**GLOBE Carbon Cycle**

# Allometry: Not A Llama Tree

Purpose
- To introduce the concept of allometry, a method for calculating tree biomass, using a simple measurement, circumference or diameter.

Overview
In this activity students will measure the height, foot length and arm span of other students in the class and graph them in relation to one another to recognize how allometry can be used to estimate the size of one part of a living thing if another part size is known. Students will then apply their understanding of allometry to the study of biomass and carbon storage in trees.

Content Question
How is allometry used to calculate forest biomass?
*Sub-Question*
How are allometric equations developed?

Student Outcomes
- Students will develop an allometric equation for human height by measuring each other for height, foot length and arm span.
- Students will validate the human allometric equation(s) by determining the heights of individuals not used in the equation development.
- Students will relate human allometry to tree allometry.
- Students will understand why allometric equations are different for different groups of tree species.

Science Concepts
5-8 & 9-12
Change, constancy, measurement
Form and function
Abilities necessary to do scientific inquiry
5-8
Diversity and adaptation of organisms

Time
60 - 90 minutes

Level
Middle & High School

Materials and Tools
- 50 meter tape measure OR meter stick OR flexible measuring tape (metric)
- Calculator
- Notebook and pencil
- Graph paper OR computers with a spreadsheet application
- National-Scale Biomass Estimators for United States Tree Species, Jenkins et al. [Optional] Available:
  http://www.fs.fed.us/ne/newtown_square/publications/other_publishers/OCR/ne_2003jenkins01.pdf
- Species Groups List adapted from Jenkins et al. paper

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- Predicted Biomass Graph adapted from Jenkins et al. paper
- Tree Identification Guide or online equivalent (http://plants.usda.gov/)

*NotALlamaTree_example.xls* – includes sample dataset, printable datasheet and spreadsheet template

Preparation
- Review Species Group List and Predicted Biomass Graph to be able to answer student questions.
- UnderstandingAllometry_example.xls
- Copy student directions sheets (1 per student)
- Copy Species Group List and Predicted Biomass Graph (1 per group of 3)

Pre-requisites
Knowledge of DBH and Biomass (See: *HowToMeasureTrees.doc, BiomassUnits.doc*)

Background
If biomass is a key unit of measurement for understanding ecosystems, it is essential that we have a way to measure it. Logically, it makes no sense to measure the mass of trees by cutting down and weighing them on a scale every time. This would ultimately mean destroying the ecosystem we are trying to understand. Because this is the case, over time, scientists have cut down many trees of different sizes and species to look for relationships between parts of the tree that can be measured easily, such as DBH or height and the whole tree's biomass. The study of this kind of relationship is known as **allometry**.

Allometry is the study of an organism's growth as is used to describe the relationship between an organism's size and the size of any of its parts.

Allometric relationships can be studied during the growth of a particular organism, as a comparison between organisms of the same species or between organisms of different species. Allometric relationships are best shown on a graph where body size is depicted on the y-axis and body part size is depicted on the x-axis. As individual measurements are added to the graph, a scatter is produced. The average through that scatter (a regression line) determines the allometric equation.

Allometric equations often take the form of:

y = mx + b (line equation)

where y = body size, x = body part size, m = slope, and b = y-intercept value of a straight line.



Not all allometric relationships are linear, such as the relationship between tree DBH and tree biomass. When this is the case, a nonlinear equation, such as log or natural log might be used. Log equations and their transformations can be confusing. For clarification see the Log Calculations Example in the appendix and/or talk to a math teacher.

ln(y) = a + b[ln(x)]
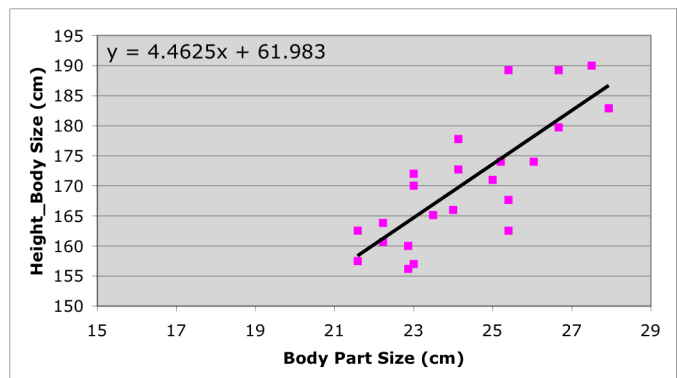
where y = body size, a and b are coefficients and x = body part size
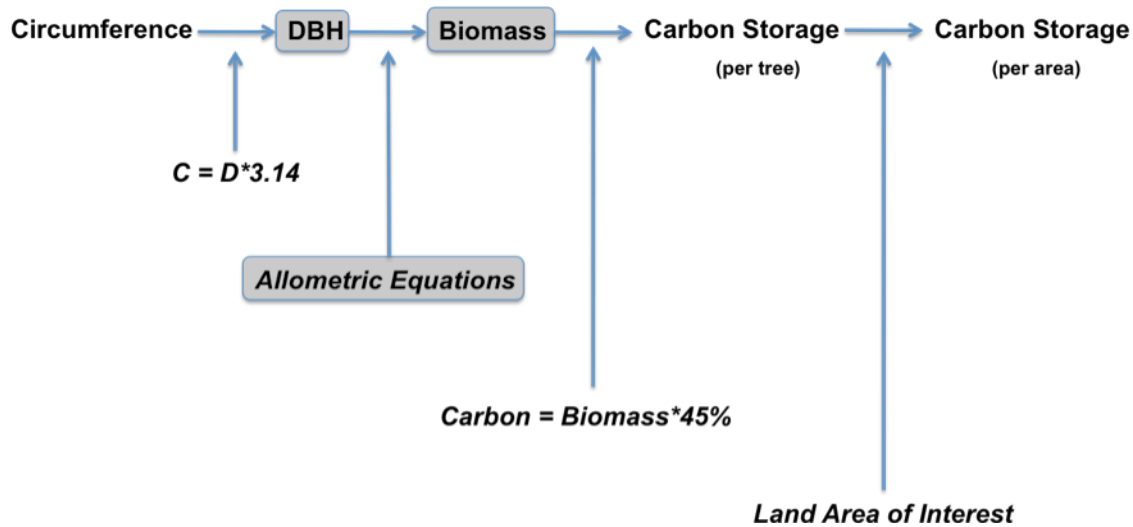
A log transformation will allow you to solve for y.

$y = e^{(a + b[\ln(x)])}$

The exact form of equations students will see in the Plot Biomass Analysis is:
biomass = Exp(B0 + B1 ln dbh), where ln = log base e (or 2.718282).

If your students participate in the field data collection and analysis, they will need to understand the basics of tree allometry. During *Sample Site Biomass Analysis* students will be able to view their circumference field data in the spreadsheet calculator and a version of the above equation, which is used to calculate biomass. Although a similar equation exists for all trees, they will differ slightly for different tree species groups. These equation differences between species groups largely exist due to differences in tree wood density (see Extensions). For additional information you can read the National-Scale Biomass Estimators for United States Tree Species (Jenkins et al. 2003) paper. Figure 1 (Predicted Biomass Graph) and Appendix A (Species Groups List) are of particular interest.

The Understanding Allometry activity addresses the connection between the two previous concept activities, DBH and biomass. By the end of the activity students should understand why they are collecting tree circumference data and how real data are used to create valuable equations.

What To Do and How To Do It

| | Student Grouping: Whole Class | Time: 10 minutes |
|---|---|---|
| **ENGAGE** | <ul><li>Students share ideas about how vegetative biomass is measured/calculated.</li><li>Discuss the implications of weighing trees in order to calculate biomass. Discuss that allometric equations allow scientists to calculate tree biomass without having to cut down trees.</li><li>Do humans have allometric relationships? Can you think of any examples?</li></ul> | |
| | Student Grouping: Small Groups | Time: 20 minutes |
| **EXPLORE** | <ul><li>Students follow the Student Directions procedure in Part 1a for measuring and recording the height, arm span and foot length of each group member.<ul><li>**Note:** Middle school students are still growing so there may not be a very clear relationship between height and the other variables. You may choose to have students ask other teachers to participate in their study.</li></ul></li><li>Compile student measurements. Measurements can be tallied on the board or in the *AllometryNotALlamaTree_example.xls* spreadsheet template.<ul><li>This may be a good opportunity to have students practice using spreadsheets for data entry and graph creation.</li></ul></li><li>Graph class data (can be done individually or as a class).<ul><li>Data can be graphed on graph paper or in the spreadsheet file.</li><li>Students should graph height versus arm span AND height versus foot length.</li></ul></li><li>Students use the data to answer thought questions in Part 1b of their student directions.</li></ul> | |
| **EXPLAIN** | Student Grouping: Whole Class | Time: 15 minutes |
| | <ul><li>Examine data and graphs as a class. Discuss answers to questions 1-3.<ul><li>If your students have studied line equations (y = mx + b) show them how their data just helped to create a line equation that can be used to predict the height of people that have not yet been measured. To emphasize this point see the Extension section.</li></ul></li><li>Discuss how this activity is related to the calculation of biomass using DBH.<ul><li>Students share answers to question 4: How does this activity relate to measuring trees? Also refer back to discussions from the Engage section.</li><li>Because there are differences between trees (wood density), there have been many equations developed, just like the equation developed for class. To make forest biomass assessments a little easier, Jenkins and others have grouped all United States trees into 10 species groups, and each species group has a slightly different equation.</li><li>Share the Predicted Biomass Graph adapted from the Jenkins et al. 2003 paper.</li></ul></li></ul> | |
| **ELABORATE / INVESTIGATE** | Student Grouping: Individual | Time: 20 minutes |
| | <ul><li>Students examine the Predicted Biomass Graph and Species Groups List in greater detail using questions in Part 2 of the student directions to ensure understanding of the species groups and differences in predicted biomass between groups.<ul><li>Students will also need access to the Internet or a tree identification guide for this section.</li></ul></li></ul> | |
| **EVALUATE / WRAP-UP** | Student Grouping: Whole Class | Time: 10 minutes |
| | <ul><li>Discuss the answers to questions in Part 2.</li></ul> **See activity example with sample calculations and answers in *AllometryNotALlamaTree_example.xls.* | |

Extension

- Analyze class data (height vs. arm span and height vs. foot length) to find an actual regression line (y = mx + b). Measure other students and/or teachers to see if your line equation makes accurate predictions of body measurements other than those used to make the original equation. (You may choose to have these data available ahead of time, e.g. from the sample data in *UnderstandingAllometry_example.xls*, from other teachers at your school, or from previous years or other classes.)
- Wood Density. After students have seen that tree species are divided into groups based on their DBH-Biomass relationships, they may have questions about why one equation cannot be used for all trees or why particular trees are grouped with other trees. The answer to these questions is wood density. To examine wood density, buy or make blocks of wood of different species. First have students mass each block. Then measure the length, width, and height of each block to find volume. Divide mass by volume to find the density of each wood species.

Assessment

- How would you use DBH and species/species groups to calculate the carbon storage for one tree? Draw, diagram or describe.

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**TEACHER ANSWERS**
Student Worksheet:
Allometry - Not A Llama Tree

Content Question: How is allometry used to calculate forest biomass?

Part 1a: Measuring Human Allometry - Procedure
1)  Form groups of three.

2)  Measure (in centimeters) the height, arm span and foot length of one student (hint – use a wall to help you).
    a)  Height: Student removes shoes.  Partners measure from the floor to the top of the head
    b)  Arm span: Student extends arms straight out to the side.  Partners extend the measuring tape across their back measuring from finger tip to finger tip.
    c)  Foot length: Place the measuring tape on the floor.  Student stands with the back of their heel on 0cm and reads the value at the front of their big toe.

3)  Record your personal data.

| Height (cm) | Arm Span (cm) | Foot Length (cm) |
|---|---|---|
|  |  |  |

4)  Repeat the measurement and recording process for all group members.

*See sample class data in Understanding Allometry_Example.xls*

Part 1b: Measuring Human Allometry – Questions
Use the class data to create graphs that help you understand the relationship between your measured variables, height, arm span, and foot length.  Use your graphs to answer the following questions.

1)  What do you notice about the relationship between height and arm span?

*Arm span and height have a strong linear relationship, close to 1:1.  As arm span increases, height increases by the same amount.*

2)  What do you notice about the relationship between height and foot length?

*Foot length is also linearly related to height.  As foot length increases, height increases.*

3)  Can you draw an "average" line through your data?
    a)  Is this line meaningful or is there a lot of scatter in the data?
    b)  Why might there be a lot of data scatter?

*There is not a great amount of scatter in the sample data because all the measured participants are adults.  Because students are still growing the relationships between foot length vs. height and arm span vs. height will likely be more scattered.*

4)  How might scientists, such as yourself, use a similar approach to determine tree biomass?

*Thought question.  Students should use their knowledge from the WhatisDBH? and BiomassUnits to make a good guess.  Measuring DBH can help us estimate biomass if there are established equations.*

Part 2: Tree Allometry
Use the Species Groups List and Predicted Biomass Graph adapted from the National Scale Biomass Estimators Paper.  Explore the follow questions and discuss answers with your peers.  Record your answers in your science journal.

1)  Review the Species Groups List.
    a)  What are the 10 species groups?

        *AspenAlder, CedarLarch, DougFir, FirHemlock, MapleOak, MixedHardwood, Pine, SoftMapleBirch, Spruce, Woodland*

    b)  How many of them are broadleaf?  How many are conifers?

        *4 broadleaf, 4 conifer, woodland has both*

    c)  Which species groups are you most likely to find in your region?

        *This will depend on your location.*

    d)  Examine some of the species that fall into each group, can you picture what any of these trees look like?  Use the Species Groups List and a tree ID guide to find out a little more about 3 trees you are likely to find during a field investigation of your schoolyard.  Describe or draw some of their primary characteristics.

        *Student's answers will vary depending on your location and the trees they select to investigate.*

2)  Examine the Predicted Biomass Graph.
    a)  Which species group has the highest predicted biomass for a DBH of 30cm?

        *MapleOak (maple/oak/hickory/beech)*

    b)  For a predicted biomass of 1000kg what is approximate DBH of the spruce group?

        *47cm*

    c)  Do you notice any patterns between species groups?

        *MapleOak biomass increases more quickly with small changes in DBH.*
        *The Woodland group has a very different relationship between biomass and DBH than all the other groups.*

*On the whole the relationship between biomass and DBH is very similar between all groups (except Woodland).*
*\*Students may see a variety of other patterns.*

d) The graph represents the predicted biomass at a given DBH for the whole tree. How do you think the percentage of biomass for individual tree components (stem, branches, leaves) might change as the same tree gets bigger? Explain your answer.

*This is a thought question with no right or wrong answer. View the Jenkins paper, figures 5 and 6, which show the change in biomass components with an increase in DBH. Students will revisit this concept during their field data analysis.*

Name:                                                                                    Date:

# Student Worksheet:
## Allometry - Not A Llama Tree

Essential Question: How is allometry used to calculate forest biomass?

Part 1a: Measuring Human Allometry - Procedure
1) Form groups of three.

2) Measure (in **centimeters**) the height, arm span and foot length of each student in the group (hint – use a wall to help you).
   a) Height: Student removes shoes.  Partners measure from the floor to the top of the head
   b) Arm span: Student extends arms straight out to the side.  Partners extend the measuring tape across their back measuring from finger tip to finger tip.
   c) Foot length: Place the measuring tape on the floor.  Student stands with the back of their heel on 0cm and reads the value at the front of their big toe.

3) Record your data.

| Height (cm) | Arm Span (cm) | Foot Length (cm) |
|---|---|---|
|  |  |  |
|  |  |  |
|  |  |  |

4) Enter your group's data into the class data table.

Part 1b: Measuring Human Allometry – Questions
Use the class data to create graphs that help you understand the relationship between your measured variables, height, arm span, and foot length.  Use your graphs to answer the following questions.

1) What do you notice about the relationship between height and arm span?



2) What do you notice about the relationship between height and foot length?



3) Can you draw an "average" line through your data?
   a) Is this line meaningful or is there a lot of scatter in the data?
   b) Why might there be a lot of data scatter?



4) How might scientists, such as yourself, use a similar approach to determine tree biomass?

Part 2: Tree Allometry
Use the Species Groups List and Predicted Biomass Graph adapted from the National Scale Biomass Estimators Paper.  Explore the follow questions and discuss answers with your peers.  Record your answers in your science journal.

1)  Review the Species Groups List.
    a)  What are the 10 species groups?
    b)  How many of them are broadleaf?  How many are conifers?
    c)  Which species groups are you most likely to find in your region?
    d)  Examine some of the species that fall into each group, can you picture what any of these trees look like?  Use the Species Groups List and a tree ID guide to find out a little more about 3 trees you are likely to find during a field investigation of your schoolyard.  Describe or draw some of their primary characteristics.

2)  Examine the Predicted Biomass Graph.
    a)  Which species group has the highest predicted biomass for a DBH of 30cm?
    b)  For a predicted biomass of 1000kg what is approximate DBH of the spruce group?
    c)  Do you notice any patterns between species groups?
    d)  The graph represents the predicted biomass at a given DBH for the whole tree.  How do you think the percentage of biomass for individual tree components (stem, branches, leaves) might change as the same tree gets bigger?  Explain your answer.

# Species Groups List

(adapted from Jenkins et al. 2003, Appendix A)

| Species Group | Common name | Genus | Species |
|---|---|---|---|
| AspenAlder | Balsam poplar | Populus | balsamifera |
| AspenAlder | Bigtooth aspen | Populus | grandidentata |
| AspenAlder | Black cottonwood | Populus | trichocarpa |
| AspenAlder | Black willow | Salix | nigra |
| AspenAlder | Cottonwood (general) | Populus | spp. |
| AspenAlder | Diamond willow | Salix | eriocephala |
| AspenAlder | Eastern cottonwood | Populus | deltoides |
| AspenAlder | Fremont cottonwood | Populus | fremontii |
| AspenAlder | Narrowleaf cottonwood | Populus | angustifolia |
| AspenAlder | Peachleaf willow | Salix | amygdaloides |
| AspenAlder | Plains cottonwood | Populus | sargentii |
| AspenAlder | Quaking aspen | Populus | tremuloides |
| AspenAlder | Red alder | Alnus | rubra |
| AspenAlder | Silver poplar | Populus | alba |
| AspenAlder | Speckled alder | Alnus | rugosa |
| AspenAlder | Swamp cottonwood | Populus | heterophylla |
| AspenAlder | White alder | Alnus | rhombifolia |
| AspenAlder | Willow (general) | Salix | spp. |
| CedarLarch | Alaska-cedar | Chamaecyparis | nootkatensis |
| CedarLarch | Atlantic white-cedar | Chamaecyparis | thyoides |
| CedarLarch | Baldcypress | Taxodium | distichum |
| CedarLarch | Eastern redcedar | Juniperus | virginiana |
| CedarLarch | Giant sequoia | Sequoiadendron | giganteum |
| CedarLarch | Incense-cedar | Calocedrus | decurrens |
| CedarLarch | Larch (general) | Larix | spp. |
| CedarLarch | Pondcypress | Taxodium | distichum var. nutans |
| CedarLarch | Port-Orford-cedar | Chamaecyparis | lawsoniana |
| CedarLarch | Redwood | Sequoia | sempervirens |
| CedarLarch | Softwoods (general) | Softwood | spp. |
| CedarLarch | Southern redcedar | Juniperus | silicicola |
| CedarLarch | Subalpine larch | Larix | lyallii |
| CedarLarch | Tamarack (native) | Larix | laricina |
| CedarLarch | Western larch | Larix | occidentalis |
| CedarLarch | Western redcedar | Thuja | plicata |
| CedarLarch | White-cedar | Thuja | occidentalis |
| DougFir | Bigcone Douglas-fir | Pseudotsuga | macrocarpa |
| DougFir | Douglas-fir | Pseudotsuga | menziesii |
| FirHemlock | Balsam fir | Abies | balsamea |
| FirHemlock | Bristlecone fir | Abies | bracteata |
| FirHemlock | California nutmeg | Torreya | californica |
| FirHemlock | California red fir | Abies | magnifica |
| FirHemlock | Carolina hemlock | Tsuga | caroliniana |
| FirHemlock | Corkbark fir | Abies | lasiocarpa var. arizonica |
| FirHemlock | Eastern hemlock | Tsuga | canadensis |
| FirHemlock | Fir (general) | Abies | spp. |
| FirHemlock | Fraser fir | Abies | fraseri |
| FirHemlock | Grand fir | Abies | grandis |
| FirHemlock | Hemlock (general) | Tsuga | spp. |
| FirHemlock | Mountain hemlock | Tsuga | mertensiana |
| FirHemlock | Noble fir | Abies | procera |
| FirHemlock | Pacific silver fir | Abies | amabilis |
| FirHemlock | Pacific yew | Taxus | brevifolia |
| FirHemlock | Shasta red fir | Abies | magnifica var. shastensis |
| FirHemlock | Subalpine fir | Abies | lasiocarpa |
| FirHemlock | Western hemlock | Tsuga | heterophylla |
| FirHemlock | White fir | Abies | concolor |

| | | | |
|---|---|---|---|
| MapleOak | American beech | Fagus | grandifolia |
| MapleOak | Bear oak, scrub oak | Quercus | ilicifolia |
| MapleOak | Bitternut hickory | Carya | cordiformis |
| MapleOak | Black hickory | Carya | texana |
| MapleOak | Black maple | Acer | nigrum |
| MapleOak | Black oak | Quercus | velutina |
| MapleOak | Blackjack oak | Quercus | marilandica |
| MapleOak | Blue oak | Quercus | douglasii |
| MapleOak | Bluejack oak | Quercus | incana |
| MapleOak | Bur oak | Quercus | macrocarpa |
| MapleOak | California black oak | Quercus | kelloggii |
| MapleOak | California live oak | Quercus | agrifolia |
| MapleOak | California white oak | Quercus | lobata |
| MapleOak | Canyon live oak | Quercus | chrysolepis |
| MapleOak | Cherrybark oak, swamp red oak | Quercus | falcata var. pagodaefolia |
| MapleOak | Chestnut oak | Quercus | prinus |
| MapleOak | Chinkapin oak | Quercus | muehlenbergii |
| MapleOak | Delta post oak | Quercus | stellata var. mississippiensis |
| MapleOak | Durand oak | Quercus | durandii |
| MapleOak | Engelmann oak | Quercus | engelmannii |
| MapleOak | Hickory (general) | Carya | spp. |
| MapleOak | Interior live oak | Quercus | wislizeni |
| MapleOak | Laurel oak | Quercus | laurifolia |
| MapleOak | Live oak | Quercus | virginiana |
| MapleOak | Mockernut hickory | Carya | tomentosa |
| MapleOak | Northern pin oak | Quercus | ellipsoidalis |
| MapleOak | Northern red oak | Quercus | rubra |
| MapleOak | Nuttall oak | Quercus | nuttalii |
| MapleOak | Oregon white oak | Quercus | garryana |
| MapleOak | Overcup oak | Quercus | lyrata |
| MapleOak | Pecan | Carya | illinoensis |
| MapleOak | Pignut hickory | Carya | glabra |
| MapleOak | Pin oak | Quercus | palustris |
| MapleOak | Post oak | Quercus | stellata |
| MapleOak | Scarlet oak | Quercus | coccinea |
| MapleOak | Scrub oak (general) | Quercus | spp. |
| MapleOak | Shagbark hickory | Carya | ovata |
| MapleOak | Shellbark hickory | Carya | laciniosa |
| MapleOak | Shingle oak | Quercus | imbricaria |
| MapleOak | Shumard oak | Quercus | shumardii |
| MapleOak | Southern red oak | Quercus | falcata var. falcata |
| MapleOak | Sugar maple | Acer | saccharum |
| MapleOak | Swamp chestnut oak | Quercus | michauxii |
| MapleOak | Swamp white oak | Quercus | bicolor |
| MapleOak | Turkey oak | Quercus | laevis |
| MapleOak | Water hickory | Carya | aquatica |
| MapleOak | Water oak | Quercus | nigra |
| MapleOak | White oak | Quercus | alba |
| MapleOak | Willow oak | Quercus | phellos |
| MixedHardwood | Ailanthus | Ailanthus | altissima |
| MixedHardwood | Allegheny chinkapin | Castanea | pumila |
| MixedHardwood | American basswood | Tilia | americana |
| MixedHardwood | American chestnut | Castanea | dentata |
| MixedHardwood | American elm | Ulmus | americana |
| MixedHardwood | American holly | Ilex | opaca |
| MixedHardwood | American hornbeam, musclewood | Carpinus | caroliniana |
| MixedHardwood | American mountain-ash | Sorbus | americana |
| MixedHardwood | Apple (general) | Malus | spp. |
| MixedHardwood | Ash (general) | Fraxinus | spp. |
| MixedHardwood | Basswood (general) | Tilia | spp. |
| MixedHardwood | Bigleaf magnolia | Magnolia | macrophylla |
| MixedHardwood | Black ash | Fraxinus | nigra |
| MixedHardwood | Black cherry | Prunus | serotina |
| MixedHardwood | Black locust | Robinia | psuedoacacia |

| | | | |
|---|---|---|---|
| MixedHardwood | Black walnut | Juglans | nigra |
| MixedHardwood | Blackgum | Nyssa | sylvatica |
| MixedHardwood | Blue ash | Fraxinus | quadrangulata |
| MixedHardwood | Buckeye (except 331, 332) | Aesculus | spp. |
| MixedHardwood | Buckeye, horsechestnut | Aesculus | spp. |
| MixedHardwood | Butternut | Juglans | cinerea |
| MixedHardwood | California buckeye | Aesculus | californica |
| MixedHardwood | California sycamore | Platanus | racemosa |
| MixedHardwood | California-laurel | Umbellularia | californica |
| MixedHardwood | Canada plum | Prunus | nigra |
| MixedHardwood | Catalpa | Catalpa | spp. |
| MixedHardwood | Cedar elm | Ulmus | crassifolia |
| MixedHardwood | Cherry, plum spp. | Prunus | spp. |
| MixedHardwood | Chinaberry | Melia | azedarach |
| MixedHardwood | Chinese tallowtree | Sapium | sebiferum |
| MixedHardwood | Chinkapin | Castanopsis | spp. |
| MixedHardwood | Chittamwood, gum bumelia | Bumelia | lanuginosa |
| MixedHardwood | Chokecherry | Prunus | virginiana |
| MixedHardwood | Common persimmon | Diospyros | virginiana |
| MixedHardwood | Cucumbertree | Magnolia | acuminata |
| MixedHardwood | Eastern hophornbeam, ironwood | Ostrya | virginiana |
| MixedHardwood | Eastern redbud | Ceriss | canadensis |
| MixedHardwood | Elm (general) | Ulmus | spp. |
| MixedHardwood | Eucalyptus (general) | Eucalyptus | spp. |
| MixedHardwood | European mountain-ash | Sorbus | aucuparia |
| MixedHardwood | Flowering dogwood | Cornus | florida |
| MixedHardwood | Golden chinkapin | Castanopsis | chrysophylla |
| MixedHardwood | Green ash | Fraxinus | pennsylvanica |
| MixedHardwood | Hackberry | Celtis | occidentalis |
| MixedHardwood | Hackberry (general) | Celtis | spp. |
| MixedHardwood | Hardwoods (general) | Hardwood | spp. |
| MixedHardwood | Hawthorn | Crataegus | spp. |
| MixedHardwood | Honeylocust | Gleditsia | triacanthos |
| MixedHardwood | Kentucky coffeetree | Gymnocladus | dioicus |
| MixedHardwood | Loblolly-bay | Gordonia | lasianthus |
| MixedHardwood | Magnolia (general) | Magnolia | spp. |
| MixedHardwood | Mulberry (general) | Morus | spp. |
| MixedHardwood | Northern catalpa | Catalpa | speciosa |
| MixedHardwood | Ogeechee tupelo | Nyssa | ogeche |
| MixedHardwood | Ohio buckeye | Aesculus | glabra |
| MixedHardwood | Oregon ash | Fraxinus | latifolia |
| MixedHardwood | Osage-orange | Maclura | pomifera |
| MixedHardwood | Ozark chinkapin | Castanea | ozarkensis |
| MixedHardwood | Pacific dogwood | Cornus | nuttallii |
| MixedHardwood | Pacific madrone | Arbutus | menziesii |
| MixedHardwood | Paulownia, Empress tree | Paulownia | tomentosa |
| MixedHardwood | Pawpaw | Asimina | triloba |
| MixedHardwood | Pin cherry | Prunus | pensylvanica |
| MixedHardwood | Plums, cherries, except 762 | Prunus | spp. |
| MixedHardwood | Pumpkin ash | Fraxinus | profunda |
| MixedHardwood | Red mulberry | Morus | rubra |
| MixedHardwood | Redbay | Persea | borbonia |
| MixedHardwood | Rock elm | Ulmus | thomasii |
| MixedHardwood | Sassafras | Sassafras | albidum |
| MixedHardwood | September elm | Ulmus | serotina |
| MixedHardwood | Serviceberry | Amelanchier | spp. |
| MixedHardwood | Siberian elm | Ulmus | pumila |
| MixedHardwood | Silverbell | Halesia | spp. |
| MixedHardwood | Slippery elm | Ulmus | rubra |
| MixedHardwood | Smoketree | Cotinus | obovatus |
| MixedHardwood | Sourwood | Oxydendrum | arboreum |
| MixedHardwood | Southern catalpa | Catalpa | bignonioides |
| MixedHardwood | Southern magnolia | Magnolia | grandiflora |
| MixedHardwood | Sparkleberry | Vaccinium | arboreum |

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|---|---|---|---|
| MixedHardwood | Sugarberry | Celtis | laevigata |
| MixedHardwood | Swamp tupelo | Nyssa | sylvatica var. biflora |
| MixedHardwood | Sweetbay | Magnolia | virginiana |
| MixedHardwood | Sweetgum | Liquidambar | styraciflua |
| MixedHardwood | Sycamore | Platanus | occidentalis |
| MixedHardwood | Tanoak | Lithocarpus | densiflorus |
| MixedHardwood | Tung-oil tree | Ailanthus | fordii |
| MixedHardwood | Walnut | Juglans | spp. |
| MixedHardwood | Water tupelo | Nyssa | aquatica |
| MixedHardwood | Water-elm | Planera | aquatica |
| MixedHardwood | Waterlocust | Gleditsia | aquatica |
| MixedHardwood | White ash | Fraxinus | americana |
| MixedHardwood | White basswood | Tilia | heterophylla |
| MixedHardwood | White mulberry | Morus | alba |
| MixedHardwood | Wild plum | Prunus | americana |
| MixedHardwood | Winged elm | Ulmus | alata |
| MixedHardwood | Yellow buckeye | Aesculus | octandra |
| MixedHardwood | Yellow-poplar | Liriodendron | tulipifera |
| Pine | Apache pine | Pinus | engelmannii |
| Pine | Arizona pine | Pinus | arizonica |
| Pine | Austrian pine | Pinus | nigra |
| Pine | Bishop pine | Pinus | muricata |
| Pine | Border pinyon | Pinus | discolor |
| Pine | Bristlecone pine | Pinus | aristata |
| Pine | California foothill pine | Pinus | sabiniana |
| Pine | Chihuahuan pine | Pinus | leiophylla |
| Pine | Coulter pine | Pinus | coulteri |
| Pine | Eastern white pine | Pinus | strobus |
| Pine | Foxtail pine | Pinus | balfouriana |
| Pine | Jack pine | Pinus | banksiana |
| Pine | Jeffrey pine | Pinus | jeffreyi |
| Pine | Knobcone pine | Pinus | attenuata |
| Pine | Limber pine | Pinus | flexilis |
| Pine | Loblolly pine | Pinus | taeda |
| Pine | Lodgepole pine | Pinus | contorta |
| Pine | Longleaf pine | Pinus | palustris |
| Pine | Monterey pine | Pinus | radiata |
| Pine | Pinyon pine | Pinus | edulis |
| Pine | Pitch pine | Pinus | rigida |
| Pine | Pond pine | Pinus | serotina |
| Pine | Ponderosa pine | Pinus | ponderosa |
| Pine | Red pine | Pinus | resinosa |
| Pine | Sand pine | Pinus | clausa |
| Pine | Scotch pine | Pinus | sylvestris |
| Pine | Shortleaf pine | Pinus | echinata |
| Pine | Singleleaf pinyon | Pinus | monophylla |
| Pine | Slash pine | Pinus | elliottii |
| Pine | Southwestern white pine | Pinus | strobiformis |
| Pine | Spruce pine | Pinus | glabra |
| Pine | Sugar pine | Pinus | lambertiana |
| Pine | Table Mountain pine | Pinus | pungens |
| Pine | Virginia pine | Pinus | virginiana |
| Pine | Western white pine | Pinus | monticola |
| Pine | Whitebark pine | Pinus | albicaulis |
| SoftMapleBirch | Bigleaf maple | Acer | macrophyllum |
| SoftMapleBirch | Birch (general) | Betula | spp. |
| SoftMapleBirch | Boxelder | Betula | negundo |
| SoftMapleBirch | Florida maple | Acer | barbatum |
| SoftMapleBirch | Gray birch | Betula | populifolia |
| SoftMapleBirch | Mountain maple | Acer | spicatum |
| SoftMapleBirch | Paper birch | Betula | papyrifera |
| SoftMapleBirch | Red maple | Acer | rubrum |
| SoftMapleBirch | River birch | Betula | nigra |

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|---|---|---|---|
| SoftMapleBirch | Silver maple | Acer | saccharinum |
| SoftMapleBirch | Striped maple | Acer | pensylvanicum |
| SoftMapleBirch | Sweet birch | Betula | lenta |
| SoftMapleBirch | Water birch | Betula | occidentalis |
| SoftMapleBirch | Western paper birch | Betula | papyrifera var. commutata |
| SoftMapleBirch | Yellow birch | Betula | alleghaniensis |
| Spruce | Black spruce | Picea | mariana |
| Spruce | Blue spruce | Picea | pungens |
| Spruce | Brewer spruce | Picea | breweriana |
| Spruce | Engelmann spruce | Picea | engelmannii |
| Spruce | Norway spruce | Picea | abies |
| Spruce | Red spruce | Picea | rubens |
| Spruce | Sitka spruce | Picea | sitchensis |
| Spruce | Spruce (general) | Picea | spp. |
| Spruce | White spruce | Picea | glauca |
| Woodland | Acacia (general) | Acacia | spp. |
| Woodland | Alligator juniper | Juniperus | deppeana |
| Woodland | Arizona cypress | Cupressus | arizonica |
| Woodland | Arizona white oak, Gray oak | Quercus | arizonica, grisea |
| Woodland | Bigtooth maple | Acer | grandidentatum |
| Woodland | Birchleaf mountain-mahogany | Cercocarpus | montanus var. glaber |
| Woodland | Bitter cherry | Prunus | emarginata |
| Woodland | California juniper | Juniperus | californica |
| Woodland | Common juniper | Juniperus | communis |
| Woodland | Curlleaf mountain-mahogany | Cercocarpus | ledifolius |
| Woodland | Cypress | Cupressus | spp. |
| Woodland | Deciduous oak spp. | Quercus | spp. |
| Woodland | Emory oak | Quercus | emoryi |
| Woodland | Evergreen oak spp. | Quercus | spp. |
| Woodland | Gambel oak | Quercus | gambelii |
| Woodland | Hairy mountain-mahogany | Cercocarpus | montanus var. pauciden |
| Woodland | Littleleaf mountain-mahogany | Cercocarpus | intricatus |
| Woodland | Mesquite | Prosopis | spp. |
| Woodland | Mexican blue oak | Quercus | oblongifolia |
| Woodland | New Mexico locust | Robinia | neomexicana |
| Woodland | Oneseed juniper | Juniperus | monosperma |
| Woodland | Pinchot juniper | Juniperus | pinchotti |
| Woodland | Redberry juniper | Juniperus | erythrocarpa |
| Woodland | Rocky Mountain juniper | Juniperus | scopulorum |
| Woodland | Rocky Mountain maple | Acer | glabrum |
| Woodland | Silverleaf oak | Quercus | hypoleucoides |
| Woodland | Tesota (Arizona ironwood) | Olneya | tesota |
| Woodland | True mountain-mahogany | Cercocarpus | montanus |
| Woodland | Utah juniper | Juniperus | osteosperma |
| Woodland | Western juniper | Juniperus | occidentalis |

# GLOBE Carbon Cycle

# Predicted Biomass Graph
(reproduced from Jenkins et al. 2003, Figure 1)