Tree Biomass & Carbon Analysis

Purpose

To provide students with an opportunity observe and understand patterns and trends in their field measurement data and the additional data achieved by using allometric equations to determine biomass and carbon storage.

Overview

Students will work with a partner or small group and will explore the field data as analyzed and synthesized by GLOBE. Students will consider a variety of questions that directly address the calculations in the spreadsheet and will discuss how these findings relate to further explorations of the local carbon cycle. Finally, students will answer some culminating questions that address the field unit's major concepts, including the calculation of how much carbon is stored in the forested area of the schoolyard.

Student Outcomes

Students will be able to:

- Examine their field data and how it was used to calculate sample site biomass and carbon storage
- Work with a partner or small group to answer a variety of application type questions help them analyze and interpret their data
- Communicate their understanding of the field data analysis in a class discussion
- Use their Tree Biomass Analysis to complete their research questions

Questions

Unit (Examples)

- How much carbon is being stored in the trees near my school?
- Is there more carbon in the global population or the vegetation of ____?
- How does carbon uptake in our schoolyard compare to carbon emissions from our school? (at least 2 years worth of data needed)
- How do carbon stocks at our sample site relate to our study of the global carbon cycle?

Content

- What is the current carbon stock of trees in our sample site?

Science Concepts

Grades 9-12

Scientific Inquiry

- Design and conduct a scientific investigation
- Use appropriate tools and techniques to gather, analyze, and interpret data
- Use mathematics in all aspects of scientific inquiry

NGSS (Black-covered directly, gray-addressed, but not directly covered)

- *Disciplinary Core Ideas*
  - Gr.6-8: ESS3.A
  - Gr. 9-12: ESS3.A
- *Science and Engineering Practices*
  - Developing and using models
  - Analyzing and interpreting data
  - Using mathematics and computational thinking
  - Constructing explanations

Time/Frequency

45-60 minutes

Level

Secondary (High School)

Materials and Tools

- At least one computer with Excel, or a smiliar spreadsheet program.
- Analyzed data spreadsheet downloaded from GLOBE (http://datasearch.globe.gov-*see instructions below*)
- Markers for white board
- Copies of Jenkins et al. 2003 "National Scale Biomass Estimators for United States Tree Species", Forest Science 49:12-35 (OPTIONAL)
- LCD projector
- Copies of *Tree Biomass Analysis Questions*

Prerequisites

- Familiarity with spreadsheets
- Field Data Entry completed
- Understanding of unit concepts: how is

Welcome Introduction Protocols Learning Activities Appendix carbon stored in trees, how and why circumference is measured, allometry, biomass units

Preparation

- Gather all materials.
- Write essential, unit, and content questions somewhere in the classroom.
- Download your data with completed analysis from GLOBE (http://datasearch.globe.gov). **Note: The spreadsheet may be easier for students to understand if you rename the headers before giving it to them. See CarbonBiomassDataExample.xls on the webpage for suggestions and interpretation.*

Background

Scientists use electronic spreadsheets, such as Microsoft Excel, in many fields of study. In general, the purpose of spreadsheets is to help improve the scientists' understanding of the data and to allow for an in-depth exploratory analysis. In addition, scientists can use spreadsheets in order to produce a variety of graphs to further analyze compiled and raw data.

This kind of analysis allows scientists to develop an understanding of their data, as well as further the development of additional research questions. As this lesson is taught it may be helpful to emphasize the GLOBE Model for Student Scientific Research (where have students arrived at in the research cycle?).

For scientific background of the concepts addressed in this activity see the introductory lessons: *BiomassUnits* and *Allometry: Not A Llama Tree.*

How To Download Data From GLOBE

Once your data are entered on the GLOBE website (for help with this, see the *Carbon Cycle eTrainings* and the *Data Entry* guide on the Carbon Cycle webpage), **the calculations to convert your raw data to biomass and carbon storage values will be completed for you.**

To download your data, complete with carbon and biomass estimates:

1. Go to http://datasearch.globe.gov (*Can also be found from globe.gov by clicking 'GLOBE Data' - 'Retrieve Data')*
2. Read through the instructions to familiarize yourself with this tool.
3. Under Data Filters, click 'Select Protocols'
4. Scroll down to find the Biosphere section, click 'Carbon Cycle', and click 'Add Protocols'
5. Select a data range that includes the date in which you collected data.
6. Under Site Filters, click 'School or Teacher', and select your school.
7. If you have multiple Carbon Cycle field sites, select the individual site in which you are interested under 'Site Name'
8. Click the green 'Apply Filter' button in the top left.
9. Click 'Obtain Measurement Data' *(Note, data will be downloaded for the whole list you see, if your school is not the only one listed, refine your filters).*
10. The button will update, and you can click 'Download Measurement Data' to download a .csv, which can be opened in a spreadsheet tool such as Excel.

** Note, you can also use the GLOBE Visualization System (vis.globe.gov) to view your and other school's Carbon Cycle data on a map. Use the Layers feature to choose Biospere, then Carbon Cycle, and then select the Protocol(s) in which you have interest. Widen your data range (top-center) to see all available data.*

What To Do and How To Do It

ENGAGE	**Grouping:** Class	**Time:** 10 Minutes

- Using field investigation data sheets and all handouts concerning tree circumference, biomass, allometry, fieldwork, and the schoolyard have students consider the research or unit question written on the board: example - How does our sample site's carbon stock relate to our study of the global carbon cycle?

- Ask students to list the calculations (in general) that they will need to do in order to answer this question. For example, students should identify that tree circumference will have to be converted to tree biomass using allometric equations. Students should list ideas using a flow chart or rough procedure, and record questions in their science notebook.
- Students share their ideas and questions. During class discussion, review the concepts students are struggling with before moving on: how carbon is stored in trees, primary factors that limit tree growth and carbon uptake, why and how circumference/DBH is measured, units of biomass, and how biomass is calculated from DBH using allometry.

EXPLORE	**Grouping:** Pairs	**Time:** 45 Minutes

- Give students a brief tour of the spreadsheet and point out any relevant features of Excel they may not know.
- Students use the *Tree Biomass Analysis Questions* to become familiar with the spreadsheet and outcomes of the data analysis.
  - **NOTE:** The questions are fairly basic, but this is a great opportunity to get students thinking about what they have learned and what it means. Encourage students to use graphs/figures to display their data in a meaningful way. These questions also prepare students to answer the broader essential and unit questions or their own research questions.

EXPLAIN	**Grouping:** Class	**Time:** 10 Minutes

- Discuss student responses to the initial questions, using the white board to document the range of student responses and to clarify concepts and skills.
  - Suggestion: have a few "math minded" students present their methods for making calculations and conversions.

ELABORATE	**Grouping:** Pairs	**Time:** Varies

- If your students collected shrub/sapling and/or herbaceous vegetation data and have not yet investigated that data using the associated analysis questions, do so now.

EVALUATE	**Grouping:** Individual	**Time:** 35 Minutes

- Students thoughtfully respond to the *Field Wrap-Up Questions* (on the GLOBE Carbon Cycle webpage in the Resources section), which are designed as a formative assessment
- Collect and read, or hold a class discussion to discover errors in thinking that need to be addressed before a summative assessment such as the *Field Unit Assessment* (also on the GLOBE Carbon Cycle webpage in the Resources section).

Assessment

- *Field Unit Assessment* (written questions)

Extensions

- Emphasize the inquiry cycle, and to encourage students to develop their own researchable question based on the field plot data and calculations available through the Excel spreadsheet. Offer students time to pursue their own question, providing access to additional resources, including the library and internet. (See *Classroom-InquiryStudentResearch, Pose Research Questions, Data Interpretation,* and *Identify New Research Questions*.)
- Work with the *Biomass Accumulation Model* to estimate biomass and carbon storage for your location. How do model results compare to field results?

TEACHER VERSION

(Suggested student responses included)

Tree Biomass Analysis Questions

Part 1: Understanding the Data

Using the shrub/sapling biomass data in the datasheet provided by your teacher, explore and compare tree dbh, biomass and carbon among the tree species in your sample site. Consider several ways of looking at the data (e.g. biomass totals, biomass by percent, carbon storage by species group). You will need to continually refer back to the spreadsheet while answering these questions. Your previous work on biomass units, how to measure trees and allometry may also be helpful in understanding the data.

Record plot summary data. Remember to include units.

Tree Biomass	Tree Carbon Storage

1. Describe or show the calculations for the relationship between biomass and carbon storage.

   Biomass (g/m_2) x 50% = Carbon storage (gC/m^2)

2. Define allometry. Explain how allometry was used to calculate forest biomass.

   Allometry is the study of an organism's parts in relation to its whole. We used allometric equations for different species groups to relate an individual tree's circumference (DBH) to its biomass.

3. Using the basic allometric equation for biomass below and the *Biomass Coefficients Table* at the end of the worksheet, provide an example of how the equation works. Select one tree from your sample site and show your work below (e.g. fill in the B0 and B1 coefficients for the species group, and the calculated diameter value from the spreadsheet).

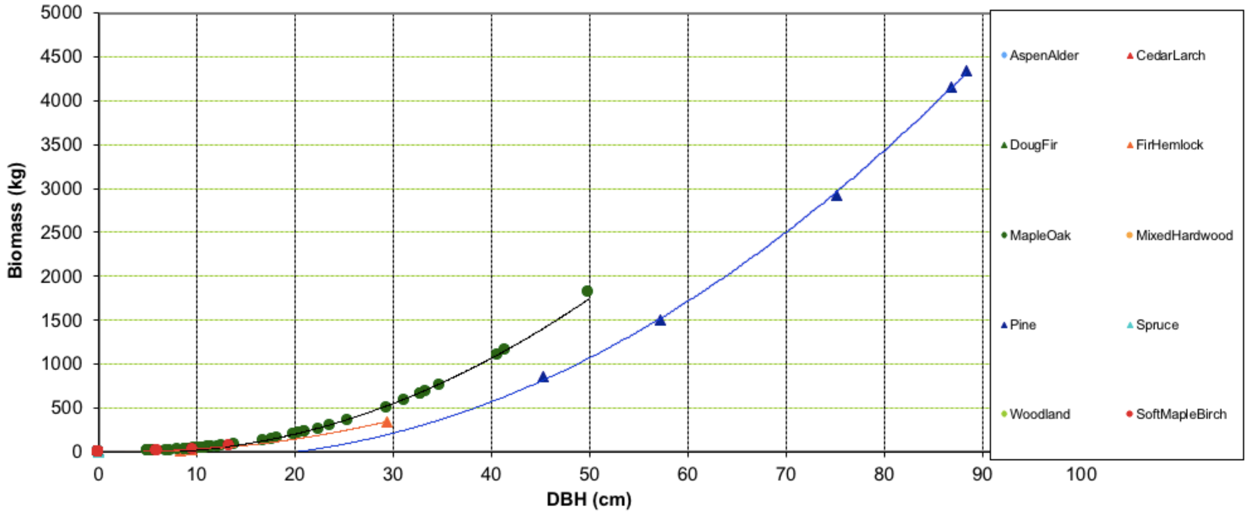
   (See the species group allometry table at the end of the worksheet.)

4. What is the circumference of the largest tree? *Depends on the field data*
   a. What is its biomass? *Total biomass of the largest tree.*
   b. How much carbon is that? *50% x biomass.*

6. For the **same diameter tree** is there more total biomass in evergreen or deciduous trees? Will this always be the case?

   This answer will depend on the species groups present on your plot. You may direct students to the DBH vs. Predicted Biomass graph by Jenkins et al. at the end of the student worksheet to help them answer this question.

7. For your plot compare carbon storage by the different species groups. Which species groups have greater carbon storage and why?
   Have students look at the biomass by species group. They should remember that biomass and carbon storage are directly related and therefore species groups with higher biomass will have greater carbon storage. You can also show them how to use Excel to graph biomass by dbh (see example below, and in the CarbonBiomass-DataExample.xls available on the GLOBE Carbon Cycle webpage).



8. What is one additional thing you notice about the data?

9. Name one thing that interests or surprises you about the data.

10. What questions do you have about the data? Be thoughtful.

Part 2: Extension Questions

1. In general, how does the size of **each** biomass component (stem, foliage, branches) change, as DBH gets larger? Explain why this might be the case?
   Within each species group, the size of all biomass components increases as DBH gets larger. However the DBH/biomass relationship differs between species groups so students should always indicate which species group they are discussing.

2. Do the biomass components in evergreen and deciduous trees change in the same way as DBH increases?
   This answer will depend on the species groups present on your plot. If students are having trouble remind them they can use graphs of the data at the end of the work-sheet to help answer these questions.

Name: Date:

Tree Biomass Analysis Questions

Part 1: Understanding the Data

Using the shrub/sapling biomass data in the datasheet provided by your teacher, explore and compare tree dbh, biomass and carbon among the tree species in your sample site. Consider several ways of looking at the data (e.g. biomass totals, biomass by percent, carbon storage by species group). You will need to continually refer back to the spreadsheet while answering these questions. Your previous work on biomass units, how to measure trees and allometry may also be helpful in understanding the data.

1. Record plot summary data. Remember to include units.

Tree Biomass	Tree Carbon Storage

2. Show the calculation for the relationship between biomass and carbon storage.

3. Define allometry. Explain how allometry was used to calculate forest biomass.

4. Using the basic allometric equation for biomass below and the *Biomass Coefficients Table* at the end of the worksheet, provide an example of how the equation works. Select one tree from your sample site and show your work below (e.g. fill in the B0 and B1 coefficients for the species group, and the calculated diameter value from the spreadsheet).

Biomass = Exp(B0 + B1 ln dbh) *where ln = log base e (or 2.718282), and dbh is in cm*

5. What is the circumference of the largest tree?

   a. What is its biomass?

   b. How much carbon is that?

6. For the **same diameter tree** is there more total biomass in evergreen or deciduous trees? Will this always be the case?

7. For your site, compare carbon storage by the different species groups. Which groups have greater carbon storage and why?

8. Name one thing that interests or surprises you about the data **OR** note one additional thing you notice about the data.

9. What is one question you have about the data? Be thoughtful.

Predicted Biomass Graph

(Jenkins et al., 2003)

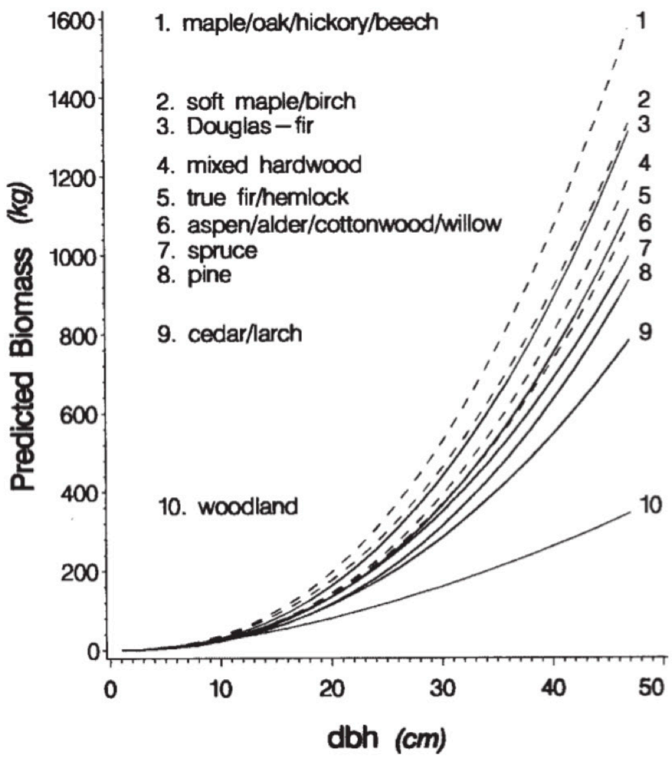


Figure 1. Graphs of ten equations for predicting total aboveground biomass by species group. Hardwoods are represented by dashed lines, softwoods by solid lines.

Biomass Coefficients Table

	Coefficients for Aboveground Biomass	
Species Group	**B0**	**B1**
AspenAlder	-2.2094	2.3867
CedarLarch	-2.0336	2.2592
DougFir	-2.2304	2.4435
FirHemlock	-2.5384	2.4814
MapleOak	-2.0127	2.4342
MixedHardwood	-2.4800	2.4835
Pine	-2.5356	2.4349
SoftMapleBirch	-1.9123	2.3651
Spruce	-2.0773	2.3323
Woodland	-0.7152	1.7029
LowWoodDensitySpecies	-2.5356	2.4349
MediumWoodDensitySpecies	-2.4800	2.4835
HighWoodDensitySpecies	-2.0127	2.4342

Part 2: Extension Questions *(use your data and the graphs below to help answer these questions)*

1. In general, how does the size of **each** biomass component (stem, foliage, branches) change, as DBH gets larger? Explain why this might be the case?

2. Do the biomass components in evergreen and deciduous trees change in the same way as DBH increases?

Deciduous Trees:

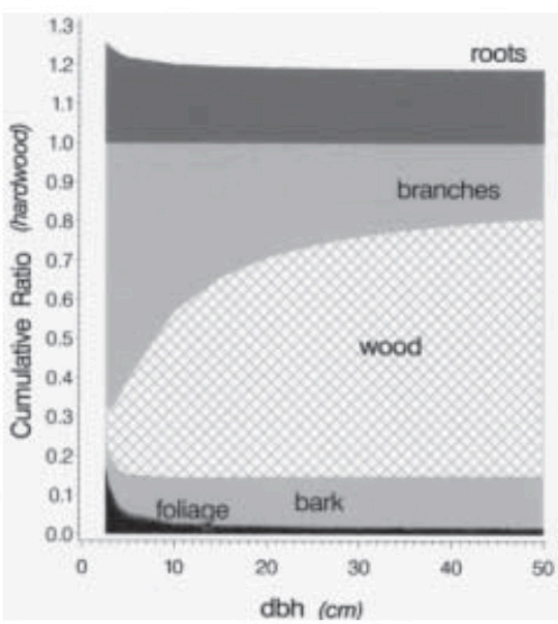


Figure 5. Proportion of aboveground biomass calculated from our generalized component ratio equations for hardwood foliage, stem bark, stem wood, branches, and roots.

Evergreen Trees:

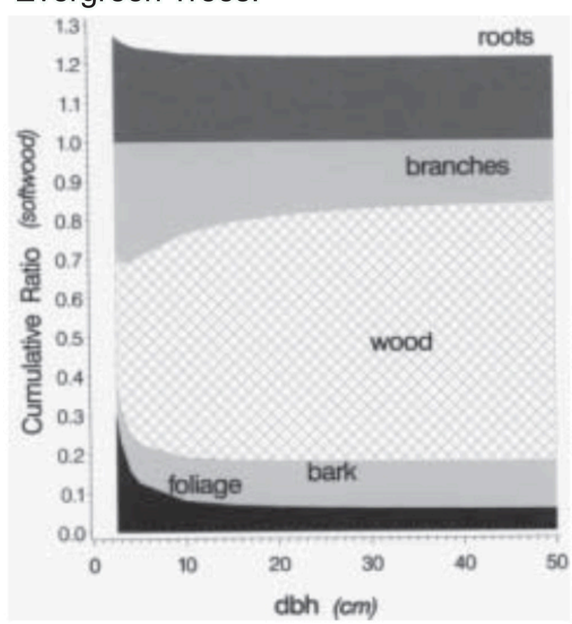


Figure 6. Proportion of aboveground biomass calculated from our generalized component ratio equations for softwood foliage, stem bark, stem wood, branches, and roots.

Graphs from Jenkins et al. 2003