CO_2 Carbon in a Tree — OPTION A: ENGLISH UNITS (1 of 3)

NAME: GROUP MEMBERS:

First, you will measure the circumference and height of at least one tree near your school. You will then use the data to calculate the amount of carbon stored in each tree.

Measuring Tree Diameter

1. Use your measuring tape to measure the circumference of the tree. Be sure to measure the circumference approximately 4.5 feet above the ground. Record the circumference in inches in Data Table 1.

2. Next, use the equation $d = c \div \pi$ to calculate the diameter of the tree (where d = diameter; c = circumference; and $\pi = 3.14$). Record tree diameter in Data Table 1.

Data Table 1

Tree	c circumference (in)	d diameter (in)
1		
2		
3		
4		
5		

Measuring Tree Height

1. Stand far enough from the base of the tree to see the top. Measure the distance between you and the tree and record it in Data Table 2. Hold the protractor with the Tree End toward the tree and look through the straw. Find the top of the tree and have another group member read the angle at which the string crosses the protractor (θ_1). Make sure your fingers are not blocking the string from moving freely. Record the angle in Data Table 2. To measure the angle to the bottom of the tree, look through the straw and find the base of the tree. Have a group member read the angle at which the string crosses the protractor (θ_2). Record the angle in Data Table 2.

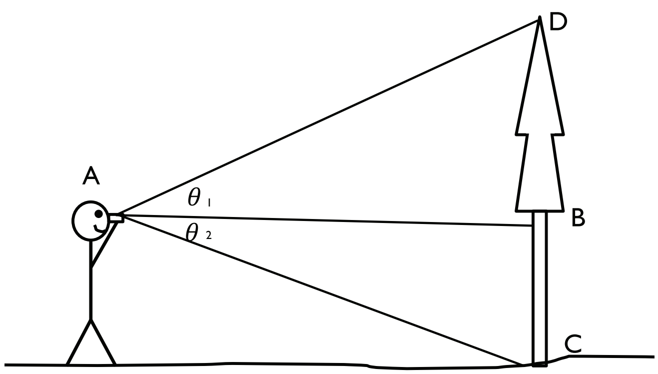
Data Table 2

Tree	θ_1 Angle to top of tree	θ_2 Angle to base of tree	AB Distance from person to tree (ft)
1			
2			
3			
4			
5			

Are you standing on a slope while using the clinometer? If your head is below the base of the tree or above the top of the tree, find a new tree to measure! The equation provided for calculating tree height cannot be used in these situations.

CO_2 Carbon in a Tree — OPTION A: ENGLISH UNITS (2 of 3)

2. Next, use the following diagram and equations to calculate the height of each tree, noting that Θ_1 is the angle to the top of the tree and Θ_2 is the angle to the base of the tree. The tangent of the angle is expressed as tan. The distance between you and the tree is expressed as AB. Record your results in Data Table 3.



$$\tan\Theta_1 = \frac{DB}{AB} \qquad DB = AB \tan\Theta_1$$

$$\tan\Theta_2 = \frac{BC}{AB} \qquad BC = AB \tan\Theta_2$$

$$\text{Total tree height} = DB + BC = AB(\tan\Theta_1 + \tan\Theta_2)$$

Data Table 3

Tree	$\tan\Theta_1$	$\tan\Theta_2$	DB $AB(\tan\Theta_1)$	BC $AB(\tan\Theta_2)$	Tree Height (h) in feet (ft) $h = DB + BC$ $h = AB(\tan\Theta_1) + AB(\tan\Theta_2)$
1					
2					
3					
4					
5					

Calculating Carbon Storage (adapted from Trees for the Future, 2007)

1. *Calculating Green Weight (GW)*

   The green weight of a tree is an estimate of the mass of the tree when it is alive. This estimate includes all of the wood content and any moisture in the tree. Because the moisture in the tree can be up to hundreds of gallons, the green weight can be quite large.

   As you can imagine, weighing a live tree and keeping it alive is not feasible! For this reason, foresters use a set of formulas to estimate green weight. These equations are based on real data—foresters cut and weighed trees and then analyzed the data to develop formulas to fit the data. The percentage of moisture in a tree varies by tree species; therefore, specific formulas have been developed for different tree species.

CO_2 Carbon in a Tree — OPTION A: ENGLISH UNITS (3 of 3)

The equations used here are an "average" for trees in the Southeast and allow you to calculate the above-ground green weight of a tree based on the tree's diameter and height. To find the green weight, insert the values you obtained for diameter (in) and height (ft) into the appropriate equation and record your answers in pounds (lbs) in Data Table 4.

For trees with diameter < 11 in: $GW = 0.25 \times d^2 \times h$

For trees with diameter > 11 in: $GW = 0.15 \times d^2 \times h$

The constant in the equation accounts for the unit conversion between inches and feet; therefore, you do not need to first convert those measurement units to be the same.

2. *Calculating Dry Weight (DW)*

   Dry weight represents the mass of the wood in the tree when dried in an oven so the moisture is removed. On average, experiments have shown that a tree's dry weight is about 50% of its green weight. Therefore, to find the dry weight, you just need to multiply green weight (GW) by 50%. Complete this equation for each tree you measured, and record your answers in Data Table 4.

   $DW = GW \times 0.5$

3. *Calculating Carbon Storage (C)*

   Carbon storage is the amount of carbon that is within the wood of the tree. This is the total amount of carbon that is captured from the atmosphere during photosynthesis as well as the amount of carbon sequestered by the tree. From experiments, scientists have found that about 50% of a tree's dry weight is carbon. To find carbon storage, multiply dry weight (DW) by 50%. Complete this equation for each tree you measured, and record your answers in Data Table 4.

   $C = DW \times 0.5$

Data Table 4

Tree	**Green Weight (GW, lbs)** d < 11 in: $GW = 0.25 \times d^2 \times h$ d > 11 in: $GW = 0.15 \times d^2 \times h$	**Dry Weight (DW, lbs)** $DW = GW \times 0.5$	**Carbon content (C, lbs)** $C = DW \times 0.5$
1			
2			
3			
4			
5			

STUDENT PAGE

Carbon in a Tree — OPTION B: ENGLISH UNITS

NAME: GROUP MEMBERS:

First, you will measure the circumference of at least one tree near your school. You will then use the data to calculate the amount of carbon stored in each tree.

Measuring Tree Diameter

1. Use your measuring tape to measure the circumference of the tree. Be sure to measure the circumference approximately 4.5 feet above the ground. Record the circumference in inches in Data Table 1.

2. Next, use the equation $d = c \div \pi$ to calculate the diameter of the tree (where d = diameter; c = circumference; and $\pi = 3.14$). Record tree diameter in Data Table 1.

Data Table 1

Tree	c circumference (in)	d diameter (in)
1		
2		
3		
4		
5		

Calculating Carbon

1. The table below provides carbon content values for trees, based on their diameter values. This table is specific to urban trees in a developed area. The values were calculated in a study conducted in Escambia County, in Florida's panhandle (Escobedo et al., 2009). We can use this information to get a general idea of the amount of carbon in a tree that falls within a certain diameter range. Using the table below, match the diameter you calculated for your tree with the diameter in the left column. Find the carbon storage capacity of the tree and record in Data Table 2.

Diameter Range (in)	Carbon Content per Tree (lbs)
0–6	49
7–12	551
13–18	1,332
19–24	2,577
25–30	5,873
31+	33,144

Data Table 2

Tree	Carbon content (lbs)
1	
2	
3	
4	
5	

Carbon in Pines — OPTION B: ENGLISH UNITS (1 of 2)

NAME:

The southeastern United States is home to many different species of pine trees, specifically: loblolly, slash, longleaf, and shortleaf pines. Pine forests are important for many reasons. They provide wildlife habitat, recreation, and clean water, and as you have learned, the trees store carbon as they grow. In the Southeast, pine trees are commonly grown in plantations to provide wood products, such as timber and paper.

Foresters and scientists measure pine trees with a method similar to the one you used on the trees in your schoolyard. Using this information they can determine how much carbon is stored in a certain area of the forest. The trees that are grown on a plantation are usually similar in size and age. This allows foresters to measure a small sample of trees and then use those numbers to estimate carbon storage for the entire area.

To estimate how much carbon typically exists in one acre of pine forest in the southeastern United States, you will use data collected by high school students during a field trip to a pine forest sample plot in North Central Florida.

In a plot that measures 1/20th of an acre, the students measured ten trees and found that the trees have an average diameter of 10.1 inches and an average height of 106.7 feet. Because the trees in this area are generally the same species, age, and size, we can use their average data to estimate the amount of carbon contained within one acre of this forest.

JESSICA IRELAND, UNIVERSITY OF FLORIDA

Students measure tree height and diameter on a sample plot of slash pine trees in a forest in North Central Florida.

CO_2 Carbon in Pines — OPTION B: ENGLISH UNITS (2 of 2)

Complete the calculations below, where d = diameter; h = height; GW = green weight; and DW = dry weight.

1. Green Weight (GW) = $0.25 \times d^2 \times h$ GW = ____________lbs/tree

2. Dry Weight (DW) = GW × 0.5 DW = ______________ lbs/tree

3. Carbon (C) = DW × 0.5 Carbon content = ___________ lbs C/tree

4. Total carbon content of plot = carbon content per tree × 10 trees

   Total carbon content of plot = _____________ lbs C in 1/20th acre plot

5. Total carbon content of 1 acre = total carbon in plot × 20

   Total carbon in 1 acre = ___________ lbs C/acre

This final number illustrates the total carbon stored in one acre of pine plantation where the students took measurements. However, this is not the same as the amount of carbon that the trees sequestered in one year of growth. Carbon sequestration is the net intake of carbon by the tree over a period of time. In this case, the forest where students sampled is 25 years old. Assume that trees sequestered carbon at the same rate during each year it lived, and use the equation below to determine what rate carbon is sequestered by the forest annually.

Total carbon in 1 acre ÷ 25 years = Carbon sequestration rate

6. Carbon sequestration rate = _________________ lbs C/acre/year

CO_2 Your Carbon Footprint — ENGLISH UNITS

NAME:

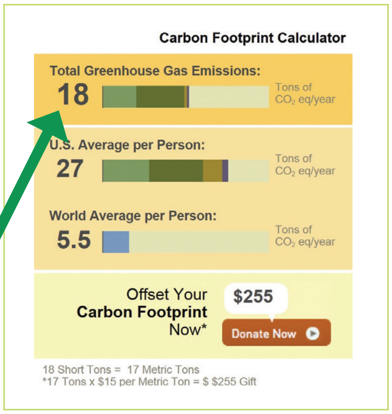
The carbon footprint of a person is the total amount of carbon emitted based on his or her daily actions and choices. A carbon footprint is measured based on factors such as fossil fuel consumption, food consumption, goods and services bought, as well as housing conditions. The Nature Conservancy has an interactive site where you can answer questions to measure your own carbon footprint. This website allows you to see how much carbon dioxide (CO_2) you emit per year measured in tons. Follow the outline below in order to obtain your own personal footprint. You might need to ask your parents to provide some information so you can accurately complete the questions in the carbon footprint calculator.

1. Go to the website http://www.nature.org/greenliving/carboncalculator/index.htm.

2. Read the instructions and select "For Me Only" because this exercise is for measuring your personal emissions. Use the survey to answer background questions as well as questions about household vehicles, home energy, and waste disposal. Answer the questions based on your personal or family lifestyle.

3. The second part of the survey estimates carbon output associated with your home energy usage. In the United States, most CO_2 is from energy generation. This part of the survey measures how much CO_2 you are responsible for emitting as a result of using electricity in your house. Answer the questions as accurately as possible.

4. The third part of the survey is based on your fossil fuel consumption associated with travel.



5. The fourth part of the survey evaluates how your choice of food and your diet affects your carbon emissions. Depending on the type of food, the amount of meat, and where you buy your food, your emissions will vary.

6. The final part of the quiz evaluates your level of waste and the impact that recycling has on it. If you recycle on a regular basis, your carbon estimate will be smaller. This is because recycled material requires less carbon to process than extracting and processing new resources.

7. Upon completing the survey, the results will display how much CO_2 you produce yearly as a result of your choices. This is the number you should record in step 8. You will see your results compared to the national average, and you will be provided with options to decrease your carbon emissions.

8. Record your results: ____________________ tons of CO_2 per year.

9. Are the results surprising to you? Why or why not?

10. What variable do you think was most responsible for your CO_2 emission rate? ________________________

CO_2 Carbon in Different Landscapes — ENGLISH UNITS (1 of 3)

NAME: GROUP MEMBERS:

Carbon Emissions

Using the data from the Your Carbon Footprint assignment, find the average carbon emissions for your group in tons of carbon dioxide (CO_2).

____
Average CO_2 emissions of group (tons/year)

1. Because most sequestration rates are calculated in terms of carbon and not in carbon dioxide, convert your tons of carbon dioxide to tons of carbon. To do this you'll use the formula below. Multiplying by 12/44 (or 0.2727) removes the weight of the two oxygen atoms (16 each) from the total weight of each carbon dioxide molecule (44).

______________________________ x $\frac{12}{44}$ = ______________________________
Average CO_2 emissions of group (tons/year) Average C emissions of group (tons/year)

2. If everyone in your state acted the way you do, find the total emissions for your state. To do this, take your group's average carbon emissions and multiply by the population of that state. Your teacher will give you this information.

______________________ x ______________ = ______________________
Average emissions of C (tons/year) State population Total C emissions of state (tons/year)

CO_2 Carbon in Different Landscapes — ENGLISH UNITS (2 of 3)

Carbon Sequestration

Since there are multiple land uses that can sequester carbon, you need to determine the relative abilities of each of these land uses in carbon sequestration: southern pine forest, mixed forest, cropland, grassland, and urban forest. Complete the chart below, using land area provided by your teacher.

Land Use Type	Area in State (acres [ac], in thousands)	Multiply	Carbon Sequestration Rate (tons/ac/yr)	Equals	Amount of Carbon Sequestered (tons/yr)
Southern Pine Forest (Binford et al., 2006)		×	1.69	=	
Mixed Forest (Turner et al., 1995)		×	0.85	=	
Urban Forest (Norwak & Crane, 2002)		×	0.36	=	
Cropland (Morgan et al., 2010)		×	0.04	=	
Rangeland/Grassland (Morgan et al., 2010)		×	0.03	=	

1. Total the amount of carbon that is sequestered by your state's land uses by adding the total carbon sequestered from the last column in the table.

____
Total C sequestered in state (tons/year)

Comparison Emissions and Sequestration

1. Is there a deficit in carbon sequestration or an excess of potential in your state? To find out if your state has the ability to sequester all of the carbon that it emits on average, subtract the total carbon sequestered in step 3 from the total carbon emitted by the population in step 2.

______________________ – ______________________ = ______________________
Total C emissions of state (tons/year) – Total C sequestered in state (tons/year) = Difference (tons/year)

2. If your answer to step 4 is negative, that means that your state is not in a deficit and that on average the state has the ability to sequester all of the carbon that it emits. What factors might make a state able to sequester the carbon emitted by the population?

CO_2 Carbon in Different Landscapes — ENGLISH UNITS (3 of 3)

3. If the answer to step 4 is positive, your state is in a deficit and cannot sequester the total carbon emitted, what could be done to increase the amount of carbon sequestered in your state?

4. If your state is in a deficit and any neighboring states are not, would you recommend that your state rely on the land uses of another state to sequester your carbon? Is it fair to the population of the other state to be responsible for your carbon emissions? Should you pay that state to sequester your carbon?

Table 1. Population and Land Use Areas for Southeastern States

States	Population[1]	Southern Pine[2]	Mixed Forest[3]	Cropland[4]	Rangeland[4]	Urban Area[4]
	(thousands)	(in thousands of acres)				
Alabama	4,779	9,550	13,327	3,104	2,642	1,140
Arkansas	2,915	5,564	13,191	8,240	3,293	589
Florida	18,801	7,396	9,946	2,760	5,558	4,052
Georgia	9,687	11,059	13,710	4,619	1,292	2,465
Kentucky	4,339	194	12,277	7,621	3,516	799
Louisiana	4,533	5,747	8,793	4,435	1,860	1,088
Mississippi	2,967	7,998	11,543	5,556	2,055	607
North Carolina	9,535	5,746	12,841	4,843	1,231	2,357
Oklahoma	3,751	1,103	11,543	12,840	18,707	736
South Carolina	4,625	6,067	7,054	2,001	795	1,230
Tennessee	6,346	936	13,005	6,019	2,093	1,594
Texas	25,145	5,298	57,126	34,115	101,735	4,646
Virginia	8,001	2,933	12,974	3,251	2,463	1,555

[1] United States Census Bureau, 2012
[2] United States Forest Service, 2013 (area given is longleaf/slash pine and loblolly/shortleaf pine forest types)
[3] United States Forest Service, 2013 (area given is the total forestland minus the longleaf/slash pine and loblolly/shortleaf pine forest types)
[4] United States Department of Agriculture, 2012 (land use definitions found in the Economic Research Service Glossary at http://www.ers.usda.gov/data-products/major-land-uses/glossary.aspx)