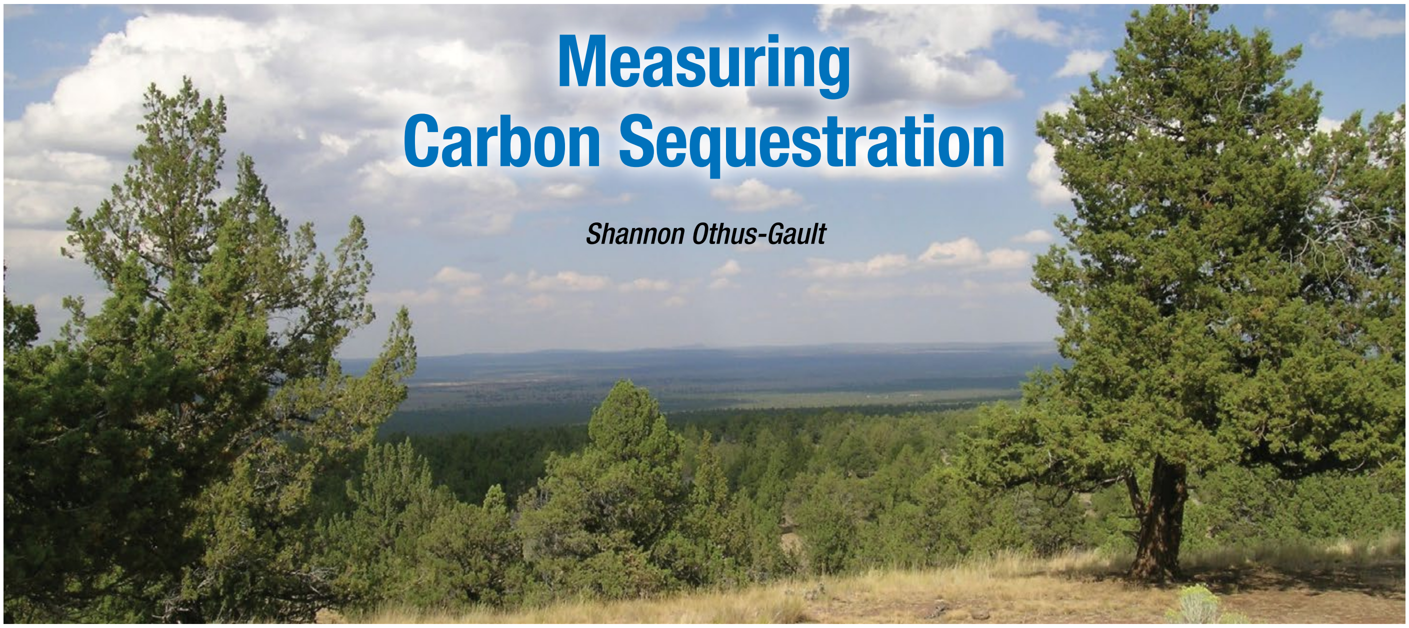

Measuring Carbon Sequestration

Shannon Othus-Gault

Abstract

Carbon sequestration by plants is one of the most important short-term processes that removes the greenhouse gas carbon dioxide from the atmosphere. As humans continue to release carbon from long term geologic sinks, through the burning of fossil fuels for example, understanding how carbon can be removed from the atmosphere by plants through photosynthesis is an important concept for students to understand. One way to attempt to measure this process is by measuring dry and ash weights of a plant to estimate the amount of carbon sequestered by the plant during its lifetime. This laboratory activity can be paired with the creation of a community garden that allows students to measure how much carbon can be sequestered through the creation of an individual green space and can connect to individual action on climate change. The green space used during the creation of this laboratory activity was funded by the National Oceanic and Atmospheric Administration (NOAA) Planet Stewards Program in 2018 (https://oceanservice.noaa.gov/education/planet-stewards/).

Introduction

The atmosphere is made out of many gases and some of those trace gases are referred to as greenhouse gases. These gases are important for the atmosphere because they absorb infrared and emit their own infrared, heating the lower atmosphere. The heat given off by greenhouse gases creates a livable climate on Earth, a whole 33^{0}C warmer than it would be without the presence of greenhouse gases (ESRL, 2005). One of the most important greenhouse gases is carbon dioxide. Carbon dioxide is also an important gas in terms of plant growth. Plants use carbon dioxide from the atmosphere during the process of photosynthesis to create biomass (NOAA, 2019). This process of obtaining carbon from the atmosphere and holding it in solid form is referred to as carbon sequestration. Carbon sequestration has become more important in recent years with the increase of carbon dioxide in the atmosphere creating an enhanced greenhouse effect and contributing to the warming of our atmosphere. In fact, historical levels of carbon dioxide remained below 300 ppm (parts per million) over the past 400,000 years; yet, since the 1950's, carbon dioxide has increased to over 400 ppm (NASA, 2016).

All humans can help to sequester carbon from the atmosphere by creating their own gardens and increasing biomass on Earth's surface. This goal of this laboratory activity was to teach students about important atmospheric processes, including the greenhouse effect and how atmospheric carbon can be sequestered by plants. Another goal of this activity was to measure the amount of carbon that can effectively be sequestered in a small green space as an example of what they can do in their own home and/or yard.

Methods

Prior to performing this lab activity, my students were provided information on the greenhouse effect and the carbon cycle and also participated in class activities related to biogeochemical cycles and greenhouse gases, such as those provided by the Science Education Resource Center (SERC) through the EarthLabs project (SERC, 2016). This base knowledge was provided to allow students to connect the related lab activity to much larger Earth systems and processes. After finishing pre-lab work, students began to measure carbon sequestration by obtaining a whole-plant sample, including the root system. A sample can be collected from a school garden (as was done for this project) or can be collected from any appropriate place noted by an instructor or even parent. Once the sample was obtained, the whole plant was cleaned to remove as much excess soil as possible so that the most accurate dry weight of the plant sample could be measured. Once cleaned, the plant was dried. I allowed samples to air dry over several weeks; however, you could attempt to dry the plants more quickly in a low temperature, drying oven. Once these samples were dried, they were used by students to measure the carbon sequestered by the plant. To do this, the dried plant was weighed and that weight recorded. Next, the dried plant matter was burned in a controlled manner so that ash can be collected and weighed.

Figure 1: Picture shows the author demonstrating to students how to combust plant samples.

Photo Credit: Shannon Othus

By subtracting the weight of the ash from the weight of the dry sample, students were able to roughly estimate the amount of carbon that was sequestered by that plant. This activity works by essentially combusting the carbon matter in the plant and creating carbon dioxide, which is transferred to the atmosphere, and leaving behind the rest of the noncombustible matter of the plant. By comparing the dry weight with the ash weight, we can make a rough estimation of the carbon that had been contained in the plant sample.

Although measuring the carbon sequestered by a single plant can be useful, students can use plant counts within a garden to calculate how much carbon a larger green space or garden can sequester. During this activity with my own class, we obtained the amount of carbon sequestered by our garden by creating a garden map and counting the number of the different plants present in the garden.

Figure 2: Picture showing the community garden and the distribution of plants used to measure carbon sequestration.

Photo Credit: Shannon Othus

Once students created their map and finished their plant counts, they multiplied the number of each example plant counted by the measurement of the carbon that type of plant sequestered. These final carbon calculations were added together to create a rough estimate of how much carbon was sequestered by our garden during that year's sampling. These easy measurements can potentially allow students to plan for future growing seasons to maximize carbon sequestration with evidence-based observations from past growing seasons.

Materials and Suggestions

This is clearly a lab activity that needs to be well supervised by an instructor due to the fact that fire is involved. Also, after students performed this lab activity for the first time in my classroom, I learned several tricks and tips for what materials are more successful for this activity and how to use those materials to fully incinerate the dry plant material. One of the most important materials you will need is a receptacle to burn your dry plant material. I obtained large food cans from the kitchen on our campus and they were big enough to allow for full combustion. You will also want to make sure that there are ventilation holes in these receptacles so that air can mix with the plant material during combustion. Also, make sure that the holes aren't big enough to lose ash material. Another possible tip to allow for combustion to occur more rapidly would be breaking the plant into smaller pieces prior to incineration so the volume of the plant is more compact. I have also found that stem lighters are best for keeping appendages away from the flames but are also useful in continuing the combustion of materials if they need to be set alight more than once. Lastly, I would suggest heat resistant gloves to protect student hands.

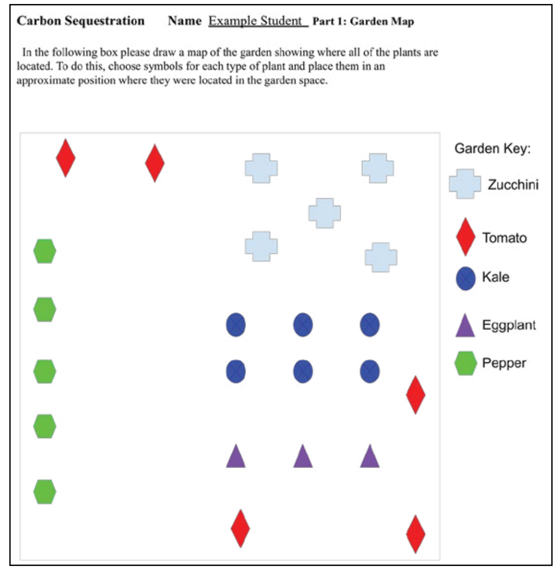

Figure 3: Map shows the placement and number of plants found in the Yamhill Valley Campus Community Garden. The plant counts found on the map were used by students when calculating the total carbon sequestered in the garden through multiplying the number of plants present with the carbon measured by students.

Student Assessment

Due to the current pandemic, I have only been able to run this lab activity with two classes using mature plants from my campus's community garden. However, students were able to work together to calculate some estimates of carbon sequestered by the plants in our garden. Some of the dried plants were not able to be fully burned leading to a low overall calculation for the carbon sequestered by plants in the garden, kale plants in particular. Results based on student calculations from the Spring of 2019 can be found in Table 1.

Table 1: Data collected and calculated by students to calculate carbon sequestered within the Yamhill Valley Campus community garden from the 2019 General Science Earth System Science class

Year and Season	Age of Plant	Plant Type	Dry Weight (g)	Ash Weight (g)	Carbon Weight (g)	Number of Plants	Total Carbon Sequestered (g)
Spring 2019	Adult	*Kale	23.6	22.3	1.3	6	7.8
Spring 2019	Adult	Peppers	80.6	11.9	68.7	5	343.5
Spring 2019	Adult	Zucchini	310.0	128.0	182.0	5	910.0
Spring 2019	Adult	Tomatoes	271.1	39.0	232.1	5	1160.5
Spring 2019	Adult	Eggplant	97.6	17.3	80.3	3	240.9
						Total carbon sequestered by adult garden:	**2662.7**

* Incomplete burn of specimen

Once students had finished calculating their measurements, they were then asked to answer several questions to put their carbon measurements into greater context of the greenhouse effect and climate processes, i.e., how does growing plants change the atmospheric concentration of carbon dioxide and, therefore, affect the greenhouse effect? The questions that I posed are as follows:

- How does carbon dioxide behave in the atmosphere (hint: what type of gas is carbon dioxide)? How can an abundance of carbon dioxide in the atmosphere become a problem for Earth's biosphere?
- Vegetation is considered a carbon sink. Based on the word "sink", what do you think that suggests in terms of the carbon that was sequestered by the plants you measured? In other

words, how is the carbon sequestered by plants related to the carbon dioxide found in the atmosphere?

- How can sequestered carbon change the composition of the atmosphere? How could this sequestration affect the greenhouse effect?
- Knowing that this garden was used for food production, how can the harvesting of food from the garden affect the carbon weight measured? How does harvesting food from the garden affect the number that you calculated for the total carbon sequestered by the garden?
- Can you think of any other sources of error that could have affected the calculations you made for carbon weights and the amount of carbon sequestered by the plants in the garden?

These questions allowed students to think deeply about how plants and atmospheric composition are directly linked and how the greenhouse effect can be affected by plant growth. It also asks students to think about errors in their calculations since this activity is truly, a very rough estimation of carbon sequestration.

Conclusion

Allowing students to connect their own personal activity to atmospheric composition and the greenhouse effect is an important lesson to learn as we begin to tackle the effects of anthropogenic climate change. This is a lab activity that is hands-on and allows for teachers and students to use green spaces, whether at school or at home, and for scientific exploration and data collection, which are important aspects of inquiry-based science learning.

A list of materials, methods and lab questions, can be found at:
https://docs.google.com/document/d/1eXa3vbX7uncsJr0hh37Kxz4MOQHbFwPrB1IOLAVqK0A/edit?usp=sharing

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About the Author

Shannon Othus-Gault began teaching as an outdoor school and science camp instructor at the age of 16 and has worked in the states of Oregon, Washington, California, New York and Wisconsin. Shannon has been teaching geology and Earth sciences for ten years at several Community Colleges but has committed to a single location, Chemeketa Community College at the Yamhill Valley Campus in McMinnville, Oregon. Prior to teaching, Shannon worked as a natural resource scientist for the Washington Department of Natural Resources in the Forestry department mapping landslides and making landslide hazard maps. She can be reached at othussm@gmail.com