



Abstract

Greenhouse gases are currently impacting Earth's climate and will continue to do so at elevated rates until we find ways to mitigate our actions. Biochar production via pyrolysis is a means to sequester carbon in the soil long term. Biochar is highly resistant to breakdown and thus becomes a sink for carbon storage. This strategy is accessible to students and can give a sense of empowerment to make change. In the course of this unit, students learn about the carbon cycle while producing biochar, test biochar's value as a soil amendment, and provide outreach on the carbon cycle to other students and the public.

Biochar

Excess greenhouse gases are linked to the climate change currently being experienced worldwide. One means of mitigation of the human impacts on the concentration of these gases is to hold carbon in sinks in order to reduce the likelihood that this carbon will cycle into the atmosphere. Biochar, which can serve as such a sink, is produced by pyrolysis (high temperature, low oxygen thermochemical decomposition) of organic matter. The production of biochar is one way to sequester some amount of carbon before it enters the atmosphere (Wolf et al, 2010). An additional documented benefit of biochar is as a soil amendment to improve yields (Cornell University Department of Crop and Soil Sciences, 2015). The chemical (negative surface charge density) and structural (high surface area) properties of biochar, when amended to soil, result in increased water retention and nutrient affinity.

Students as Stewards Sequestering Carbon

Learning about, producing and testing biochar enables students to learn about the carbon cycle while empowering them take action to mitigate climate change (Figure 1). During the fall of 2013, Cornerstone Learning Community middle school life science students produced 45 kg of biochar in a 55-gallon drum pyrolysis unit (see Packard, 2009 for design). Students collected biomass (primarily woody debris) from the campus to add to the top-lift updraft unit made from recycled metal barrels and piping. The design of the pyrolysis unit minimizes the entrance of oxygen to the bottom of the container. The biomass is lit on the top and a flame is produced by the off-gassing combustible compounds, not the combustion of biomass. Once pyrolysis is complete, the char is quenched by spraying with water to ensure that



Figure 1. Small student-built top-lift updraft pyrolyzer made from recycled cans. A fire is lit from the top as biomass (in this case pine pellets) is gasified and the volatile gases combust. When pyrolysis is completed, the remaining material is quenched, leaving behind biochar.

the char doesn't burn to ash. The biochar produced was ground and mixed at the rate of 45 kg per 4-foot by 10-foot by 1-foot raised bed garden (aging biochar in the soil before planting to enable nutrient and water absorption and bacterial colonization is recommended).



Figure 2. Experimental layout of raised-bed gardens. Treatments from left to right are 1) compost plus biochar, 2) compost only, 3) sand plus biochar, and 4) sand only.

Figure 3. Students measuring biomass produced by plants in different soil treatments.

Effect of soil treatment on biomass of leaf lettuce produced

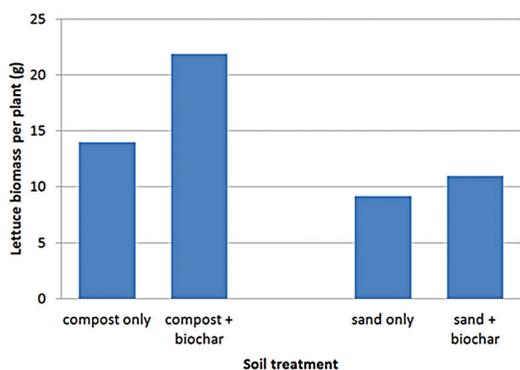


Figure 4. Student experimental data showing biomass produced by leaf lettuce plants in different treatments.

Figure 5. Student-grown vegetables being served at a transitional facility for homeless families.



Students worked collaboratively, consulting a regional planting guide, and then seeded a winter garden that included carrots, radishes, lettuce, cabbage, onions and kale. The experimental design included identical plots, varying only in the type of soil and soil amendment used to test for differences in vegetable biomass produced (Figure 2). The plots used compost, compost plus biochar, sand, and sand plus biochar to test for the effects of soil amendment and type on vegetable production.

Throughout the growing season and as vegetables were harvested, students quantified the growth in each plot and interpreted the effect of soil type on growth (Figure 3). Most vegetables produced more biomass in the compost soil type (as compared to sand) irrespective of the addition of biochar (with the exception of some very large radishes grown in sand). Of those grown with compost as a soil, the plants in plots amended with biochar grew larger. Some of vegetables produced much more biomass in biochar (such as Chinese cabbage and lettuce) (Figure 4) while others were larger, but not significantly so. Following their analysis of growth data, students were expected to generate a scientific argument about the value of biochar as a soil amendment.

Sharing the Wealth

All of the vegetables harvested from the experimental garden became part of the school's once-monthly lunch preparation and service at a local homeless transition facility (Figure 5). Students prepared salads and cooked dishes with the garden harvest. Based on experimental data, the project captured over 24,360 grams of atmospheric carbon that was converted into edible vegetable matter that has provided meals for homeless citizens. This combines with 45 kilograms of carbon that was sequestered for the long term (studies conservatively estimate 100+ years) in the form of biochar remaining in the garden.

Reaching Out to Others to Teach About Carbon

As the students finished up their analysis of the impact of biochar on plant growth, they thought about how to share this information with others. A display was designed and built to coincide with Earth Day (Figure 6). The students were tasked with generating ideas that would convey the message “carbon cycle” to visitors in elementary and middle school grades. The display took shape as a Build a Carbon Catcher activity, a large postcard with carbon cycle themed activities and individual trifold-displays of two of our school’s stewardship related activities (the biochar project, model solar car design, construction and racing). Students set up the display at our local Saturday Farmer’s Market. Students were able to share and educate passers-by. Visitors made ‘carbon catchers’ by decorating a small flowerpot and planting either a bean or sunflower seed. Puzzle pages with student-designed activities were distributed to visitors. Students also set up the display for our school Earth Day Festival. Students from kindergarten through fifth grade came to make carbon catchers and sidewalk Earth Day art, hear about biochar, and run a very popular Recycle Relay. This event was all in the hands of the students to run. They took charge of different roles and made it a big success.

Learning Gains

The results of pre- and post-tests were used to assess improvement in background knowledge about climate change and attitudes about the cause and impacts of changing climate. The survey instrument used for these tests is one from the National Center for Atmospheric Research Spark education group. The climate change questionnaire is from the module “Applications of chemistry through climate science” (Marschke, 2012). Thirty-seven of the objective questions from the questionnaire were used and eight of the questions addressing attitudes about climate change. The average student score on the objective portion of the pre-test was 74%. Post-test averages were three percent higher. Prior to starting the project, 80% of student responses indicated opinions that show urgency about human-induced climate change and the need to take action. These responses also went up three percent after the project was completed. The change in student scores however does not adequately represent the learning that took place through the project. The fact that this survey instrument was designed for high school students may have had some effect on middle school student scores.

Overall, the project was highly successful as it enabled climate change to be woven through the curriculum for the year. The connection to service-learning is an important one for the Cornerstone Learning Community school. Thinking about how to best present the carbon cycle and climate change to younger students in the display gave these middle schoolers a chance to think deeply about how to explain this topic. Their efforts produced an engaging and fun activity booth that they were able to share with others in our community.



Figure 6. Student designed and led Earth Day display and Carbon Catcher activity.

Next Generation Science Standards Addressed		
SCIENCE AND ENGINEERING PRACTICES	DISCIPLINARY CORE IDEAS	CROSSCUTTING CONCEPTS
<ul style="list-style-type: none"> Analyzing and Interpreting Data Constructing Explanations and Designing Solutions Engaging in Argument from Evidence 	<p>LS1.C: Organization for Matter and Energy Flow in Organisms LS2.A: Interdependent Relationships in Ecosystems LS2.B: Cycle of Matter and Energy Transfer in Ecosystems LS2.C: Ecosystem Dynamics, Functioning, and Resilience PS3.D: Energy in Chemical Processes and Everyday Life</p>	<ul style="list-style-type: none"> Cause and Effect Energy and Matter Stability and Change
PERFORMANCE EXPECTATIONS		
<p>MS-LS2-1. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem. MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations. MS-ESS3-5. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.</p>		

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Resources

Biochar International: Biochar in Schools

<http://www.biochar-international.org/teachers/schools>

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About the Author

Karen Metcalf is a middle school science teacher and IB Coordinator at Cornerstone Learning Community in Tallahassee, Florida. She was formerly a marine ecologist with a B.S. (Eckerd College), and M.A. (College of William and Mary) in marine science. Ten years in the classroom at the high school and middle school levels have allowed her to bring her love of the process of science and the marine environment to students. Karen's goal is to teach science concepts while encouraging students to value sustainability, practice environmental conservation, and use critical thinking. Membership in NOAA's Climate Stewards Education Project has facilitated special projects that support these goals. She is also the leader of Cornerstone's Maker Club. Karen can be reached at kmetcalf@comcast.net.