Climate Change and Farmland Soil Quality

WASHED AWAY

DESCRIPTION

Students see a demonstration of the erosion of topsoil on a farm by an extreme precipitation event and then use a soil nutrient test kit to conduct an experiment to analyze and compare the nutrients of the topsoil and lower layer. Students also use SoilWeb, a web-based tool, to investigate soil characteristics of agricultural land in three areas and at their own location.

PHENOMENON

Erosion from extreme precipitation decreases soil nutrient levels.

GRADE LEVEL
6 – 12

OBJECTIVES

Students will:

- Apply prior knowledge to make a prediction
- Analyze the results of an experiment
- Evaluate graphic and tabular information
- Apply understanding of experimental results to predict how agricultural producers will be affected by extreme precipitation events

TIME
60 MINUTES

COMMON CORE STATE STANDARDS

English Language Arts Standards » Science & Technical Subjects » Grade 6-8
CCSS.ELA-LITERACY.RST.6-8.3. Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

CCSS.ELA-LITERACY.RST.6-8.4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6-8 texts and topics.

English Language Arts Standards » Science & Technical Subjects » Grade 9-10
CCSS.ELA-LITERACY.RST.9-10.3. Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.

CCSS.ELA-LITERACY.RST.9-10.4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9-10 texts and topics.

English Language Arts Standards » Science & Technical Subjects » Grade 11-12
CCSS.ELA-LITERACY.RST.11-12.3. Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.

CCSS.ELA-LITERACY.RST.11-12.4. Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics.

Grade 6 » Statistics & Probability
CCSS.MATH.CONTENT.6.SP.B.5. Summarize numerical data sets in relation to their context, such as by: CCSS.MATH.CONTENT.6.SP.B.5.A. Reporting the number of observations.

NEXT GENERATION SCIENCE STANDARDS

High School Performance Expectation
HS-ESS3-1. Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.

Science & Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Planning and Carrying Out Investigations (MS, HS) Developing and Using Models (MS, HS) Constructing Explanations and Designing Solutions (MS, HS)	ESS2.C The Roles of Water in Earth's Surface Processes (MS, HS) ESS3.B Natural Hazards (MS, HS) ESS3.C Human Impacts on Earth Systems (MS, HS)	Cause and Effect (MS, HS) Systems and System Models (MS, HS)

AGRICULTURE, FOOD, AND NATURAL RESOURCES STANDARDS

CS.04.02. Assess and explain the natural resource related trends, technologies and policies that impact AFNR systems.
CS.04.02.01.b. Analyze natural resources trends and technologies and explain how they impact AFNR systems (e.g., climate change, green technologies, water resources, etc.).
ESS.03.01. Apply meteorology principles to environmental service systems.
ESS.03.01.03.b. Assess the environmental, economic and social consequences of climate change.
ESS.03.01.03.c. Evaluate the predicted impacts of global climate change on environmental service systems.
ESS.03.02. Apply soil science and hydrology principles to environmental service systems.
ESS.03.02.01.b. Use a soil survey to determine the land capability classes for different parcels of land in an area.
ESS.03.03. Apply chemistry principles to environmental service systems.
ESS.03.03.01.a. Examine and summarize how chemistry affects soil structure and
function (e.g., pH, cation-exchange capacity, filtration capability, flooding likelihood, etc.).
ESS.03.03.01.b. Analyze the soil chemistry of a sample.
ESS.03.03.01.c. Evaluate a sample's soil chemistry and assess how the results may impact considerations in environmental service systems.
NRS.01.03. Apply ecological concepts and principles to atmospheric natural resource systems.
NRS.01.03.02.a. Research and summarize how climate factors influence natural resource systems.

BACKGROUND

As the atmosphere becomes warmer under climate change conditions, it is able to hold more water. The amount of water vapor in the atmosphere has increased over land and oceans. As a result, extreme precipitation events with very heavy downpours are becoming more common across most of the United States. This is occurring even in areas where total precipitation is decreasing, such as the Southwest.

Although agricultural producers in many areas of the Southwest would welcome increased precipitation, extreme precipitation events can harm crops and reduce yields. Flooding and runoff can result in diminished soil quality through **soil erosion**, which is the wearing away of soil by physical forces of water and/or wind. When soil erosion occurs, it is most often the **topsoil**, or the top 0-20 cm of soil, that is worn away. Topsoil tends to be richer in **nutrients**, substances that provide needed components for energy or growth.

The soil nutrients tested in this activity are nitrogen, phosphorus, and potassium. Plants use nitrogen to make molecules for necessary functions, such as chlorophyll for photosynthesis and proteins that make up enzymes to affect the rate of reactions. Crop needs for nitrogen vary. Some crops, such as soybeans, are considered low need because of associated nitrogen-fixing bacteria. Some plants, such as potatoes, need a relatively large amount of nitrogen. Phosphorus tends to be a high-need nutrient for most crops. It is an essential component of adenosine triphosphate (ATP), which provides energy and is involved in many processes. Potassium is essential for plant growth, and it is involved in water, nutrient, and carbohydrate movement through plant tissue, enzyme activation, and the production of ATP.

In this activity, students also measure soil pH because of its importance for crops. When soil becomes too acidic, vital nutrients, such as phosphorus, become less available to plants. Most field crops need slightly acidic to neutral soil pH for optimal growth. For example, the recommended pH range for corn is 5.8 to 6.2, and the recommended pH for soybeans is 6.6 to 7.0.

MATERIALS

- *Washed Away* handout [1 per student]
- PowerPoint presentation
- Computer and projector
- Soil testing kits,* such as the one shown in Figure 1 [enough kits to provide a test for every student or every 2 students]
  - Test tubes, caps, capsules, racks [1 set for every 4 students (or 8) students]
  - Copies of soil testing instructions and pH/nutrient color charts [1 for every 4 students (or 8) students]
- Squeeze-bulb pipettes [3 for every 4 (or 8) students]
- Paper towels
- 100 mL beakers or small cups [2 for every 4 (or 8) students]
- Spoon [1 for every 4 (or 8) students]
- Play sand [1 bag, 50 lb]
- Potting soil [1 bag, 1 cubic ft]
- Play sand solution, made according to soil kit instructions [1 each for half of groups]
- Potting soil solution, made according to soil kit instructions [1 each for half of groups]
- Two heavy duty aluminum baking pans, dimensions 12.5 x 3.4 x 20.5 inches, cut for soil pan erosion demonstration as per instructions in preparation section (Figure 2) [1 set for every 3 classes]
- Tin snips or another tool that can cut aluminum
- Watering can
- Brick
- Graduated cylinder (largest available)
- Bath towel
- Trowel or cup for scooping
- Optional: computers or tablets with internet access [1 for every 2 students]
- Optional: document camera

« Figure 1. Example soil test kit

Figure 2. Cut pan setup for soil pan erosion demo

*Notes about soil testing kits: there are many low-cost soil-testing kits available. Here are links to two kits that will work well for this activity: 1) includes 40 tests (http://www.lowes.com/pd/Soil-Test-Kits/999989630); 2) includes 10 tests (https://www.amazon.com/Luster-Leaf-Rapitest-Tester-1609CS/dp/B0019AI7PU/ref=sr_1_4?ie=UTF8&qid=1467141004&sr=8-4&keywords=soil+test+kit). These kits include tests for 4 variables: pH, nitrogen, phosphorous, and potash (potassium). Ideally, each student in every group of 4 would be able to conduct a test for one of the 4 variables included in the test. However, for large numbers of students, educators may wish to only provide enough kits so that every 2 students share the testing of one variable. If a different test is used, you may need to adapt the data table to reflect the nutrients tested.

PREPARATION

1. Plan to divide students into groups of four or eight. Ideally, each student in a group of four will conduct a test of one of the four variables (nutrients/pH). However, it is possible for two students to share the testing of one variable if supplies are limited, and if so, students will be divided into groups of eight.
2. For nutrient tests, prepare potting soil solutions and play sand soil solutions according to directions in the soil test kit (may need to be done 30 min – 24 hours in advance).
   a. Label solutions made with potting soil, "topsoil," and label those made with play sand, "lower layer."
   b. Make enough soil solutions so that half of the groups in each class will receive a "topsoil"

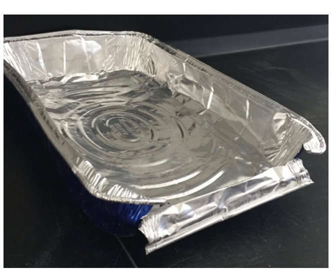

Figure 3. Soil pan, showing cut flap

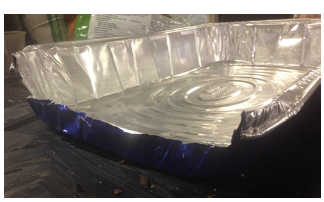

Figure 4. Catch pan, showing open side

Figure 5. Lower layer of play sand in the soil pan, tamped down so that sand is flush with opening

Figure 6. Attachment of soil pan to catch pan

solution, and the other half of the groups in each class will receive a "lower layer" solution.

3. For pH tests, fill some small beakers or cups approximately half full of dry potting soil and some small beakers or cups approximately half full of dry play sand.
   a. Label cups filled with potting soil, "topsoil," and label those filled with play sand, "lower layer."
   b. Fill enough cups so that half of the groups in each class will receive a "topsoil" cup, and the other half of the groups in each class will receive a "lower layer" cup.
4. Set up soil test stations for each group of 4 (or 8) students with the following supplies:
   a. Copy of soil color chart
   b. Copy of soil test instructions
   c. 4 tubes and caps
   d. 4 soil test capsules
   e. Tube rack (half of stations labeled "topsoil" and other half labeled "lower layer")
   f. 3 squeeze bulb pipettes
   g. Paper towels
   h. Beaker of water
   i. Beaker of soil (topsoil or lower layer)
   j. Soil solution (topsoil or lower layer)
   k. Spoon
5. Set up soil pan erosion demonstration
   a. Prepare the **soil pan** by cutting one of the short dimensions of an aluminum baking pan to make a flap (Figure 3). Measure approximately 2 inches from a corner, and make a downward cut to 1.5 inches. Measure 8 inches across, and make a second downward cut to 1.5 inches. Fold the resulting flap down.
   b. Prepare the **catch pan** by cutting away part of one of the short dimensions of an aluminum baking pan (Figure 4). Measure approximately 1 inch from a corner, and make a downward cut to 2 inches. Measure 10 inches across, and make a second downward cut to 2 inches. Cut the flap off entirely and remove it.
   c. Fill soil pan with play sand. Tamp the sand down with a brick so that it is packed tightly. Keep filling with sand and tamping it down until the sand is flush with the opening (Figure 5).
   d. Sprinkle potting soil on top of the packed play sand to about ¼ inch deep. Do not tamp down the potting soil.
   e. Lay out the bath towel in a location in which students can gather around to view it.
   f. Place the soil pan on one end of the towel.
   g. Attach the catch pan to the soil pan by sliding the catch pan under the flap of the soil pan (Figure 6). Fold the flap of the soil pan so that it creates a ramp into the catch pan.
   h. Place a brick under the unattached end of the soil pan to create a slope (Figure 2).
   i. Fill watering can with 2.5 L of water using a large graduated cylinder.
   j. The **lower layer** in the pan setup will be functional for up to three demonstrations, but the **top layer** will need to be replaced after each demonstration. Replace the top layer after each of the first two demonstrations by scraping off the wet potting soil and sprinkling on fresh, dry potting soil, and it will be set up for the next class. Dump out the water in the catch pan between demonstrations. After three demonstrations, there is generally too much standing water in the pan or the sand is too saturated, and the lower layer will need to be replaced.
   i. Either prepare enough setups to conduct the demonstration with as many classes as needed for the day, given that the setup will generally last for three classes, or after the third demonstration, dump out the soil and begin with step 5c to create a fresh soil pan setup.
6. Draw the pH and nutrients class tables from pages 4 and 5 of the handout on the board or prepare to show them with a document camera.
7. Prepare to have computers or tablets with internet access available for students. Set up one computer or tablet for every two students. As a time-saving measure, it is advised to power on each computer or tablet, open the browser, and open the following website. casoilresource.lawr.ucdavis.edu/soilweb-apps/
   a. If student computers or tablets with internet are not available, go online, and use the instructions in the *Comparing Soil on Agricultural Lands with SoilWeb* section of this educator guide to fill in the Soil Variables table on page 2 of the handout for students. Prepare to show the filled-in table with a document camera or write the data in the table on the copy master of the handout before making student copies.
8. Set up a computer and projector, and display the PowerPoint presentation.

PROCEDURES

Soil Pan Erosion Demonstration

1. Explain the soil pan erosion demonstration set up. Tell students that the soil pan erosion demonstration is a model of an agricultural (crop) field. Explain the concept of a model and that while the pan represents a field, it does not mimic a field exactly, especially not the soil layers.
   a. Tell students that on top of our field, there is nutrient-rich topsoil, which in a field has likely been fertilized.
   b. Say that underneath, there is less erodible soil that has lower nutrient levels.

Note: This soil pan erosion demonstration is not appropriate for teaching soil horizons, and it is not intended to be an accurate representation of soil horizons.

2. Conduct the demonstration.
   a. Explain that we want to see what happens if a big rainstorm occurs.

   b. Optional: ask students to make the sounds of an incoming rainstorm.
   c. Use watering can to pour 2.5 L of water onto pan. Hold the watering can 3-6 inches from soil and pour. Start at the top and move the can down the pan as the water pours out.
   d. Ask students to explain what happened to the field when the big rainstorm came through. Be sure to emphasize that the nutrient-rich topsoil washed off of the field and ended up in the catch pan. Ask where the nutrient-rich topsoil would go if this were a real agricultural field [answer: the nutrients may get carried to the nearest stream, river, or body of water].

INTRODUCTION

1. Give a short introduction about extreme events and climate change using the PowerPoint presentation.
   a. **Slide 2**: we have recorded data on Earth temperatures since 1880. Ask students to describe the trend of this graph [answer: temperature is increasing].
   b. **Slide 3**: as we saw in the graph, temperatures are increasing. Warmer temperatures result in more water evaporating into the air because warm water evaporates more readily. Plus, warmer air can hold more water. Because there is more water in the atmosphere, the frequency of intense precipitation will increase in some areas, and we will see more extreme events.
   c. **Slide 4**: soil erosion is the wearing away of soil by water or wind. As we saw in our model, extreme precipitation can erode soil.

SET UP SOIL TESTING

1. Pass out a *Washed Away* handout to each student.
2. Introduce the experiment, nutrients that we will be testing, and their importance to crops using the PowerPoint presentation.
   a. **Slide 5**: pretend that you manage an imaginary farm that will be hit by extreme rain. You are going to examine the soil quality before and after the extreme precipitation event. This extreme precipitation event will erode much of the topsoil, which is the top 0-20 cm of soil. Topsoil is usually more nutrient rich than lower layers of soil.
      i. Tell students that they will be measuring the pH and nutrients of the topsoil (before the extreme event) and lower layer of soil (after the extreme event) on our imaginary farm.
   b. **Slide 6**: pH is how acidic or basic a solution is. Vegetables need fairly neutral or slightly acidic soil. Give examples of the pH of common household solutions from the graphic.
   c. **Slide 7**: in agriculture, it is important to provide nutrients for the crops. A nutrient is a substance that provides needed components for energy or growth.
   d. **Slide 8**: an important nutrient for plants is nitrogen. It is needed to make molecules for necessary functions, such as chlorophyll, energy molecules, proteins, and DNA. Crops that need low nitrogen are beans, peas, tomatoes, and squash. Crops that need high nitrogen are potatoes, corn, broccoli, and cabbage.
   e. **Slide 9**: phosphorous is also an important nutrient for making molecules for necessary functions, such as energy molecules and DNA. It is a high need nutrient for most plants.
   f. **Slide 10**: potassium or potash is a nutrient that helps sustain plant growth and reproduction. It is used to build plant structures and aids in photosynthesis.
   g. **Slide 11**: predict whether the pH and each of the nutrients will be higher or lower in the topsoil (before the extreme event) than the lower layer (after the extreme event). Circle "higher" or "lower" for each nutrient/pH.
   h. **Slide 12**: we will begin our soil quality test in groups.
3. Put students into groups of four (or eight), and give each group a number. Tell students to record their group number in their group's data table on page 4 of the handout.
4. Direct students to find the copied instructions for the soil test, and give an overview of the instructions to students.
5. Instruct students to each take one tube and a cap and capsule of the same color. If there are eight students per group, tell each group of two students to take one tube and a cap and capsule of the same color.
6. Instruct students to place a paper towel under their tube to catch the powder from the capsule, water, or soil that may spill during the test.
7. Use the directions from the soil test kit to explain how to conduct the test and guide students through the procedures.
8. Once students have processed all of the tests in each group, ask them to place their tubes into their racks and let them sit to develop for the specified amount of time.

COMPARING SOIL ON AGRICULTURAL LANDS WITH SOIL-WEB

1. While the soil tests are developing, lead students in an investigation of agricultural soil in different locations using the online map tool, SoilWeb.
2. Put students in groups of two and seat them at computers or tablets with internet access.
   a. If computers or tablets are not available, have students use the data that you provide in Soil Variables table on page 2 of the handout to answer the conclusion questions.
3. Use the PowerPoint presentation

to guide students through the SoilWeb activity.

a. **Slide 13**: while the soil tests are developing, we will conduct an investigation of agricultural soil in different locations using the online map tool, SoilWeb.
b. **Slide 14**: SoilWeb was created with soil data collected by the US Department of Agriculture Natural Resources Conservation Service (USDA-NRCS). To gather the data, soil scientists conducted soil surveys on the ground and collected soil samples to be tested in laboratories. This information is useful to many people including farmers, foresters, and ecologists. For example, agricultural producers can use this information to help determine if a plot of land has favorable soil characteristics for crops.

4. For educators with computers or tablets with internet access, lead students to follow these instructions, which are also on **slides 15-25** of the PowerPoint presentation.
   a. Go to the California Soil Resource Lab SoilWeb Apps: casoilresource.lawr.ucdavis.edu/soilweb-apps/
   b. Click on the SoilWeb link.
   c. Click "OK" on the pop-up message.
   d. Click in the upper left corner on Menu.
   e. On the dropdown menu, click Zoom to Location.
   f. In the "Enter a location" box, enter the latitude and longitude for the first location in the Soil Variables table and press Enter.
   g. Locate the soil code for the location and click on that code.
   h. Select the soil component that comprises most of the map unit, the highest percentage.
   i. In the Soil Variables table, record % of slope. Then click on Org Matter (organic matter).
   j. Below the graph, click on the View Source Data link.
   k. Find percent organic matter and pH by water extraction on the data table, and record them in the Soil Variables table.
   l. Click on the blue triangle next to Hydraulic and Erosion Ratings to find Runoff, and record it in the Soil Variables table.
   m. In the left-hand corner, press the Close button until you get back to the Menu button. Repeat steps d-l for the next location until you have completed the first three columns of the Soil Variables table.
   n. Begin at step d to complete the last column of the Soil Variables table for your location. Instead of entering coordinates in step f, click "Use My Current Location." Use the "+" button in the right hand corner to zoom in on the map to find your location, and click on the soil code nearest your location.
5. Ask students to complete the SoilWeb conclusions questions on page 3. Discuss them as time permits.

RETURN TO SOIL TESTING

1. Instruct students to return to the soil quality tests, and use the PowerPoint presentation to explain the procedure.
   a. **Slide 26**: examine the tubes and compare the color to the copies of the color charts from the soil test kits to determine nutrient and pH levels. Try to match the shade of your test as closely as possible to the color chart. Make determinations of nutrient levels, from *high* to *very low*, and determine the number level of your pH test.
2. Tell students to work together in their group to fill out their group's data table on their handout. pH is reported as a number, and each of the nutrients is reported as *high*, *medium*, *low*, or *very low*.
3. Once groups begin to finish filling in their group's data table, ask them to report their results to the educator for recording in the class tables on the board, or a representative from each group may be selected to record results in the tables on the board.
4. Lead a discussion to determine the most common level of each of the nutrients in the class table. Explain that the most common level is the one that is reported most frequently. For example, if *high* is reported twice and *medium* is reported once, then the most common level is *high*.
   a. If there is an even number of nutrient levels reported, record the most common level as a mix of the levels reported. For example, if there is one report of *high* and one report of *medium*, record the most common level as *high/medium*.

RESULTS AND CONCLUSIONS

1. After filling out the class data tables and determining the means of the pH levels and most common levels of the nutrients, discuss with students the Results questions on page 5 of the handout. Prompt students to determine whether each factor was higher in the topsoil, lower layer, or neither.
2. Choose one of these methods or any other preferred method to have students answer the Soil Testing Conclusions questions on page 6 of the handout.
   a. Students can answer all of the questions on their own, and then you can lead a discussion of each of the questions.
   b. Students can answer the questions as a whole group. Lead students in a discussion of each question, and solicit answers from students.
   c. Organize students in small groups and have each group work on one or two questions. Have one student from each group report to the class by

reading the question and summarizing their group's answer.

EXTENSIONS

1. Ask students to bring in topsoil and lower layer soil from an agricultural field for soil testing. Instruct students to collect one cup of soil from the top of the ground, and then dig down approximately 12 inches and collect another cup of soil. Follow the instructions from the soil kit to test students' soil samples.
2. Challenge students to create a more accurate representation of the soil profile in your local area. They could bottle and label representative samples of soil from each horizon, draw a diagram, or create a physical model with materials other than soil.

ADDITIONAL RESOURCES

Websites with background about extreme precipitation and other events:

National Climate Assessment (NCA). Heavy Downpoars Increasing. Updated Oct. 2014. Web. Accessed 11 Jul. 2016. <http://nca2014.globalchange.gov/report/our-changing-climate/heavy-downpours-increasing>.

National Oceanic and Atmospheric Administration (NOAA). New Study: A Warming World Will Further Intensify Extreme Precipitation Events. Published 04 Apr. 2013. Web. Accessed 04 Oct. 2016. <http://www.noaanews.noaa.gov/stories2013/20130403_ncdcextremeprecipitationstudy.html>.

National Oceanic and Atmospheric Administration (NOAA). New report finds human-caused climate change increased the severity of many extreme events in 2014. Published 05 Nov. 2015. Web. Accessed 22 May 2017. <http://www.noaanews.noaa.gov/stories2015/110515-new-report-human-caused-climate-change-increased-the-severity-of-many-extreme-events-in-2014.html>.

Information about the effects of climate change on agriculture:

Anyamba, A, Small, JL, Britch, SC, Tucker, CJ, Pak, EW, Reynolds, CA, Crutchfield, J, Linthicum, KJ. 2014. Recent Weather Extremes and Impacts on Agricultural Production and Vector-Born Disease Outbreak Patterns. PLoS One 9(3): e92538. Accessed online 4 Aug. 2016. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3962414/>

United States Department of Agriculture (USDA). Climate Change is Affecting Agriculture in the U.S. Web. Accessed 22 May 2017. <https://www.usda.gov/topics/climate-solutions>.

Background about soil nutrients and characteristics:

Flynn, R and Idowu, J. 2015. Nitrogen Fixation by Legumes, Guide A-129. New Mexico State University Agronomy Publications. Web. Accessed 16 Feb. 2017. <http://aces.nmsu.edu/pubs/_a/A129/>

Hyland, C, Ketterings, Q, Dwing, D, Stockin, K, Czymmek, K, Albrecht, G, Geohring, L. 2005. Phosphorus Basics – the Phosphorus Cycle. Cornell University Cooperative Extension Agronomy Fact Sheet Series. Web. Accessed 16 Feb. 2017. <http://nmsp.cals.cornell.edu/publications/factsheets/factsheet12.pdf>

Johnson, C, Albrecht, G. Ketterings, Q, Beckman, J, and Stockin, K. 2005. Nitrogen Basics – the Nitrogen Cycle, Fact Sheet 2. Cornell University Cooperative Extension Agronomy Fact Sheet Series. Web. Accessed 16 Feb. 2017. <http://nmsp.cals.cornell.edu/publications/factsheets/factsheet2.pdf>

Kaiser, DE, Rose, CJ, Lamb, JA. 2016. Potassium for crop production. University of Minnesota Extension. Web. Accessed 16 Feb. 2017. <http://www.extension.umn.edu/agriculture/nutrient-management/potassium/potassium-for-crop-production/>

Ketterings, QM, Albrecht, G, Beckman, J. 2005. Soil pH for Field Crops, Fact Sheet 5. Cornell University Cooperative Extension Agronomy Fact Sheet Series. Web. Accessed 16 Feb. 2017. <http://nmsp.cals.cornell.edu/publications/factsheets/factsheet5.pdf>

Overstreet, LF, DeJong-Hughes, J. The Importance of Soil Organic Matter in Cropping Systems of the Northern Great Plains. University of Minnesota Extension. Web. Accessed 4 Aug. 2016. <http://www.extension.umn.edu/agriculture/tillage/importance-of-soil-organic-matter/>