Unit: How Much Woody Biomass is in that Forest? Why do we care?

By: Deanna Jaroche  djaroche@ebps.net
East Bridgewater High School, East Bridgewater, Massachusetts

Target grades: 10-12, Environmental Science

Unit Overview:
Students will brainstorm about how forests are important to people and other living organisms. They will take a survey about forests at the beginning and end of the unit and compare results. After students are introduced to the importance of forests they will discuss power point presentations and complete activities that will introduce them to measuring woody biomass. They will use the knowledge and skills acquired to collect data from a local forest and use data and observations to answer questions about the local forest.

Environmental Science is one semester at our school. Most students taking it are either in their Junior or Senior year. All Environmental students have taken Biology. The Environmental course begins with a review of ecology. The forestry topics introduced through Future Fuels of the Forest are ideal for developing a unit that will follow the ecology review because students will be able to apply ecology terminology and concepts when learning about biomass from forests. Some terms and concepts that will come up in this unit include: biodiversity, carbon cycling, carbon sequestration, climate change mitigation, and sustainability.

The idea for the unit came as a result of two events. First, a late night conversation with Christine Webster (she described a forestry project she used as an introduction to her environmental class) followed by the next day activity in which we took our field trip for measuring woody biomass (with Chris Webster). I thought this was a sound idea for getting students connected to their local land, which is the main idea.

The unit begins by determining student background about goods and services from global forests and then connects students to their local forest (land). The (pedagogy) methods used are cooperative teams, popcorn reading, journal writing, a field investigation, and report writing.

The lessons are designed for 68 minute class periods.

Sources Consulted

Day 1
1) Webster, Christine
Environmental Science teacher
Hudsonville, MI

The idea of developing an introductory forest field study unit came from a late night discussion with Christine Webster during Future Fuels Institute, July, 2010. The popcorn reading concept came from Christine Webster.

Popcorn reading is when the teacher begins reading material and then stops and calls on a student to continue with the reading. Christine noted that she purposely stopped at odd places, such as the middle of a paragraph, to aid in keeping student attention.

2) Project Learning Tree
Global Connections: Forests of the World
Secondary Environmental Education Module
Copyright 2008
The introductory lessons that allow students to consider the importance of forests in their life came from *Forests of the World* module. I used one lesson out of the module, but there is an excellent student handout titled, *The Forest Planet*, which would be good for the teacher to read as background, the students to read as background, or as a popcorn read and discussion in the classroom. It would be good to visit the PLT website and determine how to acquire the module, as reading the original lesson is helpful and there are many lessons and background that could be useful.

**Days 2 and 3**
In order to build background for how woody biomass forms and its potential use as a biofuel, three powerpoints from the *Future Fuels Institute* are used.
The powerpoints are:
*Biofuels in the Gas Tank: An Overview* by K.Schmitt
*Schmitt_BiofuelsInstitute_200...* by K.Schmitt
*Measuring Forest Biomass* by Chris Webster

**Day 4**
I recommend teachers read the following article as background before doing the activities below.
*Korzukhin,MichaelD., Ter-Mikaelian, Michael T., Forest Ecology and Management, 97 (1997); Biomass equations for sixty-five North American Tree Species*
The activity for this day is from *Future Fuels* and is attached.
*Tree Biomass Meast Lesson* activity: Putting on Pounds (Roth).

**Day 5**
The tree key used in this lesson came from *Future Fuels* material.
*Simple TreeKey ID* – Bill Cook, MSUE for practicing leaf identification

**Days 6 & 7**
The design of the field study itself came from a combination of Christine Webster and *Forestry Field Studies*, from NSTA press. Chapters 1 and 2 of this book provided background (popcorn reading) reading for students prior to going into the field. I was introduced to the book at Future Fuels Institute and then bought my own copy. It has supplied valuable background information for the field study portion of the unit.
Our own field trip with Chris Webster was also valuable in planning the field study.
*Forestry Field Studies*, NSTA Press
The following activity used on day 6 also came from Future Fuels and is attached.
*The Carbon in Trees.*

**Day 10**
Websites for carbon footprint calculation
Learning Objectives
Students will be able to state a minimum of two ways that forests are important to their lives.
Students will be able to define and apply the following terms when writing:
Woody biomass, biofuel, carbon sequestration, sustainable, mitigation of greenhouse gases
Students will be able to identify annual rings and use them to calculate how long it takes biomass to accumulate.
Students will be able to use a tree key to identify trees.
Students will be able to use the following terms when describing their local forest: overstory, substory, understory, softwood, hardwood, dominance, and codominance.
Students will be able to use tools appropriately to collect data in the field.
Students will be able to analyze data in order to determine the amount of above ground woody biomass in a local forest.
Students will be able to explain a connection between the woody biomass stored in the local forest and their personal habits.

State and National Benchmarks Addressed:
The following standards are addressed on days 1&2 when students are introduced to goods and services from global forests connecting to their lives.
Grades 9-12 National Academy of Sciences, Standard F (Science in Personal and Social Perspectives)
High School, National Council for the Social Studies, Standard IV (individual development and identity)

The following content standards are addressed through the powerpoint presentations and activities as students learn about the formation of woody biomass, how it is a potential energy source, and how to keep it sustainable.

Massachusetts Earth and Space Science
2. Energy Resources in the Earth System
Central Concepts: Energy resources are used to sustain human civilization. The amount and accessibility of these resources influence their use and their impact on the environment.
2.1 Recognize, describe, and compare renewable energy resources (e.g., solar, wind, water, biomass) and nonrenewable energy resources (e.g., fossil fuels, nuclear energy).
2.2 Describe the effects on the environment and on the carbon cycle of using both renewable and nonrenewable sources of energy.

Massachusetts Life Science Standards: High School Biology
6. Ecology
Central Concept: Ecology is the interaction among organisms and between organisms and their environment.
6.4 Explain how water, carbon, and nitrogen cycle between abiotic resources and organic matter in an ecosystem, and how oxygen cycles through photosynthesis and respiration.

The following frameworks are addressed when students write their rough draft, edit in cooperative teams, and rewrite a final draft of their report.

Massachusetts English Language Arts
For informational/expository writing:
19.26: Write well-organized essays (persuasive, literary, personal) that have a clear focus, logical development, effective use of detail, and variety in sentence structure.
21.8: Revise writing by attending to topic/idea development, organization, level of detail, language/style, sentence structure, grammar and usage, and mechanics.

21.9: Revise writing to improve style, word choice, sentence variety, and subtlety of meaning after rethinking how well questions of purpose, audience, and genre have been addressed.

22.9: Use knowledge of types of clauses (*main and subordinate*), verbals (*gerunds, infinitives, participles*), mechanics (*secolons, colons, hyphens*), usage (*tense consistency*), sentence structure (*parallel structure*), and standard English spelling when writing and editing.

Massachusetts Scientific Inquiry Skills Standards
The following scientific inquiry skills standards are addressed when preparing to do the field investigation, during the field trip, and in the post field trip calculations and summarizing.

SIS1. Make observations, raise questions, and formulate hypotheses.
- Observe the world from a scientific perspective.
- Pose questions and form hypotheses based on personal observations, scientific articles, experiments, and knowledge.
- Read, interpret, and examine the credibility and validity of scientific claims in different sources of information, such as scientific articles, advertisements, or media stories.

SIS2. Design and conduct scientific investigations.
- Articulate and explain the major concepts being investigated and the purpose of an investigation.
- Select required materials, equipment, and conditions for conducting an experiment.
- Identify independent and dependent variables.
- Write procedures that are clear and replicable.
- Employ appropriate methods for accurately and consistently
  - making observations
  - making and recording measurements at appropriate levels of precision
  - collecting data or evidence in an organized way
- Properly use instruments, equipment, and materials (e.g., scales, probeware, meter sticks, microscopes, computers) including set-up, calibration (if required), technique, maintenance, and storage.
- Follow safety guidelines.

Unit Classroom and Field Activities (11days):

Day 1: Introduce the importance of forests
This lesson is adapted from lesson #1, “Making a Global Connection”, from Project Learning Tree (PLT), *Forests of the World*. Please find this in references to read the original lesson and find variations and more details.

The following gives an overview of the lesson:

Begin the lesson displaying a poster of world forests (provided by PLT) in order to generate discussion about how students think their life is affected by forests. Lead them into developing a list of goods and services forests supply. I recommend the following addition to the lesson: *popcorn read* (see references) background information about forests given in the PLT, *Forests of the World*, module (or popcorn read any good article on forests and their usefulness). After this popcorn reading students may want to adjust their list of goods and services.
After developing the list, give students the survey (Opinionaire* provided by PLT) about forests. After students complete it, discuss the survey and what information the results provide. 

End class: Leave about 6 minutes at the end of class for students to write in their journal; noting any vocabulary, importance of the forest to their lives, and/or ecosystem concepts they used in the class discussion.

**Day 2: Introduce biofuels from woody biomass** as another forest product that was not mentioned yesterday (not found in PLT lesson).

As an introduction, use power point of K.Schmitt (*Biofuels in the Gas Tank: An Overview*). This is not intended to be a comprehensive unit on biofuel, just introduce students to biofuel as a possible resource from the forest. In addition, use the *Biofuels, Forests, & Carbon Sequestration* powerpoint (by Kristen Schmitt as well) as an opportunity to review the *carbon cycle*, discuss how carbon cycles in a forest, relationship to climate change, discuss *carbon sequestration*, and connect forestry, woody biomass, and biofuel. Discuss the terms renewable and nonrenewable and decide which apply to biofuel from woody biomass.

After the presentation, form cooperative teams. Have student cooperative teams design 3 questions on woody biomass/biofuel, carbon sequestration & relationship to forests to incorporate into the survey used yesterday.

Have each team write their questions on the board. As a class, eliminate any questions that repeat and then choose questions to add to the survey.

Break students back into individual seats and have them answer the survey question(s) developed.

**Day 3: Where does woody biomass come from?**

Use *Measuring Forest Biomass*, power point by Chris Webster, as a resource to review formation of woody biomass.

At the end of the presentation, leave time (about 10-12min) for students to write what they learned. Give them the following vocabulary to use in their writing and ask them to use drawings to help illustrate vocabulary and their ideas. Collect and assess their work. Use it as a formative assessment and go over any misinformation at the opening of class the following day.

Vocabulary for students to use in their 10-12minute summary:
- Crown, trunk, root system, respiration, photosynthesis, xylem, phloem, heartwood, sapwood, annual ring, productivity, diversity, woody biomass, biofuel, renewable

**Day 4: How long does it take to form woody biomass?**

Begin class by reviewing the writing they did at the end of class yesterday. Use this opportunity to discuss and clear up any misconceptions you discovered as a result of reading their closing exercise.

Give them back their papers and have them make corrections.

Follow the *Measuring Forest Biomass*, power point by Chris Webster, (Day 3) with *Tree Biomass Meast Lesson* activity: Putting on Pounds (Roth).

Introduce the activity so students understand the equation used (Teachers should read the article, *Biomass equations for sixty-five North American Tree Species*, to build background for the equation used in the above activity. Note that values for a and b are species dependent).

Form cooperative teams to do the activity. It would be good to use the same teams as day 2 for a smooth “flow” into the new activity.

Have the team turn in their paperwork.
Leave about the last 4 minutes for students to write, individually, what they learned from the activity (journal writing). Encourage them to include any new vocabulary and use drawings to illustrate vocabulary and their ideas. It will be an add-on to the journal writing done earlier in the lesson. Ask for volunteers to share some of their journal entries.

**Day 5: How do we identify trees in a forest?**
Have local leaf samples available for practicing identification. Model how to use the tree identification material. Use a tree key you are comfortable with. I used *Simple TreeKey ID* – Bill Cook, MSUE. (In addition, you may want to find keys specific to your local area.)
For assessment, let students form groups of 3 and approach each group with 3 leaves to identify. Circulate, checking in on teams, then (after about 6min) return to each team. Have the team walk you through one of the leaf identifications. State at the beginning of class that this will be the method of assessment.

**Days 6 & 7: How do we inventory a forest?**
These two days are split between the classroom and outdoors, with the first 20 minutes in the class and the remainder outside where there are trees available for measuring.
For the next 2 days, begin class with 10 minutes of popcorn reading to build background for the field study. A good resource is *Forestry Field Studies*, Chapter 1&2 (Forest History, Ecology, and Values and Principles of Forestry). At the end of the reading take a few minutes to answer questions and ask about the key concepts. Since this is background for going into the field, make certain students know the terms: *overstory, substory, understory, softwood, hardwood, dominance*, and *codominance*. Write the terms on the board and have students define from the context of the reading.

On day 6, use the remainder of class to familiarize students with taking tree measurements to determine the amount of carbon stored in trees. In order to accomplish this use the activity: *The Carbon in Trees.* Introduce the activity. Familiarize students with DBH (diameter at breast height). Breast height is 4.5ft off the ground. Have students measure 4.5ft from their feet to determine where DBH is on their body. When introducing the activity, note the use of the same equation used in *Putting on Pounds* activity.
*note: use any trees near the school for this activity.*
Have students work in pairs. Stop a couple minutes before the end of class. Check their progress by using a quick thumbs up or down to determine if students are comfortable with the measuring and calculations they did in the activity. Answer any questions.
Have students complete calculations for homework and collect their work the following day.
On day 7:
1) Begin class by reviewing and clearing up any problems with yesterday’s activity.
2) Make copies of *final assessment: guidelines for the report* (attached at the end of these lessons). Give students a copy and go through what is expected of them at the end of this process.
At this point in the unit, students know how to use a leaf key to identify trees and how to measure/calculate the DBH of a tree. It is time to organize the field trip.
3) Organize teams of 4 students. Have each group select a leader, recorder, timekeeper, and an equipment manager. Have them create a duty roster where each team member commits to doing certain tasks.
Have each team turn in their duty roster for you to check and hand back the next day.
- Note* A day or two prior to going into the field, go to the forest and mark off .1 acre study plots. Identify each plot with a letter (or number). The perimeter of the plot can be identified by tying biodegradable flagging to trees/brush/saplings on the corners and at several points along the sides.
Days 8 & 9: The field trip
Now they need to inventory of what the forest is composed and quantify the above ground woody biomass in the local forest.
The idea of this field study is to familiarize students with taking data in the field, get an overview of a local forest composition, calculate above ground woody biomass stored in a local forest, and relate quantity of biomass to their use of carbon.
To that end, I am going to have students collect the following data:
- Identify species of major trees (>5” dia)
- Measure the DBH of the major trees
- Define the vertical stand structure* by making a drawing of the trees as if they were looking at the forest from the side. In the drawing, label understory, subcanopy, overstory, dominants and codominants
*this comes from *Forestry Field Studies, NSTA Press
- Write observations of any wildlife

On day 8 & 9 go into the forest.
The forest I use is a 5-8 minute walk from the school so, I plan on arranging a double period the first day. This will give us almost 2 hours in the forest along with additional time to get out to the forest and back at the end. The 68min period the following day is used to complete any measurements and have enough time to share data and answer any questions.
For homework I will assign students to collect information about their utility bills. They are to ask their parents for average Kw hour/cost per month for electricity and average cost/month for heating fuel. This information will get used when they are concluding their field report (see day 10).

Day 10:
The teams will use their shared data to calculate the above ground woody biomass stored in pounds (lbs) per acre. It would be good to use Excel for this if you have computers available in the classroom.
The second half of class they will determine their carbon footprint and compare the value of their carbon footprint to the pounds of carbon stored in their forest. This also requires computers.
There are many carbon footprint sites to use. Below, I have listed 3 possibilities.
http://www.epa.gov/climatechange/emissions/ind_calculator.html
http://www.terrapass.com/carbon-footprint-calculator/
Homework: students should take out their copy of *final assessment: guidelines for the report*, given on day 7 and review it. Their assignment is to compile a rough draft of the report. Give this over a weekend or extend it to a 2 day assignment.

Day 11
Give students a new copy of the same survey they took on the first day of the lesson (include the portion that was developed in class). After students take the survey have them write about any answers that differed between day 1 and now.
You can extend this lesson by helping students use Excel to tabulate the results. They can calculate the frequency and percent of the responses.

When the rough draft of the report is due, put students in cooperative teams to compare rough drafts and develop questions to ask about the report. Give them time to adjust their rough draft. Collect and review rough drafts, then assign final report.
**Unit Assessment**

During the unit students will consistently write summaries of content to which they are exposed. I expect to check on these writings so they may be used as formative assessments and help identify any misconceptions. In addition, there are three activities that will be assessed: *Putting on Pounds*, leaf identification, and *Carbon in Trees*.

The final unit assessment is a report they will write which will require them to synthesize what they have learned. I am asking students to prepare it as a written report. It could also be presented as a powerpoint presentation.

**Final Assessment: The Report**

Organize the following data for the report:

1. Drawing with key (on graph or engineering paper) of the vertical stand structure
2. Tree species identification
3. dbh measurements
4. Observations of evidence of wildlife

Report Guidelines:

Upon completion of this study, construct a report with the following sections:

- **Introduction to the Field Study**: use notes, discussion, & powerpoints from class and at least one outside article to build background. Discuss the role of forests in the carbon cycle, carbon sequestration, and the importance of balancing forest maintenance with the taking and using of woody biomass.
- **Procedure**: Write a clear description of the procedure.
- **Data**: organized in the order above
- **Calculations**: write a subtitle for each type of calculation and show one example for each calculation done.

Tree circumference:

- Biomass for a whole tree
- Determine carbon content of a tree

Explain how carbon content for the entire study site was determined.

Include excel worksheet

**Discussion of data**: answer the following questions to guide your discussion.

1. Compare the vertical structure drawings made to the species and dbh data sheet. How do they compare? What is the type (species) and condition of the woody biomass?
2. Discuss how you determined the dominant and codominant species in the plot. Discuss whether they are hardwoods or softwoods and whether the carbon content is relatively high or low. To do this you should review the *Carbon in Trees* activity, look at the $a$ and $b$ values, which are species specific, and calculate high and low values, then compare to your site.
3. Discuss whether the species and the biomass calculations indicate if this forest is a good candidate for biofuel harvesting.
4. Cite data/observations when explaining the biodiversity of the habitat and why that biodiversity is necessary in order for the forest to stay healthy and produce more biomass. If all trees greater than 5” were removed, how would your vertical structure diagram change? Do a new drawing to estimate the change. Do you think the wildlife you observed would be affected by the tree removal? State why or why not, using your data.

**Conclusion**:

Choose a minimum of one goods and one service from our initial lesson and discuss how it relates to this forest and to you. Compare the carbon content of the forest study area to your estimated carbon footprint. How does it compare?

What questions do you have that were not answered? How would you change this study? Design a question you would ask about this forest and explain how you would investigate it.
Activity: Putting on Pounds
By Amber Roth <amroth@mtu.edu>, Michigan Tech School of Forest Resources & Environmental Sciences

Description: As forest resources are increasingly being used for bioenergy and biofuel industries, foresters must be able to calculate the amount of mass, or biomass, for standing trees in a forest. To do this, foresters calculate the biomass of individual trees and project these estimates across a forest stand. For this activity you will estimate the tree biomass accumulated during the lifetime of a student in your class.

Objectives: Estimate tree biomass and average annual growth rate

Materials Needed:
Tree cookie (from tree older than your student)
Metric ruler and/or tape measure
Calculator
Pencil
Allometric equation for tree species of cookie used

Instructions:

Part 1: Calculate biomass for whole tree

Step 1: With pencil, draw two perpendicular lines that pass through the cookie’s pith as indicated in the diagram. Make all measurements in this activity along those lines (guides). Measure the two diameters in cm and calculate an average. This is the average diameter at breast height, D.

Diameter 1: _______ cm
Diameter 2: _______ cm
Average 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.

For aspen cookies, use the equation \( M = 0.08 D^{2.35} \)
For balsam fir cookies, use the equation \( M = 0.17 D^{2.16} \)

Insert your total tree biomass (\( M \)) estimate in Part 3.

Part 2: Calculate biomass accumulated prior to the birth of your student (pre-birth tree biomass).

Step 1: From the bark inward, count the number of summer wood (dark) rings equal to the age of your student. Mark this ring with a pencil mark at the four places where it intersects your guides.
Measure inner diameter of the wood between your pencil marks. Take a second measurement at a right angle to the first.

Inner diameter 1: _______ cm  
Inner diameter 2: _______ cm

Step 3: Measure width of bark. Take a second measurement 90 degrees from the first.

Bark Width 1: _______ cm  
Bark Width 2: _______ cm

Step 4: Add together all measurements from Steps 2 and 3 and divide by two. This is the average diameter at breast height estimate for this tree when your student was born.

Average diameter: _______ cm

Step 5: Calculate biomass for tree growth before your student was born (pre-birth tree biomass). Use the same allometric equation as in Part 1.

For aspen cookies, use the equation $M=0.08 \ D^{2.35}$  
For balsam fir cookies, use the equation $M=0.17 \ D^{2.16}$

Insert your pre-birth tree biomass estimate ($M$) in Part 3.

**Part 3:** Calculate biomass accumulated during your student’s lifetime and the average annual growth rate during that time.

Step 1: To calculate the total biomass accumulated during a student’s life, subtract the pre-birth tree biomass from the total tree biomass.

Total tree biomass from Part 1: _______ kg  x 2.2 lbs/kg = _______ lbs  
Pre-birth tree biomass from Part 2: _______ kg  x 2.2 lbs/kg = _______ lbs  
Tree biomass accumulated during a student’s life: _______ kg  x 2.2 lbs/kg = _______ lbs

Step 2: To calculate the average annual growth rate during a student’s life, divide the tree biomass (lbs) accumulated during the student’s life by the age of your student (used in Part 2).

Average annual growth rate during a student’s life: _____ lbs/yr
Activity: 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).

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.