Farming and Weather and Runoff, Oh My!

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Overview

1. Human activities in agriculture have had major effects on land, vegetation, and water systems. This, in turn, impacts the decisions farmers make in regard to growing their crops.
2. Specifically, farmers must consider how much fertilizer to apply to their crops, when to apply the fertilizer, and what application method to use in order to reduce the amount of fertilizer that reaches water bodies as agricultural runoff.
3. Farmers must also make decisions about livestock in order to keep animals and their waste out of streams. Animal waste can also contribute to increased levels of nitrogen and phosphorus in water systems.
4. Weather also impacts agricultural runoff. Excess nitrogen and phosphorus can be washed from farm fields and into waterways during rain events and snow melts. Nitrogen and phosphorus can also leach through the soil and into groundwater over time.
5. Farmers can reduce agricultural runoff through various methods, including adopting nutrient management techniques, ensuring year-round ground cover, planting field buffers, and managing livestock access to streams are just a few examples.
6. This activity shows how agricultural activities impact water systems in the form of agricultural runoff. At the same time, it illustrates how weather (short-term atmospheric conditions) and climate (long-term atmospheric "behavior)" affect the choices farmers make about how to manage their crop growth while preventing excess runoff.

Learning Goals

1. Introduce participants to the relationship between human actions, agricultural runoff, and climate change/environmental impacts.
2. Understand how current mitigation efforts to reduce agricultural runoff do not address the problem of water sources that are already contaminated.
3. Encourage participants that they can be part of the solution to climate change by identifying and responding to the multiple interrelated issues present with current farming practices.

Materials

- Modified Stream table
    - Plastic support stand
    - 6-foot plastic hose
    - Smooth foam cut into 1-in width barriers
- A bucket that can hold at least 3L of water
- Sponges:
    - Square kitchen for Normal crops (8 cut in half for 16)
    - Small round artificial for Livestock/Cover crops (16)
    - Natural sponges for Prairie (16)
- Water (~9 L)
- Neon acrylic paint (pink)
- Pipettes
- Viva Paper Towels Cut into appropriately sized strips
- Classic Low Loft Batting cut into rectangles
- Plant growth graphic
- Water quality graphic
- Nitrates to Surface Water Maps of Minnesota and Iowa
- Agricultural Runoff Score Sheet
- Solo cup (to mix paint/water in)
- Colored pencils
- Dice
- Watering can
- A bucket that can hold about 5L of water
- Farmers Almanac Cards
- Glue gun to attach foam barriers

Materials that come in your kit:

- Stream table with 6-foot hose
- Smooth foam pieces
- Support stand
- Bag of washers
- Various Sponges
- Neon acrylic paint
- Classic Low Loft Batting (Reusable by rinsing immediately at end of the activity)
- Pipettes
- Watering can
- Dice
- Animal figures to glue on Livestock/Cover Crop Sponges

Set-up

1. Prepare your materials:
    a. Place foam barriers in the stream table using a glue gun to create eight spaces for participants to construct farms: four spaces on each side with a channel down the middle of the stream table and a small opening in each space to represent streams emptying into a river. A large space should be left open at the base of the stream table to represent a water reservoir.
    b. Display laminated handouts.
    c. Mix up neon paint and water mixture in a large cup- the mixture should be consistent and not chunky. Just enough paint to fill the bottom of the cup with the rest water.
2. Separate pipettes:
    a. One set should be for paint mixture.
    b. One set should be clean so participants can sample water quality later in the activity.
3. Sponges should be damp but not dripping before starting the activity.

Procedure

Short Form

1. Welcome participants and invite them to join an activity relating to agricultural runoff.
2. Explain that you're investigating the relationship between plant growth, nitrogen fertilizers, and local waterways and you need their help.
3. Invite participants to take two strips of paper towels and draw any kind of plant they like with colored pencils on the filter.
4. During this time, begin discussing appropriate topics relating to fertilizer runoff, agriculture, plants, mitigation strategies, and types of crops and livestock raised locally.
    a. Also, mix up and prepare pipettes with neon-water paint mixture.
5. Next, have participants pick two types of fields (sponges) to put in their fields. Be sure to place a piece of batting beneath the fields to represent the groundwater of the farm. Help them roll their plant paper towels.
6. Then have participants place their "plant" in one of the holes in either sponge.
7. Once all paper towel plants have been "planted" invite participants to fertilize their new plant with 3-5 squeezes of the pipettes filled with the neon paint.
    a. Make sure it is up to them to decide how much fertilizer they use- no hints!
    b. Also, make sure participants do their best to drop neon paint at the base of their plant/in the sponge and not directly onto the coffee filter.
    c. As the facilitator YOU have control over the paint mixture, do not allow participants to hold the cup.
    d. Assist with pipetting as necessary.
8. Once all plants have been fertilized, follow with a rain event of two seconds for each farm using the watering can. Repeat this process of fertilization application and precipitation two more times.
9. Ask the participants to harvest their paper towel plants (remove them from the sponge).
10. Instruct them to open up the filters and lay them on top of the growth ring handout. The pink areas indicate how much the plant has grown. More pink, more plant growth.
11. Invite participants to take samples with clean pipettes from the reservoir and from the groundwater batting on their own farm.
12. Place water samples on water quality laminated handouts.
13. Interpret results.
    a. If water is very light pink (falls within the first two color indicators), congratulate participants! Their plants grew but water quality levels are acceptable.
    b. If water is medium-dark pink (any other dark color indicators), encourage participants to experiment again and challenge them to still grow their plants, but lower their runoff levels.

14. If time permits, ask participants what they observed or review potential discussion topics depending on age. The discussion should be educational, but also encouraging! They are learning this information so they can empower themselves to make more environmentally conscious decisions.
15. Make sure to change out the water and ring out sponges so no residual neon paint remains in between each round of the activity.
    a. Or leave the reservoir water as is to create a greater challenge for the next group of participants.

Long Form

1. Follow previous steps for short-form activity.
2. Include dice and Farmer's Almanac Cards.

Play through three harvest seasons and achieve an accumulated Crop Growth Score that exceeds the water quality: minus score of groundwater on the farm, plus reservoir water/number of farms participating, and include any bonuses or penalties from Farmer's Almanac Cards.

Game Play

1. Design a farm with normal crop fields, cover crop fields, and/or prairie.
    a. Plants can be added to normal or cover crop fields.
    b. Prairie will not grow plants.
2. Participants will grow two plants over the three seasons.
    a. Decorate and then place plants in any available space on normal or cover crop fields.
3. At the beginning of each growing season, do the following:
    a. You can choose to move the location of your plants to other available spaces in your fields, but not required to do so.
    b. Apply 3-5 squeezes of fertilizer to each of your plants (6-10 squeezes total).
    c. Draw a Farmer's Almanac card and follow the directions indicated.
    d. End the season with three seconds of rainfall for each farm (more if directed by Farmer's Almanac card).
4. At the end of the fifth season, do the following:
    a. Check your plant to see how many crop points you scored.
    b. Check the water quality of the groundwater for your farm.
    c. Check the water quality of the reservoir water.

5. How to Score Activity: *Track on Agricultural Runoff Scoresheet*
    a. *Scores are additive*
    b. *Plant growth, add points*
    c. *Water quality, subtract points*
    d. *Include Bonus or Penalty points form Farmer's Almanac Cards*

Definition of Success

1. *Young kids (< 8 years old) don't require the scoring system. If kids understand that it's okay to use a little fertilizer, but not too much, then they have successfully completed the activity.*
2. *Kids (>8-13/Middle school age) should be scored based on their attempts at the activity. If they end up with a total score of 1 overall point or higher, they have succeeded!*
3. *High school students should be scored based on their attempts at the activity. If they end up with a total score of 5 or greater they have succeeded!*

Modifications and Guiding Questions

Modifications

1. For large events with many participants, consider prepping the stream table and plants:
    a. Roll strips of paper towels into ½ inch straw pieces (Bring a small container to collect and save straw pieces once the paper towel has been used for the activity).
    b. Place batting and two sponges in each farm space on the stream table (try to create a variety of combinations). If you have time, allow participants to switch out types of sponges. Otherwise, just ask participants to pick a farm.

Discussion Topics

1. Agricultural communities rely on fertilizer/nitrates to increase crop quality and yield-seeking a balance between crop growth and avoiding water pollution is key.
    a. Different actions can be adopted by farmers to help mitigate agricultural runoff
    b. Geographical location also affects the level of water contamination due to agricultural runoff (higher rates of contamination found downstream).

2. Nitrogen cycle
    a. Plants require nutrients to grow (Nitrogen, Phosphorous, Potassium).
    b. Livestock wastes also contribute to agricultural runoff.
    c. Effects of excess nitrogen fertilizer runoff in nearby waterways.

d. Eutrophication: The process of increased load of nutrients (usually nitrogen and phosphorus) introduced into water systems that fuel the overgrowth of algae.
e. Harmful algal blooms: Occur when algae — simple photosynthetic organisms that live in the sea and freshwater — grow out of control while producing toxic or harmful effects on people, fish, shellfish, marine mammals, and birds.
f. Hypoxic conditions: In this case, this term refers to areas in the ocean where the oxygen concentration is so low that animals can suffocate and die, and as a result are often called "dead zones."
g. Fish kills: Also known also as fish die-off, refers to a localized die-off of fish populations which may also be associated with more generalized mortality of aquatic life.
h. Increased turbidity: A measure of the level of particles such as sediment, plankton, or organic by-products, in a body of water. As the turbidity of water increases, it becomes denser and less clear due to a higher concentration of these light-blocking particles.
i. Pollution of aquifers and private wells: When rain falls on dry ground, it can soak into, or infiltrate, the ground. Some water infiltrates much deeper, into underground reservoirs called aquifers that can be tapped into via private wells. Public water systems use water treatment and monitoring to protect consumers from harmful pollutants and pathogens in the water. Generally, private wells do not receive the same services that wells supplying the public do, and they pose a greater risk to people's health.

   Source: https://www.noaa.gov

3. Water pollution

4. Health effects/exposure to nitrates in drinking water

   a. Pregnant women at high risk if exposed
   b. Blue baby syndrome

5. Climate change

   a. Variability in rainfall
   b. Increase in storm frequency and severity
   c. Droughts
   d. Diseases and pests that affect plant growth
   e. Nitrous oxides (NOx) are greenhouse gases → contribute to global warming and greenhouse effect
   f. "Dead Zone" in the Gulf of Mexico

Guiding Questions

1. How does water move on the stream table? What effect does this have on the level of contamination you see on the farms and the water reservoir?
2. Where do we see less contamination from agricultural runoff? Why do you think that is the case?
3. What do crops need to grow? How long do they have to grow compared to natural plants? How do farmers help crops to grow more quickly?
4. How do animals contribute to agricultural runoff?
5. What happens to the water after the continued use of fertilizers?
6. How do rainfall and other weather events impact the success of crop growth and the amount of agricultural runoff?

Further Resources

- Canning, James F., and Ashlynn S. Stillwell. 2018. "Nutrient Reduction in Agricultural Green Infrastructure: An Analysis of the Racoon River Watershed." Water.
- Iowa Environmental Council. 2019. Iowa's Private Wells Contaminated by Nitrate and Bacteria. April. Accessed December 8, 2019. https://www.ewg.org/interactive-maps/2019_iowa_wells/
- Iowa State University Extensions and Outreach. 2019. Integrated Crop Management. Accessed December 8, 2019. https://crops.extension.iastate.edu/
- United States Environmental Protection Agency. 2019. Nutrient Pollution- The Sources and Solutions: Agriculture. April 15. Accessed December 8, 2019. https://www.epa.gov/nutrientpollution/sources-and-solutions-agriculture
- Wall, David, David Mulla, Steve Weiss, Dennis Wasley, Thomas E. Pearson, and Bruce Henningsgaard. 2013. Nitrogen in Minnesota Surface Waters: Conditions, trends, sources, and reductions. Saint Paul: Minnesota Pollution Control Agency.

NGSS Standards

5-ESS3-1 Earth and Human Activity

Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.

MS-ESS3-3 Earth and Human Activity

Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

HS-ESS3-4 Earth and Human Activity

Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

K-ESS2-2 Earth's Systems

Construct an argument supported by evidence for how plants and animals (including humans) can change the environment to meet their needs.

Research Resources and Troubleshooting Guide

How I found my data:

1. My idea for this project came from a Guardian article published September 26, 2019: https://www.theguardian.com/environment/2019/sep/26/nitrate-problem-iowa-dont-use-the-tap-water-for-babies
2. I started to search for data with the United States Environmental Protection Agency and their page on Nutrient Pollution: https://www.epa.gov/nutrientpollution/sources-and-solutions-agriculture
    a. This site provided the basic outline for the activity. It summarized the current methods for mitigating agricultural runoff.
3. I then searched for specific data on Iowa and its relation to the issue of nutrient pollution and agricultural runoff: https://www.mdpi.com/2073-4441/10/6/749/htm
4. I also looked for similar studies in the Midwest, specifically Minnesota: https://www.mdpi.com/2073-4441/10/6/749/htm
    a. Both of these studies investigated current mitigation efforts and their drawbacks, illustrating the need for more investment in green infrastructure.
    b. They also show how water contamination is more pronounced downstream of waterways.
5. To create the Farmer's Almanac Cards, I used the Iowa State University's Integrated Crop Management web page for historical weather data and agricultural impacts: https://crops.extension.iastate.edu/
    a. I used specific weather events of the past to create different effects on the gameplay of the activity, trying to accurately represent the impacts of weather and climate on crops along with farmers' available choices to respond to these events.
6. To create regionally specific Almanac Cards, first search for similar outreach websites produced from local university agricultural programs or other agricultural research programs. Washington State University for instance has a site that pairs local weather data with weather-related decision support tools: http://weather.wsu.edu/
7. If there are no local sources for weather and agriculture data, the U.S. Department of Agriculture's National Agricultural Library provides multiple resources and links to such data: https://www.nal.usda.gov/main/

How I prepared my activity:

Some of the graphics I use for my activity come from the kNow Your Nitrates activity, specifically the plant growth bullseye and the water contamination scale. I also modified the activity's scoresheet to accommodate the use of the Farmer's Almanac Cards. I did introduce two new visuals for the activity that illustrate how water contamination from agricultural runoff is more pronounced downstream of waterways. Finally, to create the logo for the Farmer's Almanac cards, I utilized Microsoft Word to create 6x2 grids with identically sized cells. I then used Word's farmhouse icon and created text that references The Old Farmer's Almanac, simplifying it to Farmer's Almanac to avoid any copyright issues. The other sides of the cards are created from the data from Iowa State University's Integrated Crop Management webpage. This information can be modified to reflect local crops and weather data, though the gameplay elements can remain the same.

Some Troubleshooting Guidelines:

1. The activity is difficult to reset quickly, especially when it is busy.
    a. If possible, bring a second stream table to swap out with the first one during the activity. This is most effective when you have a volunteer available to reset while the other table is in use.
    b. Prepare the plants beforehand. Rolling the paper towels to fit into the sponges can be difficult and frustrating for younger participants. For prep, fold a strip of Viva paper towel in half and then roll the fold and slip on a small piece of straw to keep it in place. Bring a small container to collect the straws as the plants have been used. Reuse for future activities.
    c. If the reservoir is not full of water, ask participants to help wring out sponges and batting at the end of the activity. You can also use this to show how much fertilizer remains in the soil without reaching waterways.

2. If you don't have access to a sink for the duration of the activity. Note: I highly recommend access to a sink if possible, for this activity.
    a. You can bring a large bucket to drain the stream table. Extra towels might also be a consideration to mop up any spills.
    b. Possibly reduce the number of farms in use to prevent the stream table from collecting too much water too quickly.

3. Participants knock the foam barriers out of place during the activity.
    a. Make sure participants use only two sponges per farm space. Adding more than that strains the glued-down foam.
    b. Also make sure that sponges are cut down to a size that does not push against the foam barriers.
    c. Bring a small, low heat hot glue gun with you. If you have a second stream table, you can reattach pieces during the reset. If the second stream table isn't available after a few play-throughs ask guests for a five-minute intermission to reset the table. Guests who linger can be offered a longer introduction to the activity as you reset the table.

4. New guests arrive during a playthrough already in process. (A lot of younger participants are

drawn to the pipettes being used during the process of adding fertilizer).

a. If still in the process of the first round, offer a quick introduction and help them set-up their farm. While the newcomers finish setting-up, ask other participants for predictions and/or discuss different weather patterns that can affect plant growth. For example, if a 1 is rolled on the die for the number of seconds of rainfall, connect it to droughts, while a 6 may represent flooding.
b. If new guests arrive toward the end of the play through, encourage them to wait a few minutes so they can experience the entirety of the activity.