Agriculture and the Carbon Cycle

Tanner Dow and, Ogallala High School
Seth Heinert, Ogallala High School

Grade Level
9-12

Lesson Length
3 periods x 55 Minutes

Agriculture Careers
Microbiologist, Food Scientist, and Animal Nutritionist

Nebraska Science Standards
SC HS.13.3.E
SC HS.15.5

Next Generation Science Standards
HS LS.5

Nebraska Agricultural Science Standards
AFNR.HS.3.2b

Learning Environments Alignment


Learner-centered


Knowledge-centered


Assessment-centered


Community-centered

These lessons aim to help students make the connection between scientific, business, economic, environmental, and social issues and a degree in agriculture.

Learning Objectives

By the end of the unit, students should be able to:

- Use a model to demonstrate how farming practices in Nebraska aid in carbon sequestration.
- Compare and contrast biofuels and fossil fuels in accordance to energy and carbon release.
- Compare the characteristics and biomass of various cover crops.
- Measure the amount of ethanol made from fermenting different biofuel sources.

Materials List

- Day 1 Activity Sheet – Greenhouse Calculator
- Day 2 Activity Sheet – Comparing Cover Crops
- Day 3 Activity Sheet – Fermentation Lab (see lab for relevant materials)

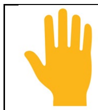
Investigation

This unit explores the role of agriculture and the carbon cycle. Students explore three aspects of agriculture: farming practices, cover crops, and biofuels as they relate to the carbon cycle. NOTE – This unit connects well with the following lessons / units: Farming the Carbon Cycle and Impacting the Carbon Cycle.

Research Question(s)

- How does agriculture impact the carbon cycle?
- How do biofuels and fossil fuels relate?
- How can we maximize carbon sequestration through the use of cover crops?

Day 1: Role of Farming Practices in the Carbon Cycle



Teacher Does: The teacher will introduce a pie chart that shows Greenhouse gas emissions by sector and then pose the following question to students: How does agriculture contribute to greenhouse gas emissions?

Student Does: Students will explore the website below to answer the discussion question.

https://www.epa.gov/ghgemissions/overview-greenhouse-gases

Teacher Does: Teacher explains the process of carbon sequestration. (what it is and how it is involved in the carbon cycle) Teacher holds a class discussion to determine students' thoughts on how different farming practices influence carbon sequestration.

Class: Class has a discussion farming practices (no till, cover crops, etc.) and their effect on carbon sequestration.

Teacher does: Teacher directs students to an online website (Michigan State Calculator) and hands out a worksheet for the students.

Students do: Students use the guiding Day 1 Activity Sheet to answer questions based on how farming practices influence the carbon cycle.

Day 2: Role of Cover Crops in the Carbon Cycle

Suggested Reading:
https://www.sare.org/Learning-Center/Topic-Rooms/Cover-Crops/Ecosystem-Services-from-Cover-Crops/Cover-Crops-and-Carbon-Sequestration

https://cropwatch.unl.edu/2019/cover-crops-and-carbon-sequestration-benefits-producer-and-planet

https://www.farmprogress.com/soybeans/7-cover-crop-options-you-should-know-and-what-each-offers

https://cropwatch.unl.edu/2018/cover-crop-and-co2-emissions

Teacher Does:

- Purpose - This short activity is intended to simulate different plant materials bringing in different amounts of carbon.
- Set up for "Hungry, Hungry Hippo"
- Materials: beans and scoops of different sizes which could be spoons, shovels, lids, etc.
- Divide students into small groups of 2-3
- Overview rules
  - Challenge is to gather as many beans as possible
  - Only allowed to use the device given to them to gather - no use of hands
  - No interfering with other teams
  - 30 seconds to gather
- Give materials, set time and go. Teacher assigns "scoops" at random.
- Discuss processing questions as a whole group after students have had time to respond.

Students Do:

- Play "Hungry, Hungry Hippo" as instructed.
- Respond to processing questions in worksheet and discuss them as a class.

Learning Activities

Teacher Does:

- Transition from discussing the opening questions to the idea that cover crops are generally good for a variety of reasons (soil improvement, potentially improved income to the producer, and greater carbon sequestration over conventional tiling methods).
- Instruct students that they will be doing a quick report to the class on a cover crop used in the Midwest.

Students Do:

- Select a cover crop to research as a small group from the list provided
- Research basic characteristics on the cover crop (15 minutes)
- Present basic information on the cover crop (~ 3 minutes each presentation) using any media necessary

Reflect (Formative Assessment)

Teacher Does:

- Write the names of cover crops discussed on individual index cards and hand to individual students
- Ask students to line up to show a ranking order of the biomass potential of each crop they have selected
- Have students discuss as a group the pros and cons of planting each crop in their specific region of the nation
- Check for misconceptions from the discussion

Students Do:

- Show a ranking order of the biomass potential of each crop they have selected
- Discuss as a class the pros and cons of each crop

Day 3: The Role of Biofuels in the Carbon Cycle

Teacher Does

- Remind students that they are investigating the role of agriculture in the carbon cycle
- Review briefly the role of farming practices and cover crops in the carbon cycle
- Set context around the use of ethanol, primarily from grains, as a fuel source.
    - Have students share what they know about ethanol production
    - Discuss briefly the pros and cons of ethanol as a fuel source
- Watch video “How is Ethanol Made” at https://ethanolrfa.org/how-ethanol-is-made/

Students Do

- Review the previous days of agriculture in the carbon cycle
- Discuss what they know about ethanol and other biofuel sources
- Watch a short video on how ethanol from grains is produced

Learning Activities

Teacher Does

- Prepare materials for the Fermentation Lab in advance
- Set context that biofuels are any fuel made from biomass and the purpose of the activity is to explore the value of different biomass materials as a fuel source
- Overview the steps for conducting the lab and review expectations for answering the processing questions
- Divide students into groups and begin the activity.
- NOTE - depending on how quickly students can work through the lab, the formative assessment may take place the following day.

Students Do

- Working in small groups, students will conduct a fermentation lab to explore the amount of ethanol produced from various biomass sources.
- After conducting the lab, students will respond to written questions and submit for a grade.

Reflect (Formative Assessment)

Teacher Does

- As group, teacher will lead the whole group in a discussion based on student responses to the questions in the fermentation lab.
- Be sure to check for accuracy in student responses.

Students Do

- Using the responses from their lab questions, students will discuss what they discovered for the relative values of ethanol production from different biomass sources.

Summative Assessment

Working individually or in small groups, students should design their own assessment to demonstrate how they would answer the question "How does agriculture impact the carbon cycle?" They are encouraged to use the information gleaned from the lessons in this unit. Their showcase must include the following elements:

- What is the role of cover crops in the carbon cycle?
- What is the role of biofuels in the carbon cycle?
- What is the role of different farming practices in the carbon cycle?
- What are other impacts, positive or negative, that agriculture has on the carbon cycle?

Example ways that a student could showcase their understanding are:

- Creating a poster, Google Slides or Prezi presentation
- Create an info graphic
- Narrate a Public Service Announcement
- Write a blog or article

Jin, V. (2019). *Fermentation Assay.*

Michigan State University. (n.d.). U.S. Cropland Greenhouse Gas Simulator. Retrieved from http://surf.kbs.msu.edu/

Activity Day 1 - Greenhouse Calculator

Background Information

Every year crops from around the world take part in the carbon cycle by both sequestration and emission. Farmers can manipulate their influence by changing not only the type of crop, but also how they farm fields. However, these changes can lead to both more emissions from carbon as well as nitrogen, both of which are major components of global warming.

Vocabulary

Crop-they type of plant being grown

Yield- How much of the crop is being harvested per acre

Tillage- the act of plowing the soil in a field
- Conventional: regular tilling
- Reduced: minimal tilling
- No-till: not tilling(plowing) the field at all

Fertilizer: Nitrogen applied to the crop to help its growth

Directions:
Access the website available**:** http://surf.kbs.msu.edu/
Follow the procedures listed below.

Procedure

1) Remove the second year be clicking on the remove last year button. Test different crops with out changing any of the other information. (Leave the pre-input as this is the averages of each crop)
   a) Which crop produces the lowest amount of greenhouse gas costs?_______

   b) Which crop produces the highest amount of greenhouse gas costs?_______
   c) Some of the crops had negative readings in the soil column. What does this negative number mean for carbon emissions?_______
2) Choose one crop of your choice. Change the tillage from conventional to reduced(not all crops can be changed to this, make sure you have one that can).
   a) How did the change from conventional to reduced affect the amount of greenhouse gas costs?_____
   b) Predict how the greenhouse gases with change when the tillage is again changed to a no-till method.
3) Using the same crop as in the step above, change the tillage to no till.
   a) How does the no-till affect greenhouse gas costs?
   b) What does the different tillage affect in recording the greenhouse gas costs?
4) Choose corn as your crop. Change the yield numbers both higher and smaller than the pre-given average. Then change the fertilizer levels.
   a) What happens when crop yield increases?
   b) What happens when fertilizer increases?
5) Now add 10 years worth of corn crop.(Add year to the rotation button). Change the last five years to a no-till plan.

a) How does the first 5 years of conventional tillage compare with each other in total greenhouse gas cost?
b) How does the last 5 years with no-till compare with each other in total Greenhouse gas cost?

6) Remove all the years except for 1(remove last year button). Experiment different scenarios to get corn to have a negative total greenhouse gas costs.
   a) What did you have to do to get a total negative greenhouse gas cost?

Analysis Questions

1. Explain the role of carbon sequestration in relation to the carbon cycle.
2. Using your idea in question 1, differentiate between the different ways of tillage and why some are better than others at carbon sequestration.
3. Describe how fertilizer can benefit carbon sequestration even though it increases the total greenhouse gas cost.
4. Differentiate between different crops and why they have different greenhouse gas costs

Activity Day 2 - Exploring Cover Crops

Hungry, Hungry Hippo:

1. Which scoop gathered the most material?

2. What characteristics about that made it possible to gather the most material?

Based on the reading and classroom discussion, answer the questions in the space below.

3. In your own words, define “cover crop”

4. What are some advantages and disadvantages of cover crops to producers in Nebraska?

5. How do cover crops impact the environment?

6. Why are some cover crops able to develop more biomass than other crops?

Directions:

1. Working in groups, research a cover crop from the list below.
2. Prepare a brief presentation on the details for your cover crop that includes a picture, characteristics, and potential biomass production.
3. Share your findings with the rest of the class.
4. Write the information in the space provided for other cover crops discussed.

Potential Cover Crops	
Cereal Rye Oats Turnips	Tillage Radish White Clover Ryegrass Winter Wheat

Cover Crop	Picture	Characteristics (2-3)	Potential Biomass Production

Activity Day 3 - Fermentation from Biofuels Lab

Source: Modified from Virginia Jin, Ph.D. USDA. Lincoln, NE

Materials

Clean Ziploc bags (snack size)
Teaspoon
Dry active yeast
Table sugar
Corn meal
Corn stover
Grass clippings
Graduated cylinder or beaker (50-100 mL)
Tap water (warm)
Ruler
Labels/tape & pen

Optional Materials:
Cellulase enzyme (25 g; dissolve 1 g or ¼ tsp in 30 mL water)
Sodium acetate buffer (1M, pH 4.5)
Graduated dropper
Plastic syringe (30 mL or larger)
Portable breathalyzer

Methods

1. Label bags, 1 each for control (no energy source) and other energy sources (table sugar, corn meal, corn stover, grass clippings). Record in the worksheet below.
2. Mix 1 tsp of yeast and 1 tsp of each energy type into a bag.
3. Add 50 mL warm water (~40 C) to each bag. Press excess air out of bag, seal. Record time.
3. Mix bag gently and let rest. First results should be seen within 15-20 minutes. Leave up to 30 minutes for greater differences in treatment results. Record final time. Record observations about the appearance of the bag and substrate (amount of bubbles, etc).
4. Roll down top of bag until all gas compressed. Tape to secure. Using the ruler, measure how much air is in the bag. Record all data in Table 1 below.

OPTIONAL
If you have cellulase: In Step 1, make additional bags for each energy source testing cellulase effects. In Step 3, add 10 drops acetate buffer + 2 drops of cellulase after adding warm water.

If you have a portable breathalyzer test: After measuring bag height in Step 4, use the syringe to carefully remove some of the gas from each bag. Inject the air into the breathalyzer and record the alcohol level. The greater the fermentation, the higher the output value.

Table 1: Comparing Different Biofuel Sources

Energy Source	Cellulase? (Y/N)	Start Time	End Time	Total Time (minutes)	Final Bag Height (cm)	Observations

Discussion Questions

1. Which energy sources showed the most gas production?

2. What is the gas being produced?

3. What other types of natural and man-made systems use fermentation?

4. What does bio-based energy and fossil-fuel based energy have in common?

Synthesis Questions

1. Fermentation is an anaerobic biological process. What does the cellulase enzyme do? At what step does the cellulase enzyme catalyze the fermentation reaction?

2. Why is energy made from plants considered carbon-neutral? How is this different from fossil fuels?

3. What is the debate about using crops to provide food vs. fuel?

4. What ecosystem processes could producing more crops for bioenergy have an effect on? How is this affected by the kind of crop used (perennial vs annual)?

5. Review the materials at https://afdc.energy.gov/fuels/fuel_comparison_chart.pdf Compare Gasoline to Ethanol production. Which fuel source has a greater amount of energy? What are some advantages of ethanol over gasoline production?

Possible responses to discussion questions

1. Table sugar > corn meal > corn stover/grass clippings

Adding cellulase will increase gas production because the enzyme will cleave more glucose molecules for fermentation to occur.

2. Carbon dioxide (CO_2)

3. Natural systems: cow rumen, decomposition

Man-made systems: beer/alcoholic beverages/kombucha, pickling (sauerkraut, etc)

4. Both capture energy from the sun, which we then release as energy using combustion.

Possible responses to Synthesis Questions

1. Fermentation is an anaerobic biological process. What does the cellulase enzyme do? At what step does the cellulase enzyme catalyze the fermentation reaction?

Plant cells are made of cellulose. Cellulose is a connected chain of glucose molecules. Fermentation degrades glucose into ethanol and carbon dioxide. Until the cellulase enzyme breaks the chain of cellulose into smaller glucose molecules, fermentation cannot occur.

2. Why is energy made from plants considered carbon-neutral? How is this different from fossil fuels?

Plants capture energy from the sun by photosynthesis where the sun's energy is trapped within carbon molecules that make up plant tissue. Annual plants capture this year's sunlight. Perennial plants capture light every year for as long as they live (a few years to decades, like trees) and can store that energy in their tissues (i.e. wood). Geologically speaking, this is all recently trapped energy – when we combust the plant material, it releases the energy as well as the carbon in which it was stored. Carbon dioxide in the atmosphere now gets recycled into plants living now, so we consider this type of biofuel as carbon-neutral (no net change in atmospheric carbon).

Fossil fuel is also sunlight captured by plants, but this sunlight was captured millions of years ago – this is why coal, natural gas, and petroleum are considered "fossil fuels." Fossil fuels are geologically trapped and would remain so without mining or other intervention by man. Therefore, when we drill for oil or mine for coal, we are bringing back energy stored within the carbon bonds that would have been captured indefinitely within the earth's crust. Once we combust that source, both ancient energy and CO2 is released into the atmosphere. We only bring back the carbon and the energy, not the fossil plants themselves that once fixed that carbon, so burning fossil fuels adds more carbon to the atmosphere than can be fixed by current vegetation. This is where the greenhouse effect originates – more CO2 in the atmosphere traps heat, leading to short-term changes in weather and long-term changes in climate.

3. What is the debate about using crops to provide food vs. fuel?

The use of grain for fermentation and energy use has been considered to compete with use of grain for human consumption. Almost 10 years ago, there was an economic argument that diverting grain away from consumption towards energy production increased food prices. This argument has since been disproven – there is no correlation between ethanol production and food price globally. Rising food prices, however, are clearly linked to increasing oil prices (World Bank, United Nations Food and Agriculture Organization, International Energy Agency). Environmentally, converting more land for fuel production is thought to endanger more environmentally sensitive lands which would otherwise remain uncultivated. The use of perennial crops instead of food crops for energy is appealing because these non-food energy crops could be grown on lands not suitable for crops – there would be no land competition between energy production vs. food production.

4. What ecosystem processes could producing more crops for bioenergy have an effect on? How is this affected by the kind of crop used (perennial vs annual)?

Ecosystem process include nutrient cycling and retention, erosion, carbon sequestration, wildlife habitat, water quality, air quality, soil health, etc. These would all be affected if more land were converted from non-crop to crop production. Perennial crops (grasses) have much lower agrochemical inputs and fewer machine passes to grow compared to row-crops. Perennial grasses also simulate native grassland structure and composition better than row-crops, so they provide better habitat for wildlife and pollinators. However, until there is a real market for perennial grasses for energy crops, there is no compelling economic incentive for growers to invest in this type of crop yet.

5. Review the materials at https://afdc.energy.gov/fuels/fuel_comparison_chart.pdf Compare Gasoline to Ethanol production. Which fuel source has a greater amount of energy? What are some advantages of ethanol over gasoline production?

While gasoline has a greater amount of total energy released, they also release more hyrdocarbons into the atmosphere. Biofuels, such as ethanol, use biomass from current available resources such as switchgrass or corn. This increases the economy for farmers in the Midwest, as well as make the United States more energy independent.