest in the use of forests for carbon sequestration and bioenergy require knowledge about the amount of carbon stored in a tree or forest. For this activity, you will estimate the amount of carbon stored in a nearby or favorite tree.

**Objectives:** Measure tree diameter; calculate biomass and carbon mass

**Materials Needed:** Tree(s); Diameter tape and/or tape measure; Calculator and/or spreadsheet software; Pencil; Allometric equation for tree species

**Instructions:**

**Step 1: Measure Diameter**

If using a **tape measure**, measure the circumference of the tree at breast height (4.5 feet off the ground; see figure). If necessary, convert this value to cm. Then, using the tree circumference, calculate the diameter.

Circumference: _______ cm   Diameter: _______ cm

*OR:* If using a **diameter tape**, the tree is measured the same way but it is not necessary to calculate diameter since the tape already does that for you. If necessary, convert this value to cm.

   Diameter: _______ cm

**Step 2: Calculate biomass for whole tree.**

To calculate tree biomass, we use a standard allometric equation of the form $M = aD^b$ where $M$ is aboveground tree biomass (dry weight; kg), $D$ is the diameter at breast height (cm), and “a” and “b” are species specific coefficients. Locate the coefficients for the species of tree that you have in the table and calculate tree biomass ($M$).

<table>
<thead>
<tr>
<th>Tree Species</th>
<th>a</th>
<th>b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ash</td>
<td>0.16</td>
<td>2.35</td>
</tr>
<tr>
<td>Aspen</td>
<td>0.05</td>
<td>2.51</td>
</tr>
<tr>
<td>Balsam fir</td>
<td>0.07</td>
<td>2.50</td>
</tr>
<tr>
<td>Basswood</td>
<td>0.09</td>
<td>2.35</td>
</tr>
<tr>
<td>Beech</td>
<td>0.20</td>
<td>2.39</td>
</tr>
<tr>
<td>Eastern hemlock</td>
<td>0.10</td>
<td>2.36</td>
</tr>
<tr>
<td>Northern white cedar</td>
<td>0.09</td>
<td>2.23</td>
</tr>
<tr>
<td>Red maple</td>
<td>0.16</td>
<td>2.31</td>
</tr>
<tr>
<td>Red oak</td>
<td>0.13</td>
<td>2.42</td>
</tr>
<tr>
<td>Red pine</td>
<td>0.78</td>
<td>2.42</td>
</tr>
<tr>
<td>Sugar maple</td>
<td>0.17</td>
<td>2.36</td>
</tr>
<tr>
<td>White birch</td>
<td>0.12</td>
<td>2.43</td>
</tr>
<tr>
<td>White oak</td>
<td>0.20</td>
<td>2.16</td>
</tr>
<tr>
<td>White pine</td>
<td>0.75</td>
<td>2.38</td>
</tr>
<tr>
<td>Yellow birch</td>
<td>0.09</td>
<td>2.59</td>
</tr>
</tbody>
</table>

   Tree Species: _____________________

   Biomass (M): _______ kg

**Step 3: Determine carbon content**

Since carbon is the major building block for life, a tree contains a large portion of carbon (about half of its biomass). To determine how much carbon is in your tree:

Multiply biomass (M) by 0.521 for **hardwood** trees.

Multiply biomass (M) by 0.498 for **softwood** trees.

   Carbon content: _______ kg C

Multiply by 2.2 to convert to lbs.

   Carbon content: _______ lb C

**Bonus Question:** One lb of C is equal to 3.67 lbs of CO$_2$. Also, a car emits 19.6 lbs of CO$_2$ for each gallon of gas. If a person uses 400 gallons of gas a year, then their CO$_2$ emissions from driving would equal the amount of carbon sequestered in _______ of these trees.

1. Explain what makes up a healthy forest ecosystem. Give examples and evidence from the forest health investigation in our school forest.

2. What influences—both natural and human-caused—are affecting our school forest?

3. What is the prognosis for this forest? What can people do to change this prognosis, either for better or worse?

4. Describe the ecosystem services and benefits provided by the local forest area.
5. Explain how you measured the height of a tree using a ruler while standing on the ground. Give an example to clarify your reasoning.

6. Explain the importance of forests in sequestering carbon and mitigating carbon dioxide (CO₂) levels in the atmosphere.

7. How could you reduce your own personal carbon footprint? How could the carbon footprint of your family be reduced? How could the carbon footprint of your school be reduced?