The Effects of
CLIMATE CHANGE ON AGRICULTURAL SYSTEMS

A 5-Hour Curriculum Unit for 6-12 Grade Students

· Developed by the Asombro Institute for Science Education (www.asombro.org)

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For more information, contact:
Asombro Institute for Science Education
PO Box 891
Las Cruces, NM 88004
www.asombro.org
information@asombro.org

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CURRICULUM DEVELOPMENT
Asombro Institute for Science Education
www.asombro.org

EDITOR
Stephanie Haan-Amato
s.haan-amato@asombro.org

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CONTRIBUTORS
Many thanks to the following educators for pilot testing and reviewing:

Katherine Arneson
Marci Behrens
Tegan Fuqua
Yvette Garza-Stevens
Rachel Knight
Amy Lopeman
Kim O'Byrne

We are extremely grateful to these scientists for reviewing science content of one or more activities:
Julian Reyes, Ph.D., USDA-ARS Jornada Experimental Range, Las Cruces, NM
Curtis Talbot, USDA-ARS Jornada Experimental Range, Las Cruces, NM
Heather Throop, Ph.D., Arizona State University, Tempe, AZ
Amy Slaughter, USDA-ARS Jornada Experimental Range, Las Cruces, NM
Sheri Spiegal, Ph.D., USDA-ARS Jornada Experimental Range, Las Cruces, NM

DESIGN AND LAYOUT
Miranda Williams
Susannah Davenport, NGSS Tables

THE EFFECTS OF CLIMATE CHANGE ON AGRICULTURAL SYSTEMS

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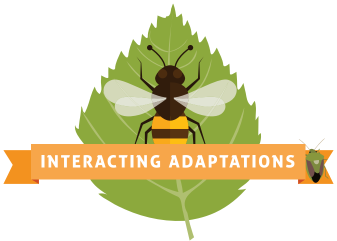

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CLICK THE ACTIVITY ICONS TO NAVIGATE TO EACH SECTION

STANDARDS ALIGNMENT

THE EFFECTS OF CLIMATE CHANGE ON AGRICULTURAL SYSTEMS

A 5-Hour Curriculum Unit for 6-12 Grade Students

Welcome! This unit was designed to introduce 6-12 grade students to the effects of climate change on agriculture, including crop production and ranching. The activities in this guide are appropriate for both formal and informal education settings, and they can be modified to fit the needs of students. All activities are aligned to Common Core State Standards and Next Generation Science Standards when applicable.

This curriculum is organized as a 5-day (or 5-hour) unit, with each activity building on the last. The unit need not be completed in its entirety, however. All five of the included activities can be conducted individually. The Unit Schedule outlines a proposed schedule of activity completion, assuming one-hour periods. Days on the schedule can be converted to hours to better suit the time available. Each activity includes an estimated time for completion.

The materials required for the activities can generally be purchased at a household goods store, and some are items that educators often have available. There are few specialized supplies needed. Each activity includes a materials section that lists the items required to complete the activity, with provided resources, such as handouts and PowerPoint files, listed first. When viewing this guide electronically with an internet connection, the links within the materials section will navigate to each of the listed resources.

We hope that you and your students enjoy these activities! Please contact the editor with questions and feedback at s.haan-amato@asombro.org.

THE EFFECTS OF CLIMATE CHANGE ON AGRICULTURAL SYSTEMS

Unit Schedule

This unit is designed to be used over 5 days (or 5 hours). The unit need not be completed in its entirety, however. All of the activities can be conducted individually.

Day 1

FARMS ON THE TABLE

Making Farmland Decisions in a Changing Climate

Day 2

INTERACTING ADAPTATIONS

Trade-Offs in the Agriculture Industry

Day 3

WILT IT BE PRODUCTIVE?

Modeling an Adaptation to Climate Change

Day 4

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Climate Change and Farmland Soil Quality

Day 5

GET OUT AND GRAZE (GO AG!)

Criollo vs. Angus Cattle in a Changing Climate

Making Farmland Decisions in a Changing Climate

FARMS ON THE TABLE

DESCRIPTION

To learn about challenges associated with agricultural production under climate change conditions, students play a game in which they make management decisions for a farm and evaluate the effects.

PHENOMENON

What methods can agricultural producers use to adapt to climate change, and is it worth the cost?

GRADE LEVEL
6 – 12

OBJECTIVES

Students will:
- Evaluate the importance of agriculture and agricultural producers in our society
- Synthesize the effects climate change can have on agriculture and food sources
- Understand some of the decisions agricultural producers make

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.

CCSS.ELA-LITERACY.RST.11-12.9. Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.

NEXT GENERATION SCIENCE STANDARDS

High School Performance Expectation
HS-ESS3-4. Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

Science & Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models (MS)	ESS3.C Human Impacts on Earth Systems (MS, HS)	Systems and System Models (MS, HS)

AGRICULTURE, FOOD, AND NATURAL RESOURCES STANDARDS

CS.01.02. Examine technologies and examine their impact on AFNR systems.
  CS.O1.02.01.a. Research technologies used in AFNR systems.
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.

BACKGROUND

Climate change will continue to result in increased global temperatures and subsequent changes in atmospheric conditions. In the United States, the last decade was the warmest on record, and 2016 was the warmest year on record. Heavy precipitation and extreme heat events are increasing in frequency, consistent with model projections. Models predict that extreme events, including drought and flooding, will continue to occur more frequently in the future. In general, extreme events tend to decrease crop productivity, degrade soil quality, and increase the prevalence of weeds, disease, and pests that can negatively affect agriculture. Climate change could have a severe impact on global food security and lead to food shortages because of a reduction in crop yields and increase in food prices.

Throughout the southwestern United States, increased temperatures are predicted. Models predict a mixture of increased precipitation and decreased precipitation with a high degree of uncertainty, depending on the area. In areas of increased precipitation, the likelihood is that the increase in annual rainfall will occur in fewer, more intense events.

Adaptation strategies have the ability to increase the resiliency of the agriculture sector to some of the major productivity impacts of climate change. These strategies can include simple improvements to equipment, such as repairing leaking pipes to eliminate waste, or more involved strategies, including planting and practice changes made in the fields, e.g. no-till planting.

MATERIALS

- *Farms on the Table* handout [1 per student]
  - o If possible, copy each page on a different colored paper to make referencing the pages during the activity easier
- PowerPoint presentation
- Dice [1 per 2-3 students]
- Calculators (optional) [1 per 2-3 students]
- *Farms on the Table* instructional video, optional introduction to the game for the instructor

PREPARATION

1. If possible, watch the *Farms on the Table* instructional video for an introduction to the game.
2. Set up a computer and projector, and display the PowerPoint presentation.

PROCEDURES

Introduction

1. Give a short introduction about climate change and its effects on agriculture using the PowerPoint presentation.
   a. **Slide 1**: we are going to play a game that will introduce the effects of climate change on agriculture and why it is important to understand these effects.
   b. **Slide 2**: global warming is the increase in Earth's average temperature. Climate change is the long-term change in Earth's climate or the climate of a region. Climate change encompasses global warming because it includes temperature changes, but it also incudes other long-term atmospheric conditions such as precipitation changes. What is the trend of this graph? [Answer: Earth's average surface temperature has been increasing since 1880.]
   c. **Slide 3**: many climate change computer models predict more extreme weather events. Some models might predict that an area will receive more rainfall in the future, but this often translates into fewer, larger rainfall events with longer periods without rainfall in between. In the Southwest, researchers predict: more heat waves, longer and more severe droughts, more extreme precipitation events, insect and pest outbreaks, and more wildfires. All of these issues will degrade soil quality

and negatively affect crop production.

Farms on the Table Game

1. Pass out a Farms on the Table handout to each student.
2. Introduce the game using the PowerPoint presentation.
    a. **Slide 4**: in this game, you will play the role of a farmer dealing with the effects of climate change on your farm. You will make decisions about how your farm will be managed on a year-to-year basis with the goal of staying in the black. In finance, staying in the black means that you are making money, and being in the red means that you are losing money.
        i. Each farm will start off with an output rating of 100. During the course of the game, if you stay at ≥100 you are in the black; if you drop to ≤99 you are now considered to be in the red. The goal of the game is to make choices that will help you stay in the black or help you get back in the black.
        ii. Look at page 1 of the handout. Choose one of the counties listed in table 1, and circle it. Most students like to choose the county that is closest to their location. This is the location of your new farm.
        iii. The first thing you will do is customize your farm by choosing climate-mitigating adaptations. You will be able to choose to take as many, or as few, of these actions as you would like on your farm. In this case, a mitigating adaptation is something you can do that will help to lessen the impacts that your farm will experience from climate change and also to reduce the impacts that your farm has on the environment.
    a. **Slide 5**: one option is no-till planting. It is a type of planting where the seeds are inserted directly into the soil, instead of the traditional planting style of turning over the soil before inserting the seeds. This style of planting can be advantageous because it has lower labor, equipment, and fuel costs. A tractor only has to go over a field once to plant the seeds (versus multiple times with traditional planting). It also reduces water runoff from precipitation and irrigation because it slows down the water, allowing it to soak into the ground. This decreases the likelihood of chemical crop treatments contaminating groundwater and streams as well. This method promotes healthier soil by limiting wind erosion of soil, increasing the organic matter layer in the soil, and limiting soil compaction. The biggest drawbacks to this method are the high upfront equipment costs and that it may require the use of herbicides and fungicides due to higher soil moisture.
    b. **Slide 6**: hedgerows are rows of wild shrubs bordering a road or field. Hedgerows create a barrier around the field, helping with the effects of wind and water erosion. They create not only pollinator habitat but also predator habitat (for example, birds and lizards), which will help prevent some of the spread of insect and fungal diseases. The major drawback to this action is that the hedgerows will require some year round watering and maintenance and reduce space for planting crops.
    c. **Slide 7**: water collection and storage units collect rainfall from roofs or runoff from fields to be used at a later date for irrigation of crops. By collecting this water, a farmer will have a water source available during droughts for irrigation purposes. Installation can be expensive and water storage units can take up a large amount of space. It can take a few years to gather enough water to help mitigate the effects of a serious drought, but once the water is collected, it will be available for use.
    d. **Slide 8**: monitoring soil moisture in a field can help a farmer determine the best time to irrigate crops, thus allowing them to eliminate unnecessary watering. The equipment can range from relatively inexpensive to very expensive. The cost of equipment is related to the amount of labor that is needed. Less expensive equipment tends to require more labor.
    e. **Slide 9**: many species of bees are declining because of loss of habitat, increased temperatures, changes in growing seasons, and insecticide use. Farmers rely on bees to pollinate their crops, and without them, many crops would not be able to fruit. If you choose to have beehives and plant flower strips among your crops, you help to ensure that you have reliable pollination of your crops by bees and other pollinators. The major drawback to this action is that you will not be able to use insecticides on your crops due to the harm they inflict on bee colonies.
    f. **Slide 10**: take a moment to decide what adaptations you would like to implement on your farm. You may choose as many adaptations as you would like. There is a cost associated with each, but they may save you money in the long term, depending on the weather conditions that year. In table 2 on page 2 of the handout, place a checkmark under each of your selected adaptions, and write the cost of each in the last column of the table. Once you have finished, add up the cost of all the adaptations you have chosen and enter the Total Cost at the bottom of table 2. Then, subtract your Total Cost from 100 to calculate the Starting

Output Factor, which will be needed for the next part of the game.

3. Ask students to turn to page 3 of the handout. Students will choose their planting practices for Year 1 on this page. Instruct students to transfer their Starting Output Factor calculated on page 2 to the Starting Output Factor blank in the top right corner.
4. Pass out the dice. Two or three students can share one die. Pass out the calculators (if using); students can share calculators. Use the PowerPoint presentation to explain how students will set up the first year on their farm.
   a. **Slide 11**: in year 1, you will choose at least two of nine planting practices and crop treatments, which we will discuss momentarily. As in real life, the success of your farm will be partially based on chance because you are choosing your options before knowing how the weather will be this year. The weather conditions will be revealed at the end of the year, and the success of your choices will be dependent on the conditions that you experienced. Remember, you are trying to stay in the black, which means having an Output Factor that is ≥100. Each option has an associated cost, but you may be rewarded for your investment. The impact of each option can be positive or negative, depending on the conditions this year, especially the weather. After the first year, you will then have the option to invest in any of these practices and treatments each year for the six total years that we will play this game.
   g. **Slide 12**: your first options are two different crop varieties. Over many years, farmers and researchers have been able to breed crops that grow more successfully in certain environments. For example, there are different varieties of wheat that grow well in drier or wetter than average conditions and varieties that are immune to insect and fungal diseases. For our game, you have the option to choose between drought resistant or flood resistant varieties of crops.
   h. **Slide 13**: interplanting is planting two crops together in a field in alternating rows. By using this method, you can decrease the need for crop treatments, such as pesticides and herbicides. This option also creates less economic risk for you in case there is a crop fail year. You may have to spend more time planning up front in order to carry out this practice.
   i. **Slide 14**: crop rotation is a planting system where varying crops are planted in the same field year after year. This style of planting has been used since the 1600s because it helps preserve soil nutrients. It will also help control weeds, disease, and other pests. Many pests are plant specific, so by moving the plants to a different field every year, it will reduce the chance that the pest will be able to follow them. You may have to spend more time planning up front in order to carry out this practice.
   j. **Slide 15**: spread spacing is increasing the amount of space between the planted rows of crops. This practice can reduce the need for crop treatments because there is less competition for resources from the plants. There will be a lower crop yield per acre because of fewer rows in a single field.
   k. **Slide 16**: most fertilizer contains nitrogen, phosphorus, and potassium. By adding more of these nutrients to what already occurs naturally in the soil, crops will grow larger, faster. Annual application of fertilizer has been shown to deplete the natural soil fertility, causing an annual reliance on it, however. If you choose to do this on your farm, you will have to reapply it every year.
   l. **Slide 17**: herbicide sprays destroy unwanted vegetation (non-crops) in a field. Spraying a field with herbicide can greatly reduce loss from plant pests, but the herbicide becomes less effective with continual use. For example, this is a common agricultural weed called pigweed. For many years, the standard way of removing pigweed was to spray it with herbicides. Now, after many years of this, pigweed is resistant to herbicides in some areas, and the only way to remove it from agriculture fields in these areas is by manual removal (typically pulling it out by hand).
   m. **Slide 18**: insecticide sprays are designed to stop herbivorous insects, and they can greatly reduce loss from insect pests, but they will harm natural pollinators and insect predators. You should not choose this option if you have beehives and flower strips on your farm. Like herbicides, they will also become less effective with continual use.
   n. **Slide 19**: fungicide sprays are designed to destroy unwanted fungal pathogens, and just like all the other crop treatments, fungicide can reduce the loss from pathogens. Unlike other treatments, you cannot use a wait-and-see approach because if the fungicide is not applied before infection, it will not be effective.
5. Give students a few minutes to decide what practices and/or treatments they would like to use on their farm for year 1 and instruct them to place checkmarks under at least two options in the table, and write the cost of each in the Chosen Costs column of the table. Emphasize that they need to think about their farm and local climate when deciding what strategies would be the most effective under those conditions.
6. Ask students to look at the bottom

of page 3 of the handout, and use the PowerPoint to explain how to finish with year 1.

a. **Slide 20**: write your Starting Output Factor into the first blank at the bottom of the page. Then calculate the cost of your planting practices and crop treatments, and write the Total Cost at the bottom of the table and in the second blank at the bottom of page 3 of the handout.
b. **Slide 21**: roll the die once for each checked item that you selected. Roll the die and assign the number rolled to the first checked item in the table. Roll the die again and assign that number to the second checked item, and repeat this for all of the items you selected.
    i. You **may not** roll the die and assign that number to whichever checked item you would like, and you **may not** roll the die until you get a number that you like. The purpose of the die is to be random, so that some practices and treatments will affect your farm more positively or negatively than others, that the effect varies year to year, and different farms are affected in different ways. This is similar to the way it works in the real world.
c. **Slide 22**: the weather for year 1 was historically normal. Record the weather in the blank near the bottom of page 3 of your handout.
    i. During historically normal weather, some of the practices and treatments that you chose will give you a positive return, and some will give you a negative return. The list on the left is positive investments. The practices on this list were helpful during the weather that we had this year, and they resulted in increased profits. Place a **plus sign** next to the die roll number for the practices and treatments from this list that you chose (and **only** the practices and treatments that you chose).
    ii. The list on the right is negative investments. The practices on this list were not helpful during the weather that we had this year, and they did not result in increased profits to offset their costs. Place a **minus sign** next to the die roll number for the practices and treatments from the list that you chose.
    iii. When you customized your farm, you may have chosen one or more of the options in table 2 on page 2 of the handout. Turn back to table 2 on page 2 for reference. If you chose any of the farm adaptations listed at the bottom of the slide, your investments paid off this year. The adaptations on this list were helpful during the weather that we experienced. For each adaptation that you chose from this list, you will receive **three Farm Adaptation Bonus points**.
        1. For example, if you implemented two of the five adaptations that helped mitigate the effects of the weather, you would receive three points for each, for a total bonus of six points.
    iv. Add up how many Farm Adaptation Bonus points you received and write that number in the appropriate blank at the bottom of page 3.
d. **Slide 23**: add up all of the positive and negative investments to calculate the Output Change Total. Be sure to **pay attention to the sign**. Most players will be adding positive and negative numbers; do not just add them all up as if they were all positive. Once you have the total, write it at the bottom of the table and in the Output Change Total blank at the bottom of the page. This number may be negative.
    i. Finally, combine all of the blanks to calculate your new Starting Output Factor. Be sure to **pay attention to the sign**.

7. Ask students to turn to page 4 of their handout and transfer the new Starting Output Factor from Year 1 (calculated on the previous page) into the blank in the top right corner. Continue the game for years 2-6 using the PowerPoint presentation.
    a. **Slide 24**: in year 2, you will again choose at least two of the nine practices and treatments. I will reveal the weather conditions at the end of the year, and the success of your choices will be dependent on the conditions that you experienced. Remember, you are trying to stay in the black. Take a moment to place checkmarks under at least two options in the table, and write the cost of each in the Chosen Costs column of the table.
        i. Write your Starting Output Factor into the first blank at the bottom of page 4 of the handout. Then calculate the cost of your planting practices and crop treatments, and write the Total Cost at the bottom of the table and in the second blank at the bottom of the page.
        ii. Roll the die once for each checked item that you selected. Assign the number rolled to the first checked item in the table, and roll it again until you have written a die roll number in the table for every practice and treatment that you selected.
    b. **Slide 25**: the weather for year 2 was a drought. Record the weather in the blank near the bottom of page 4 of your handout.
        i. Look at the list of positive

        investments, and place a **plus sign** next to the die roll number for the practices and treatments from this list that you chose.
        ii. Look at the list of negative investments, and place a **minus sign** next to the die roll number for the practices and treatments from this list that you chose.
        iii. Add up all of the positive and negative investments to calculate the Output Change Total. Be sure to **pay attention to the sign**. Write it in the Output Change Total space in the table and the blank at the bottom of the page.
        iv. Look back at the selections that you made when customizing your farm in table 2 on page 2 of the handout; for each adaptation that you chose from the list at the bottom of this slide, you will receive **three Farm Adaptation Bonus points**. Add up how many Farm Adaptation Bonus points you received and write that number in the appropriate blank at the bottom of page 4.
        v. Finally, combine all of the blanks to calculate your new Starting Output Factor. Be sure to **pay attention to the sign**.
        vi. Turn to page 5 of the handout, and transfer the new Starting Output Factor from Year 2 (calculated on the previous page) into the blank in the top right corner.
    c. **Slide 26**: in year 3, you will again choose at least two of the nine practices and treatments. I will reveal the weather conditions at the end of the year, and the success of your choices will be dependent on the conditions that you experienced. Remember, you are trying to stay in the black. Take a moment to place checkmarks under at least two options in the table, and write the cost of each in the Chosen Costs column of the table.
        i. Write your Starting Output Factor into the first blank at the bottom of page 5 of the handout. Then calculate the cost of your planting practices and crop treatments, and write the Total Cost at the bottom of the table and in the second blank at the bottom of the page.
        ii. Roll the die once for each checked item that you selected. Assign the number rolled to the first checked item in the table, and roll it again until you have written a die roll number in the table for every practice and treatment that you selected.
    d. **Slide 27**: the weather for year 3 was a heat wave. Record the weather in the blank near the bottom of page 5 of your handout.
        i. Look at the list of positive investments, and place a **plus sign** next to the die roll number for the practices and treatments from this list that you chose.
        ii. Look at the list of negative investments, and place a **minus sign** next to the die roll number for the practices and treatments from this list that you chose.
        iii. Add up all of the positive and negative investments to calculate the Output Change Total. Be sure to **pay attention to the sign**. Write it in the Output Change Total space in the table and the blank at the bottom of the page.
        iv. Look back at the selections that you made when customizing your farm in table 2 on page 2 of the handout; for each adaptation that you chose from the list at the bottom of this slide, you will receive **three Farm Adaptation Bonus points**. Add up how many Farm Adaptation Bonus points you received and write that number in the appropriate blank at the bottom of page 5.

8. **SUBSIDY YEARS** – There are two years in which students will receive a government Subsidy Bonus if they have implemented certain practices, year 3 and year 6. Use the PowerPoint presentation to explain the Subsidy Bonus for this year.
    a. **Slide 28**: this year, the government issued a subsidy for agricultural producers who installed beehives on their farms. A subsidy is a cash rebate or tax reduction given by the government to incentivize an action or help an economic sector. As mentioned earlier, many bee species populations are in decline. Pollination of crops by bees has been estimated to be worth $14 billion per year, and without them, many of our favorite foods would not exist. Look at the list on the right side of the slide. Does it include any foods that you like to eat?
        i. If you chose to invest in beehives and flower strips at the beginning of the game, you will receive 10 Subsidy Bonus points for doing so. If you did, write a 10 in the Subsidy Bonus blank at the bottom of page 5 of the handout, if you did not, write a 0 in that blank.
        ii. Combine all of the blanks to calculate your new Starting Output Factor. Be sure to **pay attention to the sign**.
        iii. Turn to page 6 of the handout, and transfer the new Starting Output Factor from Year 3 (calculated on the previous page) into the blank in the top right corner.
    b. **Slide 29**: in year 4, you will

again choose at least two of the nine practices and treatments. I will reveal the weather conditions at the end of the year, and the success of your choices will be dependent on the conditions that you experienced. Remember, you are trying to stay in the black. Take a moment to place checkmarks under at least two options in the table, and write the cost of each in the Chosen Costs column of the table.

   i. Write your Starting Output Factor into the first blank at the bottom of page 6 of the handout. Then calculate the cost of your planting practices and crop treatments, and write the Total Cost at the bottom of the table and in the second blank at the bottom of the page.
   ii. Roll the die once for each checked item that you selected. Assign the number rolled to the first checked item in the table, and roll it again until you have written a die roll number in the table for every practice and treatment that you selected.

c. **Slide 30**: the weather for year 4 was windy. Record the weather in the blank near the bottom of page 6 of your handout.
   i. Look at the list of positive investments, and place a **plus sign** next to the die roll number for the practices and treatments from this list that you chose.
   ii. Look at the list of negative investments, and place a **minus sign** next to the die roll number for the practices and treatments from this list that you chose.
   iii. Add up all of the positive and negative investments to calculate the Output Change Total. Be sure to **pay attention to the sign**. Write it in the Output Change Total space in the table and the blank at the bottom of the page.
   iv. Look back at the selections that you made when customizing your farm in table 2 on page 2 of the handout; for each adaptation that you chose from the list at the bottom of this slide, you will receive **three Farm Adaptation Bonus points**. Add up how many Farm Adaptation Bonus points you received and write that number in the appropriate blank at the bottom of page 6.
   v. Finally, combine all of the blanks to calculate your new Starting Output Factor. Be sure to **pay attention to the sign**.
   vi. Turn to page 7 of the handout, and transfer the new Starting Output Factor from Year 4 (calculated on the previous page) into the blank in the top right corner.

d. **Slide 31**: in year 5, you will again choose at least two of the nine practices and treatments. I will reveal the weather conditions at the end of the year, and the success of your choices will be dependent on the conditions that you experienced. Remember, you are trying to stay in the black. Take a moment to place checkmarks under at least two options in the table, and write the cost of each in the Chosen Costs column of the table.
   i. Write your Starting Output Factor into the first blank at the bottom of page 7 of the handout. Then calculate the cost of your planting practices and crop treatments, and write the Total Cost at the bottom of the table and in the second blank at the bottom of the page.
   ii. Roll the die once for each checked item that you selected. Assign the number rolled to the first checked item in the table, and roll it again until you have written a die roll number in the table for every practice and treatment that you selected.

e. **Slide 32**: the weather for year 5 included increased precipitation. Record the weather in the blank near the bottom of page 7 of your handout.
   i. Look at the list of positive investments, and place a **plus sign** next to the die roll number for the practices and treatments from this list that you chose.
   ii. Look at the list of negative investments, and place a **minus sign** next to the die roll number for the practices and treatments from this list that you chose.
   iii. Add up all of the positive and negative investments to calculate the Output Change Total. Be sure to **pay attention to the sign**. Write it in the Output Change Total space in the table and the blank at the bottom of the page.
   iv. Look back at the selections that you made when customizing your farm in table 2 on page 2 of the handout; for each adaptation that you chose from the list at the bottom of this slide, you will receive **three Farm Adaptation Bonus points**. Add up how many Farm Adaptation Bonus points you received and write that number in the appropriate blank at the bottom of page 7.
   v. Finally, combine all of the blanks to calculate your new Starting Output Factor. Be sure to **pay attention to the sign**.
   vi. Turn to page 8 of the

handout, and transfer the new Starting Output Factor from Year 5 (calculated on the previous page) into the blank in the top right corner.

f. **Slide 33**: in year 6, our final year, you will again choose at least two of the nine practices and treatments. I will reveal the weather conditions at the end of the year, and the success of your choices will be dependent on the conditions that you experienced. Remember, you are trying to stay in the black. Take a moment to place checkmarks under at least two options in the table, and write the cost of each in the Chosen Costs column of the table.
    i. Write your Starting Output Factor into the first blank at the bottom of page 8 of the handout. Then calculate the cost of your planting practices and crop treatments, and write the Total Cost at the bottom of the table and in the second blank at the bottom of the page.
    ii. Roll the die once for each checked item that you selected. Assign the number rolled to the first checked item in the table, and roll it again until you have written a die roll number in the table for every practice and treatment that you selected.

g. **Slide 34**: the weather for year 6 was another heat wave. Record the weather in the blank near the bottom of page 8 of your handout.
    i. Look at the list of positive investments, and place a **plus sign** next to the die roll number for the practices and treatments from this list that you chose.
    ii. Look at the list of negative investments, and place a **minus sign** next to the die roll number for the practices and treatments from this list that you chose.
    iii. Add up all of the positive and negative investments to calculate the Output Change Total. Be sure to **pay attention to the sign**. Write it in the Output Change Total space in the table and the blank at the bottom of the page.
    iv. Look back at the selections that you made when customizing your farm in table 2 on page 2 of the handout; for each adaptation that you chose from the list at the bottom of this slide, you will receive **three Farm Adaptation Bonus points**. Add up how many Farm Adaptation Bonus points you received and write that number in the appropriate blank at the bottom of page 8.

h. **Slide 35**: the government issued another subsidy this year; this time, it is for water conservation. Water conservation involves using only the water needed for crops. Due to the more prolonged and intense droughts resulting from climate change, smart water usage by agriculture has become imperative.
    i. If you invested in soil moisture monitoring you will receive a 5 point Subsidy Bonus. If you invested in water collection and storage you will receive a 10 point Subsidy Bonus. If you invested in both, you will receive a 15 point Subsidy Bonus.
    ii. Combine all of the blanks to calculate your final output factor. Be sure to **pay attention to the sign**.

Results and Conclusions

1. Instruct students to turn to the results and conclusions questions on page 9 of the handout. Answer the questions together if possible.
    a. When answering question 1, remember that for this game, being in the black is having a final output factor of 100 or more, and being in the red is having an output factor of less than 100.
    b. For question 2, think back to the positive investments at the end of each year. Were there any practices or treatments that seemed to result in a positive investment more than others? [Answer: interplanting and crop rotation were a positive investment every year.]
        i. Think about the negative investments at the end of each year. Were there any practices or treatments that seemed to result in a negative investment more than others? [Answer: flood resistant crop varieties and fungicide resulted in a negative investment most often.]
        ii. Why do you think that is the case? [Answer: interplanting and crop rotation promote soil health and overall plant health by protecting them from pathogens without causing additional harm to the environment. Buying flood resistant crop varieties and fungicide are usually not the best practices to use in the dry, hot climate throughout much of the Southwest. Even though some areas of the Southwest are predicted to receive more rainfall, the region is not predicted to get flooding that would require flood resistant varieties or cause fungal outbreaks.]
    c. In question 3, think critically about how you would play the game differently if you were to play it again. What are some of your ideas?

EXTENSIONS

1. Add more years to the game. Make additional copies of pages 3-8 of the handout. If you would like to include student input, ask students to help decide several years of weather conditions and which treatments and practices would be positive or negative, given the weather. Then choose which of their conditions to implement, adding more slides to the PowerPoint presentation if possible.
2. Add a catastrophic event, such as a wildfire, flood, or earthquake, into one of the rounds. Decide if any of the crops could have survived the natural disaster. If not, all practices and treatments chosen by students would be negative investments. If some crops did survive, decide which practices and treatments, if any, could have helped with their survival, such as flood resistant crops being planted in an area that received a flood. List any practices and treatments that could have helped with survival as positive investments.

ADDITIONAL RESOURCES

Reports, articles, and websites with helpful background information on agricultural adaptations:

California Department of Food and Agriculture (CDFA). Climate Change Consortium for Specialty Crops: Impacts and Strategies for Resilience. Published 2013. Accessed online 22 Jan. 2016. <https://www.cdfa.ca.gov/environmentalstewardship/pdfs/ccc-report.pdf>.

Howden. S, Soussana, J, Tubiello, F, Chhetri, N, Dunlop, M, and Meinke, H. 2007. Adapting agriculture to climate change. The Proceedings of National Academy of Sciences 104(50), 19691-19696. Accessed online 29 Mar. 2016. <http://www.pnas.org/cgi/doi/10.1073/pnas.0701890104>.

Intergovernmental Panel on Climate Change (IPCC). 2014. Climate Change 2014: Synthesis Report. Accessed online 29 Mar. 2016. <http://www.ipcc.ch/pdf/assessment-report/ar5/syr/SYR_AR5_FINAL_full_wcover.pdf>.

United States Department of Agriculture (USDA). Agricultural Research Service. Climate Change and Agriculture in the United States: Effects and Adaptations. Published Feb. 2013. Web. Accessed 22 Jan. 2016. <http://www.usda.gov/oce/climate_change/effects.htm>.

Name ______________________________ Date ____________

Making Farmland Decisions in a Changing Climate

FARMS ON THE TABLE

Step 1 Directions: choose **one** of the counties from table 1 to be the location for your new farm and **circle it**.

Table 1. Farm locations and data: 2015 values are averages, and 2065 values are predicted changes

Circle one county:		MARICOPA CO, AZ	YOLO CO, CA	DONA ANA CO, NM	LYON CO, NV	UTAH CO, UT
TEMPERATURE	2015 (°F)	84.8	74.4	76.2	65.0	58.4
	2065 (°F)	+5.7	+5.0	+7.9	+6.1	+6.6
PRECIPITATION	2015 (in.)	9.94	21.24	10.98	8.97	21.19
	2065 (in.)	+0.17	+0.71	+0.13	+0.64	+1.88
AVG. FARM SIZE (ACRES)		192	456	302	792	139
COMMON CROPS		cotton, alfalfa, wheat, oats, watermelon	tomato, rice, almonds, walnuts, wheat	chile, cotton, pecan, lettuce, onion	onion, potato, alfalfa, squash, wheat	alfalfa, hay, wheat, corn

Weather data source: swclimatehub.info

Step 2 Directions: customize your new farm by choosing as many, or as few, as you would like of the climate-mitigating adaptations from table 2. **Place a checkmark** under each adaptation that you choose, and **write the cost (points) in the last column** for each selected adaptation.

Table 2. Climate-mitigating adaptations

ADAPTATION	PROS	CONS	COST (POINTS)	CHOSEN COSTS
NO-TILL PLANTING ☐	-Reduces costs of labor, equipment, fuel -Reduces soil erosion from water and wind -Retains soil moisture -Increases soil organic matter -Limits soil compaction	-May require more herbicide and fungicide due to higher soil moisture -High upfront cost	**15**	
HEDGEROWS ☐	-Reduce soil erosion from water and wind -Create pollinator habitat -Prevent spread of some insects and fungal diseases	-Require some watering and maintenance -Possibly reduce number of crop rows	**5**	
WATER CISTERN COLLECTION & STORAGE UNIT ☐	-Collects rainfall and/or other water runoff for use when water is scarce	-Requires space -Can take a few years to collect enough water	**10**	
SOIL MOISTURE MONITORING ☐	-Decreases irrigation expenses by eliminating unnecessary watering of crops	-Requires labor to operate equipment	**3**	
BEEHIVES & FLOWER STRIPS ☐	-Reliable pollination of crops -Provide habitat for variety of pollinators	-Requires some maintenance -Unable to use insecticides	**5**	
			TOTAL COST (POINTS)	

STARTING OUTPUT FACTOR = 100 – ________________ = ________________

TOTAL COST

FARMS ON THE TABLE GAME DIRECTIONS

1. Your goal is to **keep your farm in the black**. Being in the black means that you are making money, and being in the red means that you are losing money.
2. Choose **at least two** of the practices and treatments from the table for each year, and write the cost of each selected item in the Chosen Costs column of the table.
3. Add up the cost of your practices and treatments, and write the Total Cost at the bottom of the table.
4. Roll the die and assign the number rolled to your first selection; write it in the last column of the table. Roll the die again and assign that number to the second checked item, and repeat this for all of the selected items.
5. Your instructor will then reveal the weather for the year and whether each of the practices and treatments were positive or negative investments. In the table, assign a plus sign to the die roll numbers of the positive investments and a minus sign to the die roll numbers of the negative investments.
6. Add up the positive and negative die roll numbers. Be sure to **pay attention to the sign**.
7. Fill in the equation at the bottom of each page, and calculate the Starting Output Factor.

YEAR 1

Starting Output Factor (from Page 2): _______

Choose **at least two** practices and/or treatments.

PLANTING PRACTICES	DESCRIPTION	COST (POINTS)	CHOSEN COSTS	+/-	DIE ROLL
DROUGHT RESISTANT CROP VARIETY ☐	Can produce a more reliable yield per acre during periods of prolonged drought, but seeds need to be purchased every year	2			
FLOOD RESISTANT CROP VARIETY ☐	Can tolerate being submerged for longer periods of time or multiple times per year, but seeds need to be purchased every year	2			
INTERPLANTING ☐	Can reduce erosion, spread of pathogens, and need for crop treatments; there is less economic risk in case of a crop fail year	2			
CROP ROTATION ☐	Can improve soil health and reduce loss from pathogens due to host plants changing locations from year to year	2			
SPREAD SPACING OF ROWS ☐	Lower crop yield/acre, but can reduce the need for crop treatments	2			
CROP TREATMENTS	**DESCRIPTION**	**COST (POINTS)**	**CHOSEN COSTS**	**+/-**	**DIE ROLL**
FERTILIZING ☐	Can increase rate of growth but depletes soil fertility causing an annual reliance	2			
HERBICIDE ☐	Can reduce loss from plant pests but becomes less effective with continual use	2			
INSECTICIDE ☐	Can reduce loss from insect pests but will harm natural pollinators; should **NOT** choose if have beehives & flower strips	2			
FUNGICIDE ☐	Can reduce loss from fungal pathogens but needs to be applied before infection to be effective	2			
		TOTAL COST (POINTS)		**OUTPUT CHANGE TOTAL**	

Weather for this year (from instructor): ______________________________

____________	-	____________	+	____________	+	____________	=	____________
Starting Output Factor		Total Cost		Output Change Total		Farm Adaptation Bonus		New Starting Output Factor

YEAR 2

New Starting Output Factor (from the end of Year 1): _______

Choose **at least two** practices and/or treatments.

PLANTING PRACTICES	DESCRIPTION	COST (POINTS)	CHOSEN COSTS	+/-	DIE ROLL
DROUGHT RESISTANT CROP VARIETY ☐	Can produce a more reliable yield per acre during periods of prolonged drought, but seeds need to be purchased every year	2			
FLOOD RESISTANT CROP VARIETY ☐	Can tolerate being submerged for longer periods of time or multiple times per year, but seeds need to be purchased every year	2			
INTERPLANTING ☐	Can reduce erosion, spread of pathogens, and need for crop treatments; there is less economic risk in case of a crop fail year	2			
CROP ROTATION ☐	Can improve soil health and reduce loss from pathogens due to host plants changing locations from year to year	2			
SPREAD SPACING OF ROWS ☐	Lower crop yield/acre, but can reduce the need for crop treatments	2			
CROP TREATMENTS	**DESCRIPTION**	**COST (POINTS)**	**CHOSEN COSTS**	**+/-**	**DIE ROLL**
FERTILIZING ☐	Can increase rate of growth but depletes soil fertility causing an annual reliance	2			
HERBICIDE ☐	Can reduce loss from plant pests but becomes less effective with continual use	2			
INSECTICIDE ☐	Can reduce loss from insect pests but will harm natural pollinators; should **NOT** choose if have beehives & flower strips	2			
FUNGICIDE ☐	Can reduce loss from fungal pathogens but needs to be applied before infection to be effective	2			
		TOTAL COST (POINTS)		**OUTPUT CHANGE TOTAL**	

Weather for this year (from instructor): ____________________________________

_____________ - _____________ + _____________ + _____________ = ____________

Starting Output Factor - Total Cost + Output Change Total + Farm Adaptation Bonus = New Starting Output Factor

YEAR 3

New Starting Output Factor (from the end of Year 2): _______

Choose **at least two** practices and/or treatments.

PLANTING PRACTICES	DESCRIPTION	COST (POINTS)	CHOSEN COSTS	+/-	DIE ROLL
DROUGHT RESISTANT CROP VARIETY ☐	Can produce a more reliable yield per acre during periods of prolonged drought, but seeds need to be purchased every year	2			
FLOOD RESISTANT CROP VARIETY ☐	Can tolerate being submerged for longer periods of time or multiple times per year, but seeds need to be purchased every year	2			
INTERPLANTING ☐	Can reduce erosion, spread of pathogens, and need for crop treatments; there is less economic risk in case of a crop fail year	2			
CROP ROTATION ☐	Can improve soil health and reduce loss from pathogens due to host plants changing locations from year to year	2			
SPREAD SPACING OF ROWS ☐	Lower crop yield/acre, but can reduce the need for crop treatments	2			
CROP TREATMENTS	**DESCRIPTION**	**COST (POINTS)**	**CHOSEN COSTS**	**+/-**	**DIE ROLL**
FERTILIZING ☐	Can increase rate of growth but depletes soil fertility causing an annual reliance	2			
HERBICIDE ☐	Can reduce loss from plant pests but becomes less effective with continual use	2			
INSECTICIDE ☐	Can reduce loss from insect pests but will harm natural pollinators; should **NOT** choose if have beehives & flower strips	2			
FUNGICIDE ☐	Can reduce loss from fungal pathogens but needs to be applied before infection to be effective	2			
		TOTAL COST (POINTS)		**OUTPUT CHANGE TOTAL**	

Weather for this year (from instructor): ___________________________________

____________	-	____________	+	____________	+	____________	+	____________	=	____________
Starting Output Factor		Total Cost		Output Change Total		Farm Adaptation Bonus		Subsidy Bonus		New Starting Output Factor

YEAR 4

New Starting Output Factor (from the end of Year 3): _______

Choose **at least two** practices and/or treatments.

PLANTING PRACTICES	DESCRIPTION	COST (POINTS)	CHOSEN COSTS	+/-	DIE ROLL
DROUGHT RESISTANT CROP VARIETY ☐	Can produce a more reliable yield per acre during periods of prolonged drought, but seeds need to be purchased every year	2			
FLOOD RESISTANT CROP VARIETY ☐	Can tolerate being submerged for longer periods of time or multiple times per year, but seeds need to be purchased every year	2			
INTERPLANTING ☐	Can reduce erosion, spread of pathogens, and need for crop treatments; there is less economic risk in case of a crop fail year	2			
CROP ROTATION ☐	Can improve soil health and reduce loss from pathogens due to host plants changing locations from year to year	2			
SPREAD SPACING OF ROWS ☐	Lower crop yield/acre, but can reduce the need for crop treatments	2			
CROP TREATMENTS	**DESCRIPTION**	**COST (POINTS)**	**CHOSEN COSTS**	**+/-**	**DIE ROLL**
FERTILIZING ☐	Can increase rate of growth but depletes soil fertility causing an annual reliance	2			
HERBICIDE ☐	Can reduce loss from plant pests but becomes less effective with continual use	2			
INSECTICIDE ☐	Can reduce loss from insect pests but will harm natural pollinators; should **NOT** choose if have beehives & flower strips	2			
FUNGICIDE ☐	Can reduce loss from fungal pathogens but needs to be applied before infection to be effective	2			
		TOTAL COST (POINTS)		**OUTPUT CHANGE TOTAL**	

Weather for this year (from instructor): ___________________________________

____________	-	____________	+	____________	+	____________	=	____________
Starting Output Factor		Total Cost		Output Change Total		Farm Adaptation Bonus		New Starting Output Factor

YEAR 5

New Starting Output Factor (from the end of Year 4): _______

Choose **at least two** practices and/or treatments.

PLANTING PRACTICES	DESCRIPTION	COST (POINTS)	CHOSEN COSTS	+/-	DIE ROLL
DROUGHT RESISTANT CROP VARIETY ☐	Can produce a more reliable yield per acre during periods of prolonged drought, but seeds need to be purchased every year	2			
FLOOD RESISTANT CROP VARIETY ☐	Can tolerate being submerged for longer periods of time or multiple times per year, but seeds need to be purchased every year	2			
INTERPLANTING ☐	Can reduce erosion, spread of pathogens, and need for crop treatments; there is less economic risk in case of a crop fail year	2			
CROP ROTATION ☐	Can improve soil health and reduce loss from pathogens due to host plants changing locations from year to year	2			
SPREAD SPACING OF ROWS ☐	Lower crop yield/acre, but can reduce the need for crop treatments	2			
CROP TREATMENTS	**DESCRIPTION**	**COST (POINTS)**	**CHOSEN COSTS**	**+/-**	**DIE ROLL**
FERTILIZING ☐	Can increase rate of growth but depletes soil fertility causing an annual reliance	2			
HERBICIDE ☐	Can reduce loss from plant pests but becomes less effective with continual use	2			
INSECTICIDE ☐	Can reduce loss from insect pests but will harm natural pollinators; should **NOT** choose if have beehives & flower strips	2			
FUNGICIDE ☐	Can reduce loss from fungal pathogens but needs to be applied before infection to be effective	2			
		TOTAL COST (POINTS)		**OUTPUT CHANGE TOTAL**	

Weather for this year (from instructor): ____________________________________

____________	-	____________	+	____________	+	____________	=	____________
Starting Output Factor		Total Cost		Output Change Total		Farm Adaptation Bonus		New Starting Output Factor

YEAR 6

New Starting Output Factor (from the end of Year 5): _______

Choose **at least two** practices and/or treatments.

PLANTING PRACTICES	DESCRIPTION	COST (POINTS)	CHOSEN COSTS	+/-	DIE ROLL
DROUGHT RESISTANT CROP VARIETY ☐	Can produce a more reliable yield per acre during periods of prolonged drought, but seeds need to be purchased every year	2			
FLOOD RESISTANT CROP VARIETY ☐	Can tolerate being submerged for longer periods of time or multiple times per year, but seeds need to be purchased every year	2			
INTERPLANTING ☐	Can reduce erosion, spread of pathogens, and need for crop treatments; there is less economic risk in case of a crop fail year	2			
CROP ROTATION ☐	Can improve soil health and reduce loss from pathogens due to host plants changing locations from year to year	2			
SPREAD SPACING OF ROWS ☐	Lower crop yield/acre, but can reduce the need for crop treatments	2			
CROP TREATMENTS	**DESCRIPTION**	**COST (POINTS)**	**CHOSEN COSTS**	**+/-**	**DIE ROLL**
FERTILIZING ☐	Can increase rate of growth but depletes soil fertility causing an annual reliance	2			
HERBICIDE ☐	Can reduce loss from plant pests but becomes less effective with continual use	2			
INSECTICIDE ☐	Can reduce loss from insect pests but will harm natural pollinators; should **NOT** choose if have beehives & flower strips	2			
FUNGICIDE ☐	Can reduce loss from fungal pathogens but needs to be applied before infection to be effective	2			
		TOTAL COST (POINTS)		**OUTPUT CHANGE TOTAL**	

Weather for this year (from instructor): ____________________________________

______________	-	______________	+	______________	+	______________	+	______________	=	______________
Starting Output Factor		Total Cost		Output Change Total		Farm Adaptation Bonus		Subsidy Bonus		New Starting Output Factor

RESULTS AND CONCLUSIONS

1. How many years were you able to keep your farm in the black? Did you end the game in the red or in the black?

2. Were there certain practices or treatments that seemed to be a positive investment more than others? Were there certain practices or treatments that seemed to be a negative investment more than others? Why do you think that is the case?

3. If you were to play this game again, what would you do differently? Why?

ANSWER KEY

Step 1 Directions: choose **one** of the counties from table 1 to be the location for your new farm and **circle it**.

Table 1. Farm locations and data: 2015 values are averages, and 2065 values are predicted changes

Circle one county:		MARICOPA CO, AZ	YOLO CO, CA	DONA ANA CO, NM	LYON CO, NV	UTAH CO, UT
TEMPERATURE	2015 (°F)	84.8	74.4	76.2	65.0	58.4
	2065 (°F)	+5.7	+5.0	+7.9	+6.1	+6.6
PRECIPITATION	2015 (in.)	9.94	21.24	10.98	8.97	21.19
	2065 (in.)	+0.17	+0.71	+0.13	+0.64	+1.88
AVG. FARM SIZE (ACRES)		192	456	302	792	139
COMMON CROPS		cotton, alfalfa, wheat, oats, watermelon	tomato, rice, almonds, walnuts, wheat	chile, cotton, pecan, lettuce, onion	onion, potato, alfalfa, squash, wheat	alfalfa, hay, wheat, corn

Weather data source: swclimatehub.info

Step 2 Directions: customize your new farm by choosing as many, or as few, as you would like of the climate-mitigating adaptations from table 2. **Place a checkmark** under each adaptation that you choose, and **write the cost (points) in the last column** for each selected adaptation.

Table 2. Climate-mitigating adaptations

ADAPTATION	PROS	CONS	COST (POINTS)	CHOSEN COSTS
NO-TILL PLANTING ☐	-Reduces costs of labor, equipment, fuel -Reduces soil erosion from water and wind -Retains soil moisture -Increases soil organic matter -Limits soil compaction	-May require more herbicide and fungicide due to higher soil moisture -High upfront cost	15	
HEDGEROWS ☐	-Reduce soil erosion from water and wind -Create pollinator habitat -Prevent spread of some insects and fungal diseases	-Require some watering and maintenance -Possibly reduce number of crop rows	5	
WATER CISTERN COLLECTION & STORAGE UNIT ☐	-Collects rainfall and/or other water runoff for use when water is scarce	-Requires space -Can take a few years to collect enough water	10	
SOIL MOISTURE MONITORING ☐	-Decreases irrigation expenses by eliminating unnecessary watering of crops	-Requires labor to operate equipment	3	
BEEHIVES & FLOWER STRIPS ☐	-Reliable pollination of crops -Provide habitat for variety of pollinators	-Requires some maintenance -Unable to use insecticides	5	
			TOTAL COST (POINTS)	

student answers will vary

STARTING OUTPUT FACTOR = 100 – ____________________

TOTAL C

student answers will vary

FARMS ON THE TABLE GAME DIRECTIONS

1. Your goal is to **keep your farm in the black**. Being in the black means that you are making money, and being in the red means that you are losing money.
2. Choose **at least two** of the practices and treatments from the table for each year, and write the cost of each selected item in the Chosen Costs column of the table.
3. Add up the cost of your practices and treatments, and write the Total Cost at the bottom of the table.
4. Roll the die and assign the number rolled to your first selection; write it in the last column of the table. Roll the die again and assign that number to the second checked item, and repeat this for all of the selected items.
5. Your instructor will then reveal the weather for the year and whether each of the practices and treatments were positive or negative investments. In the table, assign a plus sign to the die roll numbers of the positive investments and a minus sign to the die roll numbers of the negative investments.
6. Add up the positive and negative die roll numbers. Be sure to **pay attention to the sign**.
7. Fill in the equation at the bottom of each page, and calculate the Starting Output Factor.

YEAR 1

Starting Output Factor (from Page 2): _______

Choose **at least two** practices and/or treatments.

PLANTING PRACTICES	**DESCRIPTION**	**COST (POINTS)**	**CHOSEN COSTS**	**+/-**	**DIE ROLL**
DROUGHT RESISTANT CROP VARIETY ☑	Can produce a more reliable yield per acre during periods of prolonged drought, but seeds need to be purchased every year	2	2	-	4
FLOOD RESISTANT CROP VARIETY ☐	Can tolerate being submerg[illegible] periods of time or m[illegible] year, but seed[illegible] every [illegible]	[illegible]			
INTERPLANTING ☐	[illegible]	2			
CROP ROTATION ☑	[illegible] nd reduce l[illegible] ns due to host plants c[illegible] ocations from year to year	2	2	+	6
SPREAD SPACING OF ROWS ☐	Lower crop yield/acre, but can reduce the need for crop treatments	2			
CROP TREATMENTS	**DESCRIPTION**	**COST (POINTS)**	**CHOSEN COSTS**	**+/-**	**DIE ROLL**
FERTILIZING ☐	Can increase rate of growth but depletes soil fertility causing an annual reliance	2			
HERBICIDE ☑	Can reduce loss from plant pests but becomes less effective with continual use	2	2	+	3
INSECTICIDE ☐	Can reduce loss from insect pests but will harm natural pollinators; should **NOT** choose if have beehives & flower strips	2			
FUNGICIDE ☑	Can reduce loss from fungal pathogens but needs to be applied before infection to be effective	2	2	+	1
		TOTAL COST (POINTS)	8	**OUTPUT CHANGE TOTAL**	6

Weather for this year (from instructor): Historically Normal

(From blank at bottom of page 2)	-	8	+	6	+	(Three points for each chosen on page 2)	=	________
Starting Output Factor		Total Cost		Output Change Total		Farm Adaptation Bonus		New Starting Output Factor

YEAR 2

New Starting Output Factor (from the end of Year 1): _______

Choose **at least two** practices and/or treatments.

PLANTING PRACTICES	DESCRIPTION	COST (POINTS)	CHOSEN COSTS	+/-	DIE ROLL
DROUGHT RESISTANT CROP VARIETY ☐	Can produce a more reliable yield per acre during periods of prolonged drought, but seeds need to be purchased every year	**2**			
FLOOD RESISTANT CROP VARIETY ☐	Can tolerate being submerged for longer periods of time or multiple times per year, but seeds need to be purchased every year	**2**			
INTERPLANTING ☐	Can reduce erosion, spread of pathogens, and need for crop treatments; there is less economic risk in case of a crop fail year	**2**	*student answers will vary*		
CROP ROTATION ☐	Can improve soil health and reduce loss from pathogens due to host plants changing locations from year to year	**2**			
SPREAD SPACING OF ROWS ☐	Lower crop yield/acre, but can reduce the need for crop treatments	**2**			
CROP TREATMENTS	**DESCRIPTION**	**COST (POINTS)**	**CHOSEN COSTS**	**+/-**	**DIE ROLL**
FERTILIZING ☐	Can increase rate of growth but depletes soil fertility causing an annual reliance	**2**			
HERBICIDE ☐	Can reduce loss from plant pests but becomes less effective with continual use	**2**			
INSECTICIDE ☐	Can reduce loss from insect pests but will harm natural pollinators; should **NOT** choose if have beehives & flower strips	**2**	*student answers will vary*		
FUNGICIDE ☐	Can reduce loss from fungal pathogens but needs to be applied before infection to be effective	**2**			
	TOTAL COST (POINTS)			**OUTPUT CHANGE TOTAL**	

Weather for this year (from instructor): *Drought*

______	-	______	+	______		______	=	______
Starting Output Factor		Total Cost		ange Total		Farm Adaptation Bonus		New Starting Output Factor

student answers will vary

YEAR 3

New Starting Output Factor (from the end of Year 2): _______

Choose **at least two** practices and/or treatments.

PLANTING PRACTICES	**DESCRIPTION**	**COST (POINTS)**	**CHOSEN COSTS**	**+/-**	**DIE ROLL**
DROUGHT RESISTANT CROP VARIETY ☐	Can produce a more reliable yield per acre during periods of prolonged drought, but seeds need to be purchased every year	**2**			
FLOOD RESISTANT CROP VARIETY ☐	Can tolerate being submerged for longer periods of time or multiple times per year, but seeds need to be purchased every year	**2**			
INTERPLANTING ☐	Can reduce erosion, spread of pathogens, and need for crop treatments; there is less economic risk in case of a crop fail year	**2**	*student answers will vary*		
CROP ROTATION ☐	Can improve soil health and reduce loss from pathogens due to host plants changing locations from year to year	**2**			
SPREAD SPACING OF ROWS ☐	Lower crop yield/acre, but can reduce the need for crop treatments	**2**			
CROP TREATMENTS	**DESCRIPTION**	**COST (POINTS)**	**CHOSEN COSTS**	**+/-**	**DIE ROLL**
FERTILIZING ☐	Can increase rate of growth but depletes soil fertility causing an annual reliance	**2**			
HERBICIDE ☐	Can reduce loss from plant pests but becomes less effective with continual use	**2**			
INSECTICIDE ☐	Can reduce loss from insect pests but will harm natural pollinators; should **NOT** choose if have beehives & flower strips	**2**	*student answers will vary*		
FUNGICIDE ☐	Can reduce loss from fungal pathogens but needs to be applied before infection to be effective	**2**			
		TOTAL COST (POINTS)		**OUTPUT CHANGE TOTAL**	

Weather for this year (from instructor): *Heat Wave*

_______ Starting Output Factor - _______ Total Cost + _______ Output C... + _______ ...m Adaptation Bonus + _______ Subsidy Bonus = _______ New Starting Output Factor

student answers will vary

YEAR 4

New Starting Output Factor (from the end of Year 3): ________

Choose **at least two** practices and/or treatments.

PLANTING PRACTICES	DESCRIPTION	COST (POINTS)	CHOSEN COSTS	+/-	DIE ROLL
DROUGHT RESISTANT CROP VARIETY ☐	Can produce a more reliable yield per acre during periods of prolonged drought, but seeds need to be purchased every year	2			
FLOOD RESISTANT CROP VARIETY ☐	Can tolerate being submerged for longer periods of time or multiple times per year, but seeds need to be purchased every year	2			
INTERPLANTING ☐	Can reduce erosion, spread of pathogens, and need for crop treatments; there is less economic risk in case of a crop fail year	2	*student answers will vary*		
CROP ROTATION ☐	Can improve soil health and reduce loss from pathogens due to host plants changing locations from year to year	2			
SPREAD SPACING OF ROWS ☐	Lower crop yield/acre, but can reduce the need for crop treatments	2			
CROP TREATMENTS	**DESCRIPTION**	**COST (POINTS)**	**CHOSEN COSTS**	**+/-**	**DIE ROLL**
FERTILIZING ☐	Can increase rate of growth but depletes soil fertility causing an annual reliance	2			
HERBICIDE ☐	Can reduce loss from plant pests but becomes less effective with continual use	2			
INSECTICIDE ☐	Can reduce loss from insect pests but will harm natural pollinators; should **NOT** choose if have beehives & flower strips	2	*student answers will vary*		
FUNGICIDE ☐	Can reduce loss from fungal pathogens but needs to be applied before infection to be effective	2			
		TOTAL COST (POINTS)		**OUTPUT CHANGE TOTAL**	

Weather for this year (from instructor): *Wind*

________	-	________	+	________		________	=	________
Starting Output Factor		Total Cost		ange Total		Farm Adaptation Bonus		New Starting Output Factor

student answers will vary

YEAR 5

New Starting Output Factor (from the end of Year 4): _______

Choose **at least two** practices and/or treatments.

PLANTING PRACTICES	**DESCRIPTION**	**COST (POINTS)**	**CHOSEN COSTS**	**+/-**	**DIE ROLL**
DROUGHT RESISTANT CROP VARIETY ☐	Can produce a more reliable yield per acre during periods of prolonged drought, but seeds need to be purchased every year	**2**			
FLOOD RESISTANT CROP VARIETY ☐	Can tolerate being submerged for longer periods of time or multiple times per year, but seeds need to be purchased every year	**2**			
INTERPLANTING ☐	Can reduce erosion, spread of pathogens, and need for crop treatments; there is less economic risk in case of a crop fail year	**2**	*student answers will vary*		
CROP ROTATION ☐	Can improve soil health and reduce loss from pathogens due to host plants changing locations from year to year	**2**			
SPREAD SPACING OF ROWS ☐	Lower crop yield/acre, but can reduce the need for crop treatments	**2**			
CROP TREATMENTS	**DESCRIPTION**	**COST (POINTS)**	**CHOSEN COSTS**	**+/-**	**DIE ROLL**
FERTILIZING ☐	Can increase rate of growth but depletes soil fertility causing an annual reliance	**2**			
HERBICIDE ☐	Can reduce loss from plant pests but becomes less effective with continual use	**2**			
INSECTICIDE ☐	Can reduce loss from insect pests but will harm natural pollinators; should **NOT** choose if have beehives & flower strips	**2**	*student answers will vary*		
FUNGICIDE ☐	Can reduce loss from fungal pathogens but needs to be applied before infection to be effective	**2**			
		TOTAL COST (POINTS)		**OUTPUT CHANGE TOTAL**	

Weather for this year (from instructor): *Increased Precipitation*

student answers will vary

________	-	________	+	________		________	=	________
Starting Output Factor		Total Cost		ange Total		Farm Adaptation Bonus		New Starting Output Factor

YEAR 6

New Starting Output Factor (from the end of Year 5): _______

Choose **at least two** practices and/or treatments.

PLANTING PRACTICES	DESCRIPTION	COST (POINTS)	CHOSEN COSTS	+/-	DIE ROLL
DROUGHT RESISTANT CROP VARIETY ☐	Can produce a more reliable yield per acre during periods of prolonged drought, but seeds need to be purchased every year	2			
FLOOD RESISTANT CROP VARIETY ☐	Can tolerate being submerged for longer periods of time or multiple times per year, but seeds need to be purchased every year	2			
INTERPLANTING ☐	Can reduce erosion, spread of pathogens, and need for crop treatments; there is less economic risk in case of a crop fail year	2	student answers will vary		
CROP ROTATION ☐	Can improve soil health and reduce loss from pathogens due to host plants changing locations from year to year	2			
SPREAD SPACING OF ROWS ☐	Lower crop yield/acre, but can reduce the need for crop treatments	2			
CROP TREATMENTS	**DESCRIPTION**	**COST (POINTS)**	**CHOSEN COSTS**	**+/-**	**DIE ROLL**
FERTILIZING ☐	Can increase rate of growth but depletes soil fertility causing an annual reliance	2			
HERBICIDE ☐	Can reduce loss from plant pests but becomes less effective with continual use	2			
INSECTICIDE ☐	Can reduce loss from insect pests but will harm natural pollinators; should **NOT** choose if have beehives & flower strips	2	student answers will vary		
FUNGICIDE ☐	Can reduce loss from fungal pathogens but needs to be applied before infection to be effective	2			
		TOTAL COST (POINTS)		**OUTPUT CHANGE TOTAL**	

Weather for this year (from instructor): *Heat Wave*

_______ - _______ + _______ + _______ + _______ = _______

Starting Output Factor - Total Cost + Outpu m Adaptation Bonus + Subsidy Bonus = New Starting Output Factor

student answers will vary

RESULTS AND CONCLUSIONS

1. How many years were you able to keep your farm in the black? Did you end the game in the red or in the black?

   Student answers will vary.

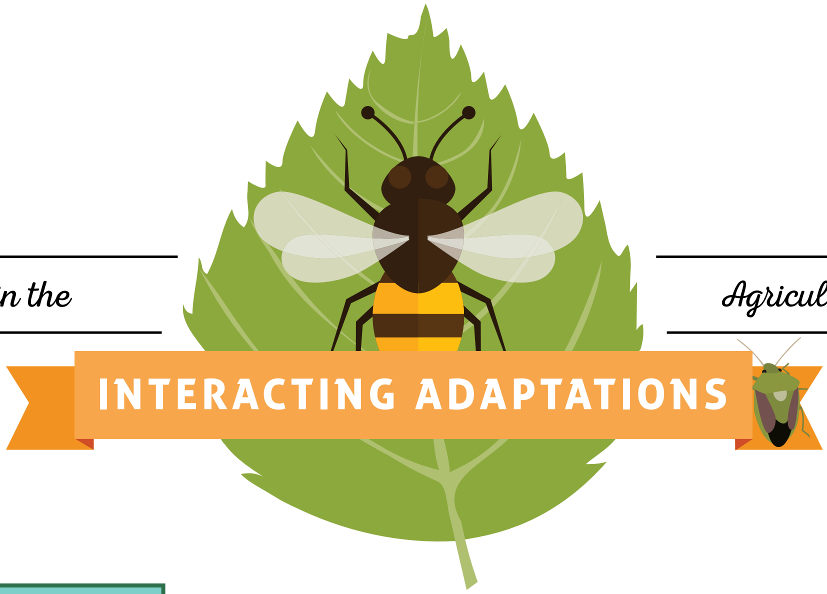
2. Were there certain practices or treatments that seemed to be a positive investment more than others? Were there certain practices or treatments that seemed to be a negative investment more than others? Why do you think that is the case?

   Interplanting and crop rotation were a positive investment every year. Flood resistant crop varieties and fungicide resulted in a negative investment most often.

   Interplanting and crop rotation promote soil health and overall plant health by protecting them from pathogens without causing additional harm to the environment. Buying flood resistant crop varieties and fungicide are usually not the best practices to use in the dry, hot climate throughout much of the Southwest. Even though some areas of the Southwest are predicted to receive more rainfall, the region is not predicted to get flooding that would require flood resistant varieties or cause fungal outbreaks.

3. If you were to play this game again, what would you do differently? Why?

   Student answers will vary.



Trade-Offs in the Agricultural Industry

INTERACTING ADAPTATIONS

DESCRIPTION

Students conduct research on agricultural adaptations to climate change, create posters, and carry out a gallery walk to analyze the interconnectedness of adaptations.

PHENOMENON

How do adaptations to climate change interact with other components of agricultural systems?

GRADE LEVEL
6 – 12

OBJECTIVES

Students will:
- Identify the trade-offs of agricultural adaptations to various climate change effects
- Evaluate the effectiveness of agricultural adaptations to climate conditions
- Analyze the roles of actors in the agriculture industry and how they overlap

TIME
60 MINUTES

COMMON CORE STATE STANDARDS

English Language Arts Standards > Writing > Grades 6-8
CCSS.ELA-LITERACY.W.6-8.7. Conduct short research projects to answer a question, drawing on several sources and refocusing the inquiry when appropriate.

English Language Arts Standards > Speaking and Listening > Grades 6-8
CCSS.ELA-LITERACY.SL.6-8.1. Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6-8 topics, texts, and issues, building on others' ideas and expressing their own clearly.

English Language Arts Standards > Reading: Informational Text > Grade 6
CCSS.ELA-LITERACY.R1.6.7. Integrate information presented in different media or formats (e.g., visually, quantitatively) as well as in works to develop a coherent understanding of a topic of issue.

English Language Arts Standards > Writing > Grades 9-10
CCSS.ELA-LITERACY.W.9-10.7. Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

English Language Arts Standards > Speaking and Listening > Grades 9-10
CCSS.ELA-LITERACY.SL.9-10.1. Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 9-10 topics, texts, issues, building on others' ideas and expressing their own clearly and persuasively.

English Language Arts Standards > Writing > Grades 11-12
CCSS.ELA-LITERACY.W.11-12.7. Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

English Language Arts Standards > Speaking and Listening > Grades 11-12
CCSS.ELA-LITERACY.SL.11-12.1. Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 11-12 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.

English Language Arts Standards » Science & Technical Subjects » Grade 11-12
CCSS.ELA-LITERACY.RAT.11-12.7. Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.

NEXT GENERATION SCIENCE STANDARDS

High School Performance Expectation
HS-ESS3-4. Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

NEXT GENERATION SCIENCE STANDARDS

Science & Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Engaging in Argument from Evidence (MS, HS) Obtaining, Evaluating, and Communicating Information (MS, HS)	ESS3.A Natural Resources (HS) ESS3.C Human Impacts on Earth Systems (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.).
CS.06.02. Analyze and explain the connection and relationships between different AFNR systems on a national and global level (e.g. using less irrigation water, reduction of inputs, etc.).
  CS.06.02.02.a. Examine and summarize changes that happen in AFNR systems on a national and global level (e.g. using less irrigation water, reduction of inputs, 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.

BACKGROUND

Climate adaptations are adjustments in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderate harm or exploit beneficial opportunities. Agricultural adaptations are actions that attempt to:

- Satisfy human food and fiber needs, and contribute to biofuel needs
- Enhance environmental quality and resources, such as water or soil
- Sustain the economic viability of agriculture
- Enhance the quality of life for farmers, farm workers, and society as a whole

There are limits to agricultural adaptations to climate change; these can be ecological, social, or economic. Ecologically, many adaptations are dependent on the success of other adaptations and ecosystem services. Socially, the perception of the need for adaptation is influenced by political norms and values, as well as cultural ideologies. Economically, access to funds can limit a producer's capability to adapt. Cross-scale interactions between the three agricultural actors (producers, agro-industry, and government) and the actions they can take on some of the factors affected by climate change should be understood to avoid an increase in agricultural vulnerability to climate change. In this activity, students will examine the role of agricultural actors in adapting farming practices to reduce the negative impacts of these four effects of climate change: temperature, water availability, pests, and pollinator patterns.

MATERIALS

- *Actors and Impacts* handout [1 per student]
- *Interacting Adaptations* handout [1 per student]
- *Reference Sheet* handout [12, 1 per group]
- Set of 12 *Impact* cards
- Set of 12 *Actor* cards
- PowerPoint presentation
- Computer and projector
- Set of four colors of sticky notes (yellow, green, blue, and pink) [3 sets]
- Set of four colors of highlighters (yellow, green, blue, and pink) [12 sets]
- 12 blank poster pages from self-stick easel pad (25 x 30.5 inches or similar size) [1 set per class]
- Markers (a variety of colors for 12 groups)
- *Interacting Adaptations* instructional video, optional introduction to the activity for the instructor

PREPARATION

1. If possible, watch the *Interacting Adaptations* instructional video for an introduction to the activity.
2. Plan to divide the class into 12 groups. This will allow for enough groups for each impact/actor combination. If fewer groups are preferable, the pest and pollinator impacts can be combined, reducing the number of groups to 9.
2. Prepare Impact cards (3 temperature, 3 water, 3 pest, 3 pollinator):
    a. Print the Impact cards document (quantity: 3 total) double sided (short edge binding).
    b. Cut the cards, 4 per each double sided sheet.

4. Prepare Actor cards (4 producer, 4 agro-industry, 4 government):
   a. Print the Actor cards document (quantity: 4 total) double sided (short edge binding).
   b. Cut the cards, 3 per each double sided sheet

PROCEDURES

1. Give an introduction to agricultural adaptations to climate change using the PowerPoint presentation.
   a. **Slide 2**: we are going to use California as a case study to learn about how agricultural actors can react to climate change. California is an ecologically diverse state. Within its borders are desert, Mediterranean, forested mountains, and coastal mountain systems.
   b. **Slide 3**: California is also home to many large- and small-scale agricultural producers. Nearly half of the fruit, vegetables, and nuts in the US are produced in California. Several crops are only producible in California because of the diverse ecosystems there.
   c. **Slide 4**: the state has been in a severe drought since 2012. California's 2014 and 2015 water years (12 month precipitation totals) were the warmest on record causing Governor Jerry Brown to declare a state of emergency for the state in 2014. What would you do in this situation?
   d. **Slide 5**: in response to the drought, some farmers started digging more wells to tap into groundwater supplies to compensate for the decreased amount of surface water. **Groundwater** is supplied by underground aquifers that are gradually replenished by rain, rivers, streams, and irrigation as it percolates through the soil. This became a popular way for farmers to adapt to sustain their crops through a changing climate. Accessing groundwater became such a popular short-term solution to the drought that many counties saw a dramatic increase in drilling permits over a five-year period.
   e. **Slide 6**: in response to this severe drought, many farmers adjusted their methods to sustain their crops as climate factors changed. When farmers and ranchers alter their practices to meet the needs of a changing climate it is called an **adaptation**. An adaptation is an adjustment in human systems as a response to actual or expected climatic effects, which moderates harm or exploits beneficial opportunities.
   f. **Slide 7**: some of these agricultural adaptations will have short-term benefits that allow crops to grow well but will also have long-term effects that can have a greater, potentially negative, effect on future productivity. Accessing groundwater has been a method used by farmers for decades. In this picture, the telephone pole has three numbers on it. The number at the top is 1925; this is where the ground level was in that year. The middle number is 1955, and the number at the bottom is 1977. Tapping into groundwater for irrigation purposes caused this dramatic change in the ground level, called subsidence, because the aquifers underneath this area have been diminished. In addition, it is very expensive to dig the wells that access the groundwater. These are examples of trade-offs. In the short-term, crops are getting watered, but in the long run, it costs a lot of money. Also, the aquifers are not getting replenished as quickly as they are getting used.
   g. **Slide 8**: there are no quick fixes for farmers to adapt to climate change because the effects can be related. For example, when farmers experience decreased water availability, they are often dealing with increased temperature as well. Adapting to climate change is also going to require knowledge about how the climate will change in the future and of the impacts of various adaptation methods. Many of these methods can be expensive, so adapting to climate change can be financially challenging. These are some of the trade-offs that farmers have to consider.
   h. **Slide 9**: farmers are not the only ones who need to adapt to climate change; the agricultural industry and government should adjust their practices and policies to support agricultural sustainability because the effects of climate change will affect all three actors.

PART 1

1. Introduce the activity setup using the PowerPoint presentation.
   a. **Slide 10**: for our activity today, we will be exploring the roles of three different agriculture actors (producers, agro-industry, and government) and how they can react to four different pressures placed on agriculture as a result of climate change.
      i. Producers are farm operators.
      ii. Agro-industry is made up of the businesses associated with agriculture. This can be through researching technologies or disseminating information/ products to producers.
      iii. Government consists of the agencies responsible for programs and policies supporting the producers and agro-industry.
   b. **Slide 11**: you will be separated into 12 groups (no more than 3 students per group) and each group will receive an *Actor* card that describes one of the three agriculture actors.
   c. **Slide 12**: each group will also draw an *Impact* card. As a result

of climate change, temperature will change, water availability will change, pests will change, and pollinators will change. When you get your *Impact* card, read aloud the impact climate change will have on your group.

PART 2

1. Pass out an *Actors* and *Impacts* handout to each student and a *Reference Sheet* handout and set of highlighters to each group.
2. Introduce the research portion of the activity using the PowerPoint presentation.
    a. **Slide 13**: in today's activity, we will ultimately make posters about our assigned actors and the impacts of climate change and then conduct a gallery walk. First, we will learn more about the actors involved and climate impacts by doing some research. Take a few minutes to read the descriptions of all of the actors and impacts on the *Reference Sheet* handout.
        i. On the *Actors* and *Impacts* handout is a list of adaptations. You will read through each adaptation and identify which actor is responsible for each. Then color code each adaptation using highlighters: yellow for temperature, green for pests, blue for water, and pink for pollinators. Use the *Reference Sheet* handout as needed.
        ii. The first one is done for you as an example. Adaptation # 1 should be highlighted green because it has to do with pests. "Agro-industry" is the actor that should be written in the blank because they are involved in researching technology.
3. Optional: if time permits and technology resources are available, allow students to conduct their own online research on their actors and impacts instead of using the *Actors and Impacts* handout. See the Extensions section below for instructions.
4. Use the *Actors and Impacts* handout answer key to lead a discussion with students, making sure that they have all of the correct answers on their Actors and Impacts handout and understand them. Students will use this handout to create their posters in Part 3.

PART 3

1. Give each group a poster page from a self-stick easel pad and a selection of markers.
2. Explain student poster creation using the PowerPoint presentation.
    a. **Slide 14**: your group will now create a poster for our gallery walk.
        i. Begin by writing your actor and impact in large print at the top of your poster.
        ii. Look on your *Actors and Impacts* handout to find the 2-3 adaptations that apply to your actor/impact combination and list them on your poster.
        iii. Once you have finished listing your adaptations, find a spot along the wall to hang your poster.
    b. **Slide 15**: each group will now receive a pad of sticky notes based on their impact: yellow for temperature, green for pests, blue for water, and pink for pollinators. You will walk around the room as a group and review each poster and consider how the adaptations may apply to your impact.
    c. **Slide 16**: if an adaptation would apply to your impact, mark it with a sticky note. If it would have a positive effect, add a plus sign to the sticky note. If it would have a negative effect, add a minus sign to the sticky note.
        i. For example, if producers add shade structures to reduce the impact of increased temperature, it will also decrease evaporation from soil and evapotranspiration from plants, increasing water efficiency. This adaptation would affect both temperature and water. The groups that researched water would add a blue sticky note next to that adaptation. It would have a positive impact, so those groups would add a plus sign to their sticky note.
        ii. Optional: instruct students to write how the adaptation could affect their actor/impact in addition to the plus or minus sign.

PART 4

1. Once students have had the chance to visit each poster and add sticky notes with their groups, ask them to return their seats.
2. Pass out an *Interacting Adaptations* handout to each student.
3. Use the PowerPoint presentation to lead a discussion about the gallery walk.
    a. **Slide 17**: look around the room at all of the posters. What is something that you notice? [Answer: most posters have multiple sticky notes or posters have different colored sticky notes on them.]
4. Ask students to answer question 1 on the *Interacting Adaptations* handout. Give them a few moments to write down their answers, and then engage students in a discussion about their answers. Touch on the idea of trade-offs during the discussion:
    a. As we have demonstrated, all of the agriculture actors and all of the climate change impacts are connected. Each adaptation has trade-offs. Producers, the agriculture industry, and the government must consider these trade-offs when adapting to climate change. There is no perfect solution, but with knowledge of how these factors affect one another and some cooperation, all agriculture

actors can make the most informed, sustainable decision. [Seek out some sticky-notes with a minus sign to talk about trade-offs with these adaptations.]

5. Return to the PowerPoint presentation to wrap up the activity.
   a. **Slide 18**: remember the California example at the beginning of the today's activity. Farmers in several areas, such as Tulare County, are digging more wells to tap into the groundwater supply.
6. Ask students to answer question 2 on the *Interacting Adaptations* handout. Give them a few moments to write down their answers, and then engage students in a discussion about their answers.

EXTENSIONS

1. Use computers with internet access for students to conduct research online instead of using the *Actors and Impacts* handout. The goal is for students to research ways that their actor can adapt to the assigned climate impact. Students should find at least three adaptations that their actor can implement to mitigate the effects of their climate impact. If students are experienced with finding reliable internet sources, they can be allowed to conduct the research independently, but if they may need more help, the educator can provide these websites as helpful resources:
   a. https://swclimatehub.info/adaptation-menu-crops
   b. https://www.usda.gov/oce/climate_change/effects_2012/effects_agriculture.htm
   c. https://www.cdfa.ca.gov/environmentalstewardship/pdfs/ccc-report.pdf
2. Before the activity, have students read a New York Times article from June 5, 2015, "California Farmers Dig Deeper for Water, Sipping their Neighbors Dry." It is a real-world example of an agricultural adaptation with trade-offs and possibly serious consequences. The article can be accessed online: http://www.nytimes.com/2015/06/07/business/energy-environment/california-farmers-dig-deeper-for-water-sipping-their-neighbors-dry.html

ADDITIONAL RESOURCES

Reports, articles, and websites with helpful background information on agricultural adaptations:

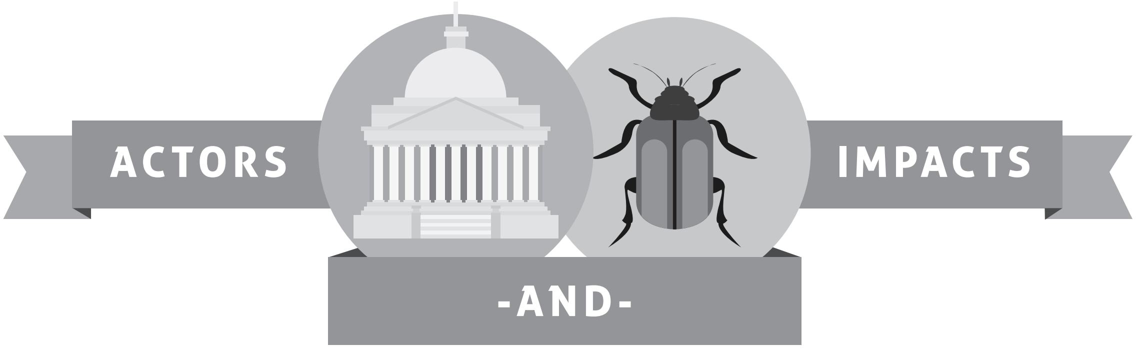
California Department of Food and Agriculture (CDFA). Climate Change Consortium for Specialty Crops: Impacts and Strategies for Resilience. Published 2013. Accessed online 22 Jan. 2016. <https://www.cdfa.ca.gov/environmentalstewardship/pdfs/ccc-report.pdf>.

Howden. S, Soussana, J, Tubiello, F, Chhetri, N, Dunlop, M, and Meinke, H. 2007. Adapting agriculture to climate change. The Proceedings of National Academy of Sciences 104(50), 19691-19696. Accessed online 29 Mar. 2016. <http://www.pnas.org/cgi/doi/10.1073/pnas.0701890104>.

Intergovernmental Panel on Climate Change (IPCC). 2014. Climate Change 2014: Synthesis Report. Accessed online 29 Mar. 2016. <http://www.ipcc.ch/pdf/assessment-report/ar5/syr/SYR_AR5_FINAL_full_wcover.pdf>.

United States Department of Agriculture (USDA). Agricultural Research Service. Climate Change and Agriculture in the United States: Effects and Adaptations. Published Feb. 2013. Web. Accessed 22 Jan. 2016. <http://www.usda.gov/oce/climate_change/effects.htm>.

Name ____ Date ________________



ACTORS -AND- IMPACTS

This table lists ways that producers, agro-industry, and government agencies can adapt to climate change. Each *adaptation* is an adjustment to mediate climate impacts of changing temperature, water availability, pests, and/or pollinators.

DIRECTIONS

1. In the actor column, write which actor or actors are responsible for each adaptation: producers, agro-industry, and/or government. More than one actor may be responsible; if so, write the names of two actors or "all" if all three actors are responsible.
2. Using the colors in the key below, highlight each adaptation to indicate the impact that it is mediating. Adaptations may help to address more than one impact; if so, highlight the adaptation with more than one color.

ACTORS

Producer: the person, or group of people that operate a farm

Agro-Industry: business connected with agriculture; involves researching technologies and disseminating information to producers

Government: agencies responsible for the creation and implementation of programs and policies to support producers and the agro-industry

YELLOW TEMPERATURE	**GREEN** PESTS	**BLUE** WATER	**PINK** POLLINATORS

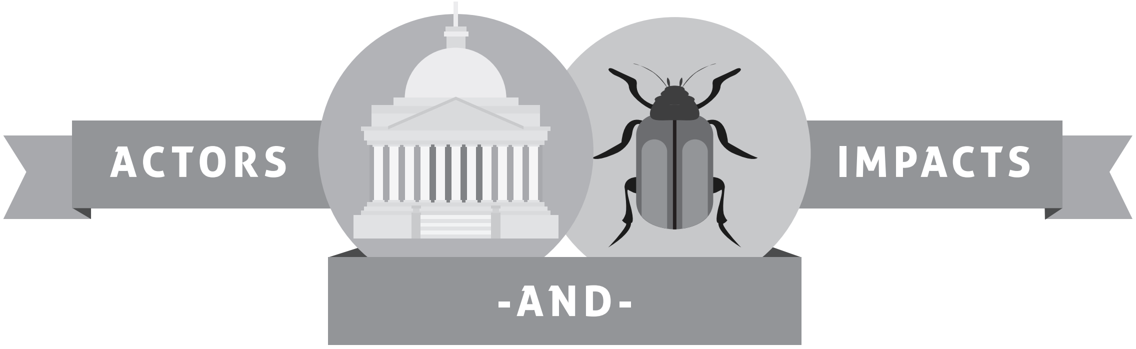
ACTOR Write Producer, Agro-Industry, or Government	**IMPACT** Highlight each *adaptation* to indicate the **impact** that it is mediating
EXAMPLE **1.** *Agro-Industry*	Develop pest suppression technologies *(Green)*
2.	Switch to an established heat-tolerant or low-chill tolerant plant variety
3.	Develop pest insurance programs for producers
4.	Alter planting and harvesting schedules
5.	Study the use of solar panels as shade structures over crops

CONTINUE ⇨

YELLOW TEMPERATURE	**GREEN** PESTS	**BLUE** WATER	**PINK** POLLINATORS

ACTOR Write Producer, Agro-Industry, or Government	**IMPACT** Highlight each *adaptation* to indicate the **impact** that it is mediating
6.	Develop technologies for efficient irrigation systems and excess water management systems
7.	City and county agencies restore habitat for native pollinators (e.g. adjusting roadside maintenance to include locally-appropriate options for vegetated roadsides)
8.	Provide technical assistance for risk management
9.	Provide cooling, such as shade structures or intercropping, to sensitive crops
10.	Choose appropriate flood tolerant or drought-resistant crops
11.	Implement an integrated pest management plan
12.	Study intercropping to reduce heat stress
13.	Develop pest resistant crop varieties
14.	Provide nesting sites for native pollinators
15.	Develop technologies of drought resistant and flood tolerant crop varieties
16.	Identify and register new and safe products or biocontrol methods to deal with Varroa mites, which attack honeybees
17.	Stay updated on emerging pests of concern
18.	Modify land management policies and programs to improve resilience to climate change
19.	Attract native pollinators and other beneficials with hedgerows, flower strips, and polyculture
20.	Study nutritional needs of honeybees, methods of supplying nutrition, and pesticide impact on honeybee health (e.g. hedgerows, flower strips)

ANSWER KEY



This table lists ways that producers, agro-industry, and government agencies can adapt to climate change. Each *adaptation* is an adjustment to mediate climate impacts of changing temperature, water availability, pests, and/or pollinators.

DIRECTIONS

1. In the actor column, write which actor or actors are responsible for each adaptation: producers, agro-industry, and/or government. More than one actor may be responsible; if so, write the names of two actors or "all" if all three actors are responsible.
2. Using the colors in the key below, highlight each adaptation to indicate the impact that it is mediating. Adaptations may help to address more than one impact; if so, highlight the adaptation with more than one color.

ACTORS

Producer: the person, or group of people that operate a farm

Agro-Industry: business connected with agriculture; involves researching technologies and disseminating information to producers

Government: agencies responsible for the creation and implementation of programs and policies to support producers and the agro-industry

YELLOW	**GREEN**	**BLUE**	**PINK**
TEMPERATURE	PESTS	WATER	POLLINATORS

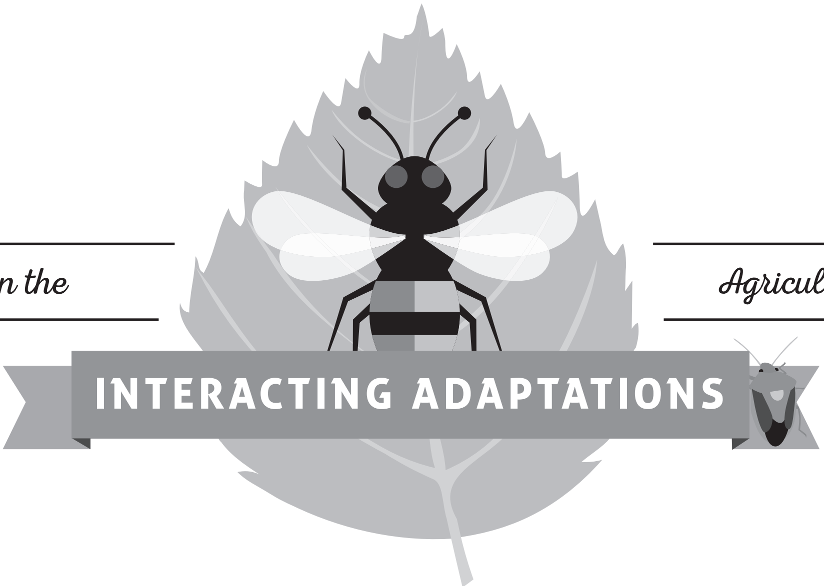
ACTOR Write Producer, Agro-Industry, or Government	**IMPACT** Highlight each *adaptation* to indicate the **impact** that it is mediating
EXAMPLE **1.** *Agro-Industry*	Develop pest suppression technologies *(Green)*
2. *Producer*	Switch to an established heat-tolerant or low-chill tolerant plant variety *(Yellow)*
3. *Government*	Develop pest insurance programs for producers *(Green)*
4. *Producer*	Alter planting and harvesting schedules *(Yellow/Blue)*
5. *Agro-Industry*	Study the use of solar panels as shade structures over crops *(Yellow)*

CONTINUE ⇨

YELLOW	GREEN	BLUE	PINK
TEMPERATURE	PESTS	WATER	POLLINATORS

ACTOR Write Producer, Agro-Industry, or Government	**IMPACT** Highlight each *adaptation* to indicate the **impact** that it is mediating
6. Agro-Industry	Develop technologies for efficient irrigation systems and excess water management systems (Blue)
7. Government	City and county agencies restore habitat for native pollinators (e.g. adjusting roadside maintenance to include locally-appropriate options for vegetated roadsides) (Pink)
8. Government	Provide technical assistance for risk management (All)
9. Producer	Provide cooling, such as shade structures or intercropping, to sensitive crops (Yellow)
10. Producer	Choose appropriate flood tolerant or drought-resistant crops (Blue)
11. Producer	Implement an integrated pest management plan (Green)
12. Agro-Industry	Study intercropping to reduce heat stress (Yellow)
13. Agro-Industry	Develop pest resistant crop varieties (Green)
14. Producer	Provide nesting sites for native pollinators (Pink)
15. Agro-Industry	Develop technologies of drought resistant and flood tolerant crop varieties (Blue)
16. Agro-Industry	Identify and register new and safe products or biocontrol methods to deal with Varroa mites, which attack honeybees (Pink/Green)
17. All	Stay updated on emerging pests of concern (Green)
18. Government	Modify land management policies and programs to improve resilience to climate change (All)
19. Producer	Attract native pollinators and other beneficials with hedgerows, flower strips, and polyculture (Pink)
20. Agro-Industry	Study nutritional needs of honeybees, methods of supplying nutrition, and pesticide impact on honeybee health (e.g. hedgerows, flower strips) (Pink/Green)

Name ____ Date ________________



Trade-Offs in the Agricultural Industry

INTERACTING ADAPTATIONS

1. Examine the distribution of the sticky notes on the posters around the classroom and fill in the blank for the following sentence (**CIRCLE ONE**).

   When an adaptation to the effects of climate change is put
   in place, it **DOES / DOES NOT** affect other parts of agriculture.

   a. How does the distribution of sticky notes show this?

   b. What does this tell us about the way actors in agriculture should work together to adapt to the effects of climate change?

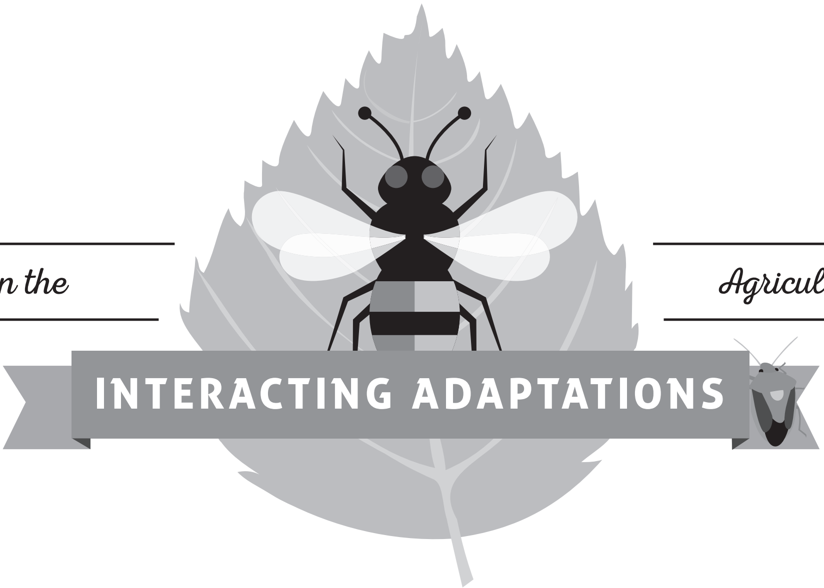
2. Think back to the farmers in Tulare County, CA. If you were one of these farmers, knowing what you know now, would you still tap into groundwater as an adaptation to climate change? (**CIRCLE ONE**)

   YES **NO**

   a. Why or why not?

   b. What could have been done differently to increase sustainability of water resources?

ANSWER KEY



Trade-Offs in the INTERACTING ADAPTATIONS *Agricultural Industry*

1. Examine the distribution of the sticky notes on the posters around the classroom and fill in the blank for the following sentence (**CIRCLE ONE**).

When an adaptation to the effects of climate change is put
in place, it [✓ **DOES**] / **DOES NOT** affect other parts of agriculture.

   a. How does the distribution of sticky notes show this?

   Most posters have multiple sticky notes (or posters have different colored sticky notes on them).

   b. What does this tell us about the way actors in agriculture should work together to adapt to the effects of climate change?

   Finding and implementing effective adaptations are the responsibilities of all actors. Adaptations are interconnected, and agricultural actors should work together to find solutions to the issues related to all of the major climate impacts. When an adaptation for an impact is implemented, it can have an effect on other impacts, and the trade offs should be considered by all actors.

2. Think back to the farmers in Tulare County, CA. If you were one [illegible] farmers, knowing what you know now, would you still tap into groundwater as an adaptation [illegible]nge? (**CIRCLE ONE**)

student answers will vary

NO

   a. Why or why not?

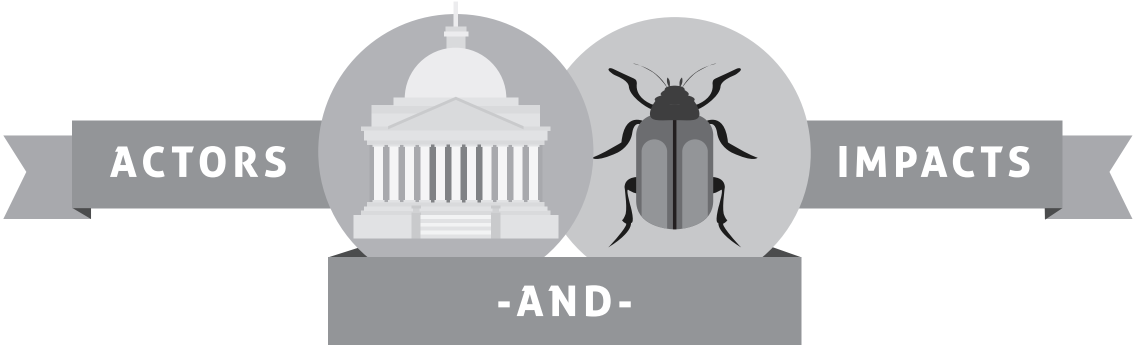
   Reasons for answering "yes" could include: there is not enough surface water; I need to water my crops in the short term; my neighbors are doing it, and I do not want to lose out on my share; etc.

   Reasons for answering "no" could include: we will run out of groundwater; we should stop the subsidence (or sinking) of land; I may be taking more than my fair share of water; drilling for water is expensive

   b. What could have been done differently to increase sustainability of water resources?

   Alter planting and harvesting schedules, develop efficient irrigation systems and excess water systems, develop/plant drought-resistant crop varieties, implement other water conservation methods (watering schedules, incentives), monitor soil moisture and water only when needed

REFERENCE SHEET



ACTORS

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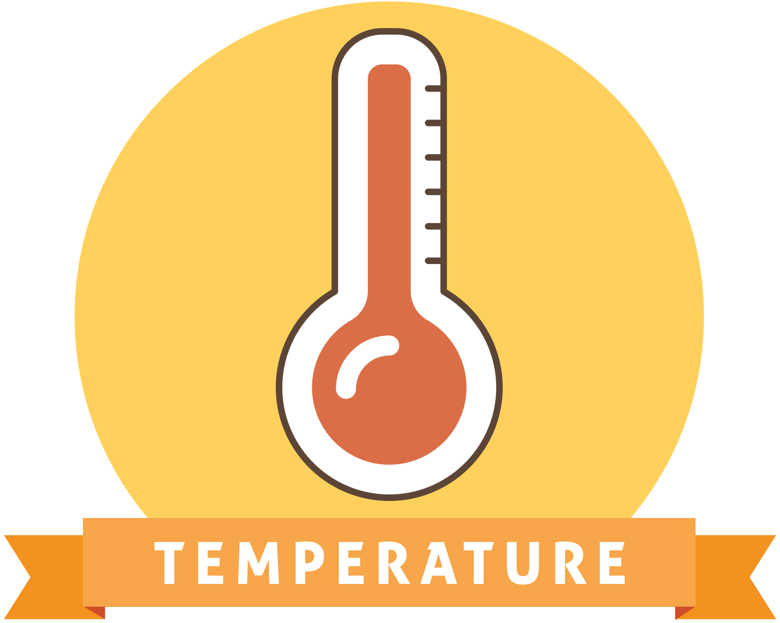
IMPACTS OF CLIMATE CHANGE

Temperature:
- Increased average, minimum, and maximum temperatures in all seasons, and increased temperature variability
- More frequent and longer-lasting heat waves in the summer
- Reduced number of winter chill hours and fog
- Uncertainty in temperature change projections and forecasts
- High spatial variability

Water:
- Reduced precipitation (drought) or increased precipitation (floods)
- Decreased winter snowpack, altered (earlier) timing of snowmelt and spring river runoff
- More variable temperatures resulting in more variable precipitation and snowpack accumulation
- Altered reservoir storage regimes
- Reduced natural groundwater recharge
- Reduced water quality due to reduced fresh water supplies
- Uncertainty in predictions

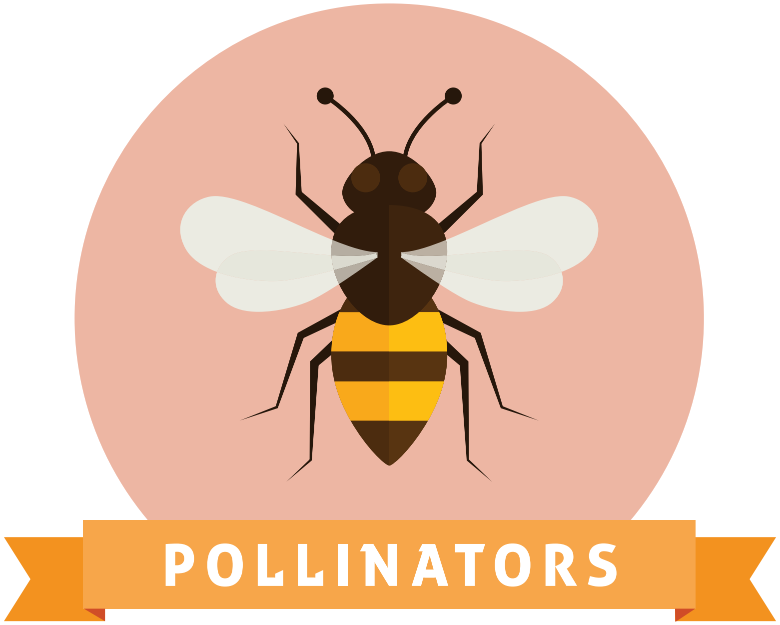
Pests:
- Altered temperature and water availability will have direct impact on individual pest species
- Climate change will alter inter-species dynamics and the larger ecosystems upon which agriculture depends
- Conventionally grown, monoculture agriculture will be more vulnerable to pest changes
- Climate change impacts to pests are complex and unpredictable

Pollinators:
- Altered temperature and water availability will have direct impact on pollinator species
- Climate change will alter inter-species dynamics and the larger ecosystems upon which agriculture depends
- Over-reliance on managed pollinators (honey bees) poses a potential risk to agriculture in light of climate change
- Climate change impacts to pollinator species are complex and unpredictable


TEMPERATURE


WATER


PESTS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(CDFA,2013)

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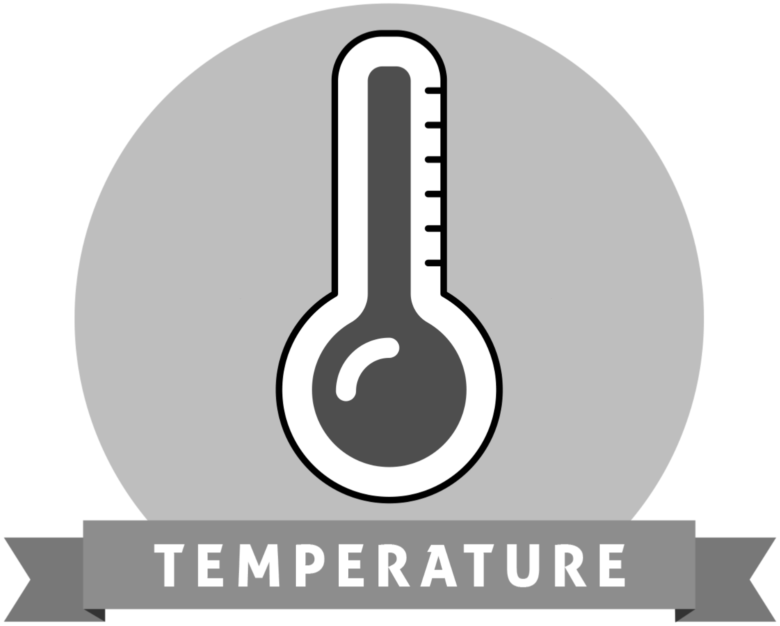
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AGRO-INDUSTRY


GOVERNMENT

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businesses connected with agriculture; involves researching technologies and disseminating information to producers

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the person, or group of people, that operate a farm

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Modeling an Adaptation to Climate Change

WILT IT BE PRODUCTIVE?

DESCRIPTION

To evaluate an agricultural adaptation to climate change, students conduct an experiment to test the effectiveness of a model shade structure in reducing transpiration from spinach leaves under lights.

PHENOMENON

Can a shade structure prevent crops from wilting?

GRADE LEVEL
6 – 12

OBJECTIVES

Students will:

- Explain how global change, especially increased temperatures and carbon dioxide levels, affects plant transpiration and photosynthesis
- Analyze the results of an experiment and use them to determine the feasibility of an agricultural adaptation to climate change

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 » Writing » Grade 6-8

CCSS.ELA-LITERACY.WHST.6-8.2.D. Use precise language and domain-specific vocabulary to inform about or explain the topic.

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 » Writing » Grade 9-10

CCSS.ELA-LITERACY.WHST.9-10.2.D. Use precise language and domain-specific vocabulary to manage the complexity of the topic and convey a style appropriate to the discipline and context as well as to the expertise of likely readers.

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.

English Language Arts Standards » Writing » Grade 11-12

CCSS.ELA-LITERACY.WHST.11-12.2.D. Use precise language, domain-specific vocabulary and techniques such as metaphor, simile, and analogy to manage the complexity of the topic; convey a knowledgeable stance in a style that responds to the discipline and context as well as to the expertise of likely readers.

Grade 7 » Ratios & Proportional Relationships

CCSS.MATH.CONTENT.7.RP.A.3. Use proportional relationships to solve multistep ratio and percent problems. Examples: simple interest, tax, markups and markdowns, gratuities and commissions, fees, percent increase and decrease, percent error.

NEXT GENERATION SCIENCE STANDARDS

Middle School Performance Expectation

MS-LS1-6. Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms.

High School Performance Expectation

HS-ESS3-4. Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

NEXT GENERATION SCIENCE STANDARDS

Science & Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Planning and Carrying Out Investigations (MS) Developing and Using Models (MS, HS) Using Mathematics and Computational Thinking (MS) Analyzing and Interpreting Data (MS) Constructing Explanations and Designing Solutions (MS)	ESS3.C Human Impacts on Earth Systems (MS, HS) LS1.C Organization for Matter and Energy Flow in Organisms (MS, HS) PS3.D Energy in Chemical Processes and Everyday Life (MS, HS)	Energy and Matter (MS) Systems and System Models (MS, HS)

AGRICULTURE, FOOD, AND NATURAL RESOURCES STANDARDS

CS.01.02. Examine technologies and analyze their impact on AFNR systems.
    CS.01.02.01.a. Research technologies used in AFNR systems.
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.
PS.01.01. Determine the influence of environmental factors on plant growth.
    PS.01.01.02.a. Identify and summarize the effects of air and temperature on plant metabolism and growth.
    PS.01.01.01.b. Analyze and describe plant responses to light color, intensity and duration.
    PS.01.01.02.c. Design, implement, and evaluate a plan to maintain optimal air and temperature conditions for plant growth.

BACKGROUND

High temperatures are detrimental to many crops. Excessive heat can result in crop wilting, scalding and scorching of leaves and stems, sunburn on fruits and stems, leaf drop, reduction in growth, and decreased photosynthesis. Because of these complications, high temperatures will lead to reduced yields in many crops.

As climate change intensifies, it will be increasingly necessary for agricultural producers to adapt to rising temperatures. Adaptations may include changing planting locations, changing crop varieties, adjusting planting and harvesting dates, increased irrigation, and the use of shade structures. Shade structures reduce the temperature for crops growing under them, and increased crop yields with the use of shade structures have been demonstrated in tomatoes, cherries, and bell peppers.

Plants have the ability to regulate temperature and gas exchange through the opening and closing of pores on their leaves called **stomata** (singular: **stoma**). When stomata are open, carbon dioxide enters, and water and oxygen escape. The release of water from plants is called **transpiration**. Transpiration helps to draw up minerals and water through the roots because, as water evaporates from the leaves, it is replaced by other water molecules. These water molecules move up through the plant in a continuous column from the soil, through the roots, stem, and leaves, and ultimately into the atmosphere. An important function of transpiration is to allow evaporative cooling of the plant.

Carbon dioxide (CO_2) levels in the atmosphere are increasing, which has contributed to increased global temperatures. Increased CO_2 generally causes stomata to be proportionally more closed because stomata do not need to be open as long to take up adequate CO_2 for photosynthesis. This causes a reduction of water loss by transpiration. However, increased temperatures can result in increased transpiration because warmer air has a greater ability to hold more water (relative humidity). This warmer air effectively pulls water more quickly out of the open stomata. Researchers have demonstrated that, for crops growing in the warmest parts of the year, increased transpiration due to increased temperatures cannot be offset by the partial closure of stomata due to CO_2 levels. In other words, crops will experience increased transpiration as temperatures increase, and increased CO_2 will not counteract the loss of water.

MATERIALS

- *Wilt it Be Productive? and Don't Be a Loser!* handout packet [1 per student]
- Set of *Don't Be a Loser!* game cards [1 set per every 2 students]
- PowerPoint presentation
- Computer and projector
- Scissors
- Calculators [1 per every 2 students]
- Dinner-sized paper plates (thin and easily cut with scissors) [1 per every 4 students]
- Dessert-sized paper plates [2 per every 4 students, plus a few extras]
- Soda cans, empty or full [2 per every 4 students]
- Clip-on reflective shop lights [2 per every 4 students]
- Large bunch of spinach [1 per every 16 students]
- Electronic balance with 0.1g accuracy [1-5 per class]
- Kitchen timer [optional]
- Extension cords [optional]
- *Wilt it Be Productive?* instructional video, optional introduction to the experiment for the educator

PREPARATION

1. If possible, watch the *Wilt it Be Productive?* instructional video for an introduction to the experiment.
1. Plan to divide students into teams of four. If necessary, teams of three or five would also be acceptable, as activity tasks can be combined or divided.
2. Make one shade plate for every team of four students. Make shade plates by gently folding the dinner plate in half without creasing it. Cut five narrow triangle shapes along the center fold, approximately 1-inch wide x 5-inch long. Unfold the plate and smooth it out so that it will lay flat. It should look roughly like the top plate in Figure 1.

Figure 1. Experimental set up of shade treatment with plates and soda cans

4. Set up scale(s) around the room in easily accessible locations.
   a. Place an empty dessert plate next to each scale.
5. Draw the whole class data table from page 3 of the handout on the board or prepare to show it with a document camera.
6. Place a calculator on each group's table or in an accessible location.
7. Set up a computer and projector and display the PowerPoint presentation.
8. Thoroughly rinse or soak the spinach to remove any soil sticking to the leaves. Blot it dry. If possible, keep it in a refrigerator or cooler when not using.
9. Label and pre-weigh two paired dessert plates of spinach for each group. Label one plate: "Shade." Label the other plate: "Open." On one of the paired plates, arrange eight spinach leaves so that there is very little overlap between leaves. Place an empty dessert plate on the scale, press the tare button, and then remove the empty plate. Take the mass of the plate of spinach, and record it in Table i. below. Then place

Table i. Starting masses of spinach on open and shade plates for each group

GROUP	OPEN MASS (G)	SHADE MASS (G)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

eight spinach leaves, with very little overlap, on the second plate of the pair so that the starting mass of the two treatments is approximately equal (+/- 0.2g). In other words, if the starting mass of the first plate of spinach is 9.4g, be sure that the second plate is between 9.2g and 9.6g. This can be accomplished by removing the stem of one or more leaves or swapping out a leaf for a larger or smaller one. Do not forget to tare the scale with an empty dessert plate before taking the mass every time.

   a. Place the weighed spinach plates in an area near the stations for student collection, keeping the paired plates together.

Note: Time permitting, the educator may instruct students to complete this step before conducting the activity. For educators with one hour or less to conduct this activity, however, it is recommended to pre-weigh spinach for the experiment. Minimize the time that spinach is left sitting out after weighing. If not conducting the activity within 45 minutes, place spinach inside labeled plastic zipper bags and refrigerate.

PROCEDURES

Optional Engage Activity

Bring in a wilted plant and ask students to hypothesize about how the plant became wilted. Elicit that the plant likely was not watered enough, and without water, the leaves and stems wilted. Pose questions to get students thinking about its ability to survive and photosynthesize, such as:

- What usually happens to plants that look like this if they do not get some water? [Answer: they usually die.]
- Why do plants need water? [Answer: for turgidity, obtaining nutrients, and to conduct the chemical reactions needed to live, such as photosynthesis. Note: there is no need to go into depth in your explanation of photosynthesis; it will be addressed later in the activity.]

INTRODUCTION

1. Divide students into teams of four.
2. Pass out a *Wilt it Be Productive?* and *Don't Be a Loser!* handout packet to each student.
3. Give a short introduction using the PowerPoint presentation.
   a. **Slide 2**: as you probably know, crops need to be watered. Today, we are going to examine what happens to the water that plants take up.
   b. **Slide 3**: one of the things that happens to the water that plants take up is a process called transpiration. It is the loss of water from inside plants into the atmosphere. It functions to cool the plant. Also, it helps to drive water movement through the plant and bring water and nutrients up through the roots and into the stems and leaves. It is basically an invisible process, but if you cover the leaves of a plant with a bag, the bag will get foggy with the water that is being transpired.
   c. **Slide 4**: transpiration does not always happen at the same rate. Environmental variables affect transpiration rates, and here are some of the factors that can slow down or speed up transpiration: temperature, light, relative humidity, wind, carbon dioxide, and soil moisture.
   d. **Slide 5**: let's think for a moment about the climate currently and how it is changing. Since 1958, scientists at Mauna Loa, on a Hawaiian island in the North Pacific, have been collecting atmospheric data. This graph shows the concentration of carbon dioxide in the atmosphere as measured at Mauna Loa. Ask students to describe the trend of this graph [answer: carbon dioxide is increasing; some students may also notice that there is a sawtooth pattern from seasonal CO2 uptake and release in the northern hemisphere].
   e. **Slide 6**: we have recorded data on Earth temperatures since 1880. Ask students to describe the trend of this graph [answer: temperature is increasing].
   f. **Slide 7**: remember the factors that affect transpiration. We just mentioned that the concentration of carbon dioxide in the atmosphere is increasing. With this increase, we are also seeing an increase in temperature. We will focus on these two factors in our activities today. First, we will investigate the effects of temperature on plant transpiration. We are going to conduct an experiment that will serve as a model for crops in a warming climate and a way to examine a possible adaptation.
   g. **Slide 8**: farmers in many areas will need to strategize about how they will adapt to increasing temperatures. Some may shift the seasons in which they grow certain crops. Some may switch to more heat-resistant varieties of crops. Another adaptation that is being used experimentally is shade. It has been used with bell peppers, tomatoes, and cherries. The shade helps to reduce the temperature underneath. Producers have experienced increased yields in these crops with the use of shade structures.

Set Up and Begin Experiment

1. Explain the experiment using the PowerPoint presentation.
   a. **Slide 9**: we are going to conduct an experiment that uses a shade structure model made out of a paper plate with holes cut out of it that is resting on two soda cans. We will be comparing the water loss from two bunches of spinach placed under lights for 30 minutes. One will be placed under a paper-plate shade structure, and one will be left out in the

open under the light. Instruct students to make a prediction about which treatment will result in higher water loss and then fill in the blank of the prediction statement on page 1 of the handout.

2. Instruct students to read the team member roles on the front page of the handout and choose one role for each student in the group.
3. Once roles are chosen, explain that the materials manager in each group will collect two paired spinach plates. Ensure that students pick up a matched pair of plates.
4. Ask all team members in each group to take the spinach plates to a station with two lights.
5. Instruct the lights operator to place the spinach plates on the table under each of the lights. Ensure that they do not adjust the distance of the lights from the table and do not turn on the lights yet.
6. Tell the lights operator to set up the shade treatment by placing a soda can on each side of the spinach plate labeled “Shade.” They will then balance the dinner plate with cutouts on top of the two soda cans.
7. Explain that they will leave the spinach plate un-shaded under the other light because this is the open treatment.
8. If you pre-weighed the spinach plates, ask students to take the mass again before conducting the experiment because the masses may have changed slightly since you weighed and recorded them.
9. Instruct the scale operator and data recorder to take the two paired spinach plates to the scale, along with the handout.
10. Instruct the scale operator to place an empty dessert plate on the scale, press the tare button, and then remove the empty plate.
    a. It is very important that students tare the scale to account for the mass of the dessert plate.
11. Ask the scale operator to take the mass of each of the spinach plates and the data recorder to record them in the starting mass column of the data table on page 2 of the handout.
12. Instruct the scale operator to carry the two spinach plates back to the light station.
13. Ask the lights operator to place the spinach plates back under the lights, being sure to place the plate labeled “Shade” under the shade structure and the plate labeled “Open” under the open light.
14. Once each group has placed the plates back under the lights, instruct all of the lights operators to turn both lights on at the same time. Tell students that you will give a count of three and ask them to turn on both of their lights as you say three.
15. Spinach plates should remain under the lights for at least 30 minutes to produce results that show a difference between treatments. You may set a timer for 30 minutes if you have one; otherwise, you may just watch the clock until at least 30 minutes have elapsed. It is preferable to conduct the experiment for longer if possible; in fact, a greater difference between treatments will be obtained if you are able to let the experiment run for a longer period of time.
16. While waiting for the experiment, play the *Don’t Be a Loser!* game, and then students will return to their stations to measure and record ending masses.

Don’t Be a Loser! Game

1. Prepare to divide students into teams of two for the game.
2. Give a short introduction to related concepts and the game using the PowerPoint presentation.
    a. **Slide 10**: plants have pores on their structures called stomata that allow them to exchange gases with the atmosphere. They are usually microscopic. They open and close in response to the environment. When a stoma is open, carbon dioxide needed for photosynthesis enters, and water and oxygen escape.
    b. **Slide 11**: now let’s think about climate change and how it is affecting transpiration. As we saw earlier, carbon dioxide is increasing in the atmosphere. When carbon dioxide is abundant, stomata tend to close because the plant is able to take in carbon dioxide quickly, and the plant gets as much as it needs. When the stomata are closed, the plant does not lose water to the atmosphere. This can be good for farmers because less water is needed when stomata are closed. However, the global average temperature is also increasing. In warmer temperatures, stomata are usually open because warmer air tends to drive water out of the stomata. This is usually the case if plants have sufficient water and are not under water stress.
    c. **Slide 12**: we are going to play a game to examine the effects of climate change on water loss through transpiration called *Don’t Be a Loser!* Our game will be dealing with the reality of our changing climate, in which carbon dioxide and temperatures are increasing. We will also include some science fiction. Imagine that you are a farmer with the ability to miniaturize. For 9 days, every day at 12:00 pm you will miniaturize and visit the same stoma on the same tomato plant. You will observe whether the stoma is open or closed. You assume that the stoma that you observe is giving you a reasonably good idea about how the rest of the stomata on the plant are behaving. You will also consider the temperature at that time each day relative to the historic temperature average of the previous 30 years.
    d. **Slide 13**: you and your partner will be given a stack of nine cards, and each card represents what you see on your daily 12:00 pm visit to the stoma on your tomato plant. You

will begin by looking at the A side of your first card. You will fill in the conditions noted on the card on your scorecard on page 6 of your handout. We will use this example to look at how to fill in the scorecard. Just follow along with me; do not write anything on your handout yet. Carbon dioxide is at an increased level on this card, which is how it will be on every card over the course of the game. We see that the temperature is 1 degree Celsius (°C) above historic level, so, on our scorecard, we will write a one in the blank for temperature and circle "above." Because it is warm, the stoma is open, and the card reads "open stoma." We will circle "open" in the stoma column on our scorecard. Now we will flip our card over to the B side. It says that we will lose two water points because our stoma is open. We will write "2" in the lost column in the water points section of our scorecard. If we were playing, we would then go on to our next card. You will now receive a stack of cards, and you will record the conditions from the A side and water points from the B side of each card over nine rounds.
   i. Note that we are using degrees Celsius (°C) in this activity since this is how scientists measure temperature. A change in the temperature in °C is equivalent to a larger number when measured in Fahrenheit (°F). Let us imagine, for example, that it is a warm summer day in the Southwest, and it is 35°C, which is 95°F. If the temperature were to increase by 2°C, or to 37°C, it would equal 98.6°F. To convert temperatures in Celsius to temperatures in Fahrenheit, we multiply by 1.8 and add 32.
3. Hand a full set of nine of cards to each team of two students. If students are currently grouped in teams of four, divide each team in half. Otherwise, students may need to be rearranged to work in pairs.
4. Once teams have had enough time to fill out their scorecards, instruct them to add up all of the water points that were gained during the game and all of the water points that were lost during the game, and record them in the last row of the scorecard.
5. Explain that students will then enter the water points gained and lost into the blanks of the subtraction problem under the scorecard on page 6 of the handout.
6. Tell students to subtract the number of water points lost from the number of water points gained to determine the net water points for the game.
7. The difference will be negative. As students solve this problem, be sure that they are being mindful of the sign.
8. Instruct students to answer the results questions on page 6 of the handout. Use the questions to elicit a discussion about the water loss of their plants during the game.
9. Go back to the PowerPoint presentation to show students the results of a related study.
   a. **Slide 14**: in the game, you saw that the amount of water transpired increased as the temperature increased. For example, you can see on your scorecard that when the temperature was 1 degree C above historic temperature, the plant lost 2 water points, and when the temperature was 2.5 degrees C above historic temperature, the plant lost 7 water points. This is what research demonstrates as well. This graph is from a research paper that shows that when temperature increases, crop transpiration also increases. The two lines show two different equations used to calculate transpiration, and they both show an increased rate with increased temperature.
10. Give an explanation of photosynthesis using the PowerPoint presentation.
   a. **Slide 15**: this is the equation for photosynthesis. Carbon dioxide and water are on the left side of the arrow. These are the reactants of the chemical reaction. Plants must obtain carbon dioxide and water from the environment to conduct photosynthesis. Remember, plants take up water through their roots and carbon dioxide through the stomata. When a stoma is open, however, water is released to the atmosphere during transpiration. Without sufficient carbon dioxide or water, plants are not able to photosynthesize. Oxygen and a sugar, called glucose, are on the right side of the arrow. These are the products of the chemical reaction. Most of the oxygen a plant produces is released through the stomata, and the sugar is used by the plant for energy or to build other carbohydrates to make structures, such as leaves, stems, and fruit.
11. Ask students to answer the conclusions questions on page 7. Time permitting, elicit a discussion about the importance of water in photosynthesis and fruit production.
12. Once it has been at least 30 minutes since turning on the lights in the experiment, announce to students that it is time to return to the experiment.

Return to Experiment: Collect and Analyze Data

1. Explain that students are to follow the instructions on page 2 of their handout, beginning with step 8.
2. All team members will return to their station, and then instruct the lights operator to turn off both lights at the same time.
3. Instruct the scale operator to carry the two spinach plates to the scale

and the data recorder to take the handout to the scale.

4. Once at the scale, the scale operator will tare the scale with an empty dessert plate, and then remove it.
5. Instruct the scale operator to take the mass of each of the spinach plates and the data recorder to record each mass in the ending mass column of the "Your Group" table on page 2 of the handout.
6. Ensure that each team has access to a calculator.
7. Once the data are collected, all team members will calculate the percent change of each treatment, which puts the measurements of each treatment on "equal ground" so that a fair comparison can be made.
    a. Explain that students will first calculate the percent change of the shade treatment. Instruct students to use the formula at the bottom of page 2. They will subtract the starting mass from the ending mass, divide the difference by the starting mass, and then multiply it by 100.
    b. Next, instruct students to follow the same procedure to calculate the percent change of the open treatment using the formula at the bottom of page 2.
    c. The percent change values should be **negative** because the mass should have decreased during the experiment. As students solve these problems, be sure that they are being mindful of the signs.
8. Fill in the "Whole Class" table written on the board or projected with the document camera from page 3 of the handout.
    a. Either ask each team to call out their values and record them in the table, or have one representative from each team come up and write their values in the table.
9. Ask students to fill in the "Whole Class" table on page 3 of their handout using the data from the table on the board (or projected with the document camera).
    a. Instruct students to calculate the mean percent change for the shade treatment and the mean percent change for the open treatment, and enter them in the bottom of the Whole Class table.

RESULTS AND CONCLUSIONS

1. Go over the results questions with students to ensure that they understand them well enough to answer the conclusion questions.
    a. Emphasize the answer to results question 1; calculations were negative because the mass of the spinach declined over the course of the experiment, and the negative value denotes a decrease.
2. Direct students to answer the conclusions questions.
    a. For conclusions question 4, ensure that students use the answer to results question 3, considering the mean percent change for the whole class, not simply their own results.
    b. For conclusions question 7, use the PowerPoint presentation to show students a photo of large agricultural fields.
        i. **Slide 16**: this is a photo of lettuce growing in California. Can you think of some of the challenges of using shade structures on these agricultural fields? [Answer: these fields are very large, so constructing shade structures over them would be very costly and require a great deal of labor, materials, and time.] Now answer question 7 on page 4 of your handout.

EXTENSIONS

1. After conducting the experiment, students may have their own ideas about how a model shade structure could be designed. Encourage students to bring in materials from home to construct a model shade structure and then conduct the experiment again. Note: Ideally, students will be able to replicate their design at least 4-10 times by constructing a number of duplicate structures or by repeating the trials several times.

ADDITIONAL RESOURCES

Websites with background information about transpiration:

Johnson, G. How High Heat Affects Vegetables and Other Crop Plants. Weekly Crop Update. University of Delaware Cooperative Extension. Published 17 Jun. 2011. Web. Accessed 24 October 2016. <https://agdev.anr.udel.edu/weeklycropupdate/?p=3203>

United States Geological Survey (USGS). Transpiration – the Water Cycle. Published 15 Apr. 2014. Web. Accessed 1 May 2016. <http://water.usgs.gov/edu/watercycletranspiration.html>.

Articles about using shade structures with crops:

California Department of Food and Agriculture (CDFA). 2013. Climate Change Consortium for Specialty Crops: Impacts and Strategies for Resilience Report. Accessed online. 26 Apr. 2016. <https://www.cdfa.ca.gov/environmentalstewardship/pdfs/ccc-report.pdf>

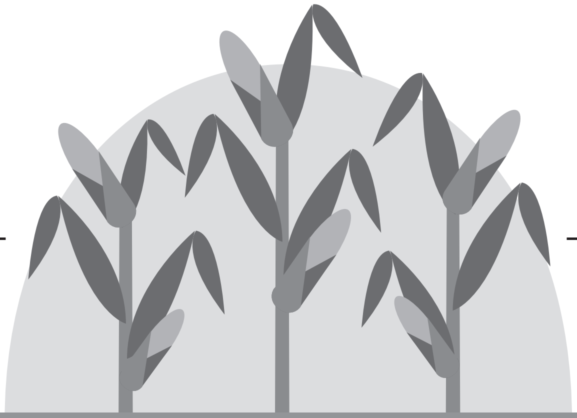
Gent, MPN. 2007. Effect of degree and duration of shade on quality of greenhouse tomato. HortScience 42: 514-520. Accessed online 26 Apr. 2016. <http://hortsci.ashspublications.org/content/42/3/514.short>

Hochmuth, RC, Treadwell, DD, Simonne, EH, Landrum, LB, Laughlin, WL, Davis, LL. 2015. Growing bell peppers in soilless culture under open shade structures. University of Florida, IFAS Extension Report HS-1113. Accessed online. 26 Apr. 2016. <https://edis.ifas.ufl.edu/hs368>.

Article with helpful information about how carbon dioxide affects crops:

Lovelli, S, Perniola, M, Di Tommaso, T, Ventrella, D, Moriondo, M., Amato, M. 2010. Effects of rising atmospheric CO2 on crop evapotranspiration in a Mediterranean area. Agricultural Water Management 97: 1287-1292. Accessed online. 26 Apr. 2016. <http://www.sciencedirect.com/science/article/pii/S0378377410001022>

Name ____ Date ________________



Modeling an Adaptation to Climate Change

WILT IT BE PRODUCTIVE?

TEAM MEMBER ROLES

MATERIALS MANAGER
SCALE OPERATOR
LIGHTS OPERATOR
DATA RECORDER

Figure 1. Experimental set up of shade treatment with plates and soda cans

MATERIALS

- 2 dessert-sized paper plates containing spinach leaves
- Calculator

EXPERIMENT SET UP

1. Please work with your instructor to assemble into teams of 4.
2. Complete the prediction below.
3. Each team member will choose a role from the list of team member roles.
4. Materials manager, collect two paired spinach plates.
5. All team members, take the plates and spinach to a station with two lights.
6. Lights operator, place the spinach plates on the table under each of the lights. Do not adjust the distance of the lights from the table, and do not turn the lights on.
7. Lights operator, set up the shade treatment by placing a soda can on each side of the spinach plate labeled “Shade.” Balance the dinner plate with cutouts on top of the two soda cans (Figure 1).
8. Lights operator, under the other light, leave the spinach plate un-shaded; this is the open treatment.
9. All team members, follow the procedures on page 2.

PREDICTION

I predict that the water loss of the ____________________________ treatment will be **higher**.

A. SHADE **B. OPEN** **C. NEITHER (THEY WILL BE THE SAME)**

PROCEDURES

1. Scale operator, carry the two spinach plates to the scale, and data recorder, take this handout to the scale.
2. Scale operator, place an empty dessert plate on the scale, press the tare button, and then remove the empty plate.
3. Scale operator, take the mass of each of the spinach plates, and data recorder, record it in the starting mass column of the data table on page 2 of this handout.
4. Scale operator, carry the two spinach plates to the light station.
5. Lights operator, place the spinach plates back under the lights, being sure to place the plate labeled "Shade" under the shade structure and the plate labeled "Open" under the open light.
6. Lights operator, when instructed by your teacher, turn both lights on at the same time.
7. Leave the spinach under the lights for 30 minutes.
8. All team members, after 30 minutes, return to the station, and lights operator, turn off both lights at the same time.
9. Scale operator, carry the two spinach plates to the scale and data recorder, take this handout to the scale.
10. Scale operator, tare the scale with an empty dessert plate, and then remove it.
11. Scale operator, take the mass of each of the spinach plates, and data recorder, record it in the ending mass column of the "Your Group" table below.
12. All team members, calculate the percent change of each treatment, fill in the "Whole Class" table on page 3 of this handout, and answer the results and conclusions questions.

DATA & ANALYSIS

YOUR GROUP		
	STARTING MASS (G)	ENDING MASS (G)
SHADE		
OPEN		

Calculate the percent change in order to make a fair comparison. Value may be negative.

SHADE TREATMENT

(______________g – ______________g)
Ending Mass **Starting Mass**
____ X 100 = _______________% **Change in Mass**
______________g
Starting Mass

OPEN TREATMENT

(______________g – ______________g)
Ending Mass **Starting Mass**
____ X 100 = _______________% **Change in Mass**
______________g
Starting Mass

WHOLE CLASS – CHANGE IN MASS OF SPINACH		
GROUP	**SHADE (%)**	**OPEN (%)**
GROUP 1		
GROUP 2		
GROUP 3		
GROUP 4		
GROUP 5		
GROUP 6		
GROUP 7		
GROUP 8		
MEAN		

RESULTS

1. In **your group**, the percent changes in the mass of spinach that you calculated were:

   A. POSITIVE **B. NEGATIVE**

   Why were your calculations positive or negative?

2. In **your group**, which treatment had a **greater percent change in mass**? In other words, which treatment lost a larger percentage of water?

   A. SHADE TREATMENT **B. OPEN TREATMENT**

3. In the **whole class**, the __________________ treatment had a **greater mean percent change**.

   A. SHADE **B. OPEN**

CONCLUSIONS

4. Turn back to the first page and review your prediction. Was your prediction correct? Use your answer to question 3 above regarding greater mean percent change.

A. YES **B. NO**

5. Considering the results of this experiment, does shading tend to reduce the amount of water lost from plant leaves?

A. YES **B. NO**

6. Imagine that the spinach leaves in this experiment are a model for the leaves of a tomato plant. Under climate change conditions, in which treatment would you expect a tomato plant to produce more tomatoes?

A. SHADE TREATMENT **B. OPEN TREATMENT**

7. List one or more challenges to using shade structures for crops as an adaptation to heat.

DON'T BE A LOSER!

MATERIALS

- Set of game cards
- Calculator

SCENARIO

Reality: the climate is changing due to increasing levels of atmospheric carbon dioxide.

Science fiction: you are a farmer that has the ability to miniaturize and monitor the microscopic stomata on your tomato leaves. Your hope is that your tomato plants are conserving enough water that they will not wilt.

Over a 9-day period, every day at 12:00 pm, you visit the same stoma on the same tomato leaf to determine whether it is open or closed and how much water is being conserved or lost. You assume that the stoma that you observe is giving you a reasonably good idea about how the rest of the stomata on the plant are behaving and how much water the plant is conserving or losing. You also consider the temperature at that time each day relative to the historic temperature average of the previous 30 years.

GAME INSTRUCTIONS

1. Shuffle the game cards and place them in a pile with the A side up.

2. Begin by drawing a game card to play round 1.

3. Read the A side of the card to determine the climatic conditions and the position of the stoma. The card will indicate the carbon dioxide level and temperature (°C) relative to the historic level.

4. Turn the game card over to the B side, and read how many water points you gained or lost in this round.

5. On your scorecard on page 6 of this handout, for this round, record the relative temperature (°C) and whether it was above or below the historic level, the position of the stoma (open or closed), and how many water points were gained or lost.

6. Play rounds 2-9 by repeating steps 2-6.

7. Add up all of the water points that were gained during the game and all of the water points that were lost during the game, and record them in the last row of the scorecard.

8. Subtract the number of water points lost from the number of water points gained to determine the net water points for the game.

9. Answer the results and conclusion questions.

SCORECARD

			WATER POINTS	
ROUND	**TEMP (°C) / HISTORIC**	**STOMA**	**GAINED**	**LOST**
1	_______**ABOVE / BELOW**	**OPEN / CLOSED**		
2	_______**ABOVE / BELOW**	**OPEN / CLOSED**		
3	_______**ABOVE / BELOW**	**OPEN / CLOSED**		
4	_______**ABOVE / BELOW**	**OPEN / CLOSED**		
5	_______**ABOVE / BELOW**	**OPEN / CLOSED**		
6	_______**ABOVE / BELOW**	**OPEN / CLOSED**		
7	_______**ABOVE / BELOW**	**OPEN / CLOSED**		
8	_______**ABOVE / BELOW**	**OPEN / CLOSED**		
9	_______**ABOVE / BELOW**	**OPEN / CLOSED**		
		TOTAL		

ANALYSIS: WATER POINTS DIFFERENCE

_______________ – _______________ = _______________

Gained **Lost** **Net**

RESULTS

1. In your analysis, did you find that the net water points result was positive or negative?

A. POSITIVE **B. NEGATIVE**

2. Over the 9-day observation period, did your tomato leaf conserve more water than it lost or lose more water than it conserved?

A. CONSERVED MORE WATER THAN IT LOST **B. LOST MORE WATER THAN IT CONSERVED**

CONCLUSIONS

Consider the equation for **photosynthesis** to answer the following questions.

$6CO_2 + 6H_2O \rightarrow 6O_2 + C6H1_2O6$
Carbon dioxide + Water → Oxygen + Sugar

3. What two chemical compounds do plants need to undergo photosynthesis? In other words, what are the two reactants in this chemical reaction?

   a. Which of the two chemical compounds listed above is available in increased abundance under climate change conditions?

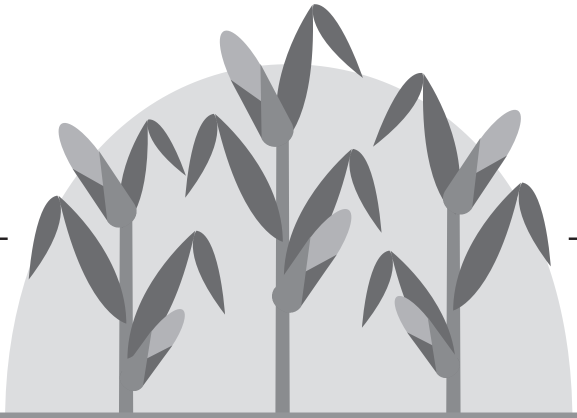
4. Given your answer to question 2 regarding the amount of water conserved or lost by your tomato leaf, do you think that your tomato plant had enough water to photosynthesize efficiently?

5. One of the products of photosynthesis is sugar, which is used as energy for the plant or to build other carbohydrates that make up plant structures such as leaves, stems, and fruit. If your tomato plant is not photosynthesizing efficiently, will it be able to build carbohydrates to produce tomatoes (the fruit of the plant)?

A. YES **B. NO**

Why or why not?

ANSWER KEY



Modeling an Adaptation to Climate Change

WILT IT BE PRODUCTIVE?

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LIGHTS OPERATOR
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Figure 1. Experimental set up of shade treatment with plates and soda cans

MATERIALS

- 2 dessert-sized paper plates containing spinach leaves
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7. Lights operator, set up the shade treatment by placing a soda can on each side of the spinach plate labeled "Shade." Balance the dinner plate with cutouts on top of the two soda cans (Figure 1).
8. Lights operator, under the other light, leave the spinach plate un-shaded; this is the open treatment.
9. All team members, follow the procedures on page 2.

PREDICTION

I predict that the water loss of the *student answers will vary* treatment will be **higher**.

A. SHADE **B. OPEN** **C. NEITHER (THEY WILL BE THE SAME)**

PROCEDURES

1. Scale operator, carry the two spinach plates to the scale, and data recorder, take this handout to the scale.
2. Scale operator, place an empty dessert plate on the scale, press the tare button, and then remove the empty plate.
3. Scale operator, take the mass of each of the spinach plates, and data recorder, record it in the starting mass column of the data table on page 2 of this handout.
4. Scale operator, carry the two spinach plates to the light station.
5. Lights operator, place the spinach plates back under the lights, being sure to place the plate labeled "Shade" under the shade structure and the plate labeled "Open" under the open light.
6. Lights operator, when instructed by your teacher, turn both lights on at the same time.
7. Leave the spinach under the lights for 30 minutes.
8. All team members, after 30 minutes, return to the station, and lights operator, turn off both lights at the same time.
9. Scale operator, carry the two spinach plates to the scale and data recorder, take this handout to the scale.
10. Scale operator, tare the scale with an empty dessert plate, and then remove it.
11. Scale operator, take the mass of each of the spinach plates, and data recorder, record it in the ending mass column of the "Your Group" table below.
12. All team members, calculate the percent change of each treatment, fill in the "Whole Class" table on page 3 of this handout, and answer the results and conclusions questions.

DATA & ANALYSIS

YOUR GROUP		
	STARTING MASS (G)	**ENDING MASS (G)**
SHADE		
OPEN		

student answers will vary

Calculate the percent change in order to make a fair comparison. Value may be negative.

SHADE TREATMENT

(______________g – ______________g)
Ending Mass **Starting Mass**
____ X 100 = *will vary* % **Change in Mass**
______________g
Starting Mass

OPEN TREATMENT

(______________g – ______________g)
Ending Mass **Starting Mass**
____ X 100 = *will vary* % **Change in Mass**
______________g
Starting Mass

WHOLE CLASS – CHANGE IN MASS OF SPINACH		
GROUP	**SHADE (%)**	**OPEN (%)**
GROUP 1		
GROUP 2		
GROUP 3		
GROUP 4		
GROUP 5		
GROUP 6		
GROUP 7		
GROUP 8		
MEAN		

student answers will vary

RESULTS

1. In **your group**, the percent changes in the mass of spinach that you calculated were:

   A. POSITIVE [✓ **B. NEGATIVE**]

   Why were your calculations positive or negative?

   The mass of the spinach declined over the experiment, and the negative value denotes a decrease.

2. In **your group**, which treatment had a **greater percent change in mass**? In other words, which treatment lost a larger percentage of water?

   This is usually the case

   A. SHADE TREATMENT [✓ **B. OPEN TREATMENT**]

3. In the **whole class**, the ________________ treatment had a **greater mean percent change**.

   This is usually the case

   A. SHADE [✓ **B. OPEN**]

CONCLUSIONS

4. Turn back to the first page and review your prediction. Was your prediction correct? Use your answer to question 3 above regarding greater mean percent change.

student answers will vary

A. **B. NO**

5. Considering the results of this experiment, does shading tend to reduce the amount of water lost from plant leaves?

This is usually the case

[✓ **A. YES**] **B. NO**

6. Imagine that the spinach leaves in this experiment are a model for the leaves of a tomato plant. Under climate change conditions, in which treatment would you expect a tomato plant to produce more tomatoes?

This is usually the case

[✓ **A. SHADE TREATMENT**] **B. OPEN TREATMENT**

7. List one or more challenges to using shade structures for crops as an adaptation to heat.

Student responses may include any of the following or any other valid ideas:
Agricultural fields tend to be very large. Constructing shade structures over them would be very costly and require a great deal of labor, materials, and time.

DON'T BE A LOSER!

MATERIALS

- Set of game cards
- Calculator

SCENARIO

Reality: the climate is changing due to increasing levels of atmospheric carbon dioxide.

Science fiction: you are a farmer that has the ability to miniaturize and monitor the microscopic stomata on your tomato leaves. Your hope is that your tomato plants are conserving enough water that they will not wilt.

Over a 9-day period, every day at 12:00 pm, you visit the same stoma on the same tomato leaf to determine whether it is open or closed and how much water is being conserved or lost. You assume that the stoma that you observe is giving you a reasonably good idea about how the rest of the stomata on the plant are behaving and how much water the plant is conserving or losing. You also consider the temperature at that time each day relative to the historic temperature average of the previous 30 years.

GAME INSTRUCTIONS

1. Shuffle the game cards and place them in a pile with the A side up.
2. Begin by drawing a game card to play round 1.
3. Read the A side of the card to determine the climatic conditions and the position of the stoma. The card will indicate the carbon dioxide level and temperature (°C) relative to the historic level.
4. Turn the game card over to the B side, and read how many water points you gained or lost in this round.
5. On your scorecard on page 6 of this handout, for this round, record the relative temperature (°C) and whether it was above or below the historic level, the position of the stoma (open or closed), and how many water points were gained or lost.
6. Play rounds 2-9 by repeating steps 2-6.
7. Add up all of the water points that were gained during the game and all of the water points that were lost during the game, and record them in the last row of the scorecard.
8. Subtract the number of water points lost from the number of water points gained to determine the net water points for the game.
9. Answer the results and conclusion questions.

SCORECA

student answers may be in different order

			WATER POINTS	
	MP (°C) / HISTORIC	STOMA	GAINED	LOST
	0.5 [✓ ABOVE] / BELOW	[✓ OPEN] / CLOSED		1
2	1 [✓ ABOVE] / BELOW	[✓ OPEN] / CLOSED		2
3	1.5 [✓ ABOVE] / BELOW	[✓ OPEN] / CLOSED		3
4	2 [✓ ABOVE] / BELOW	[✓ OPEN] / CLOSED		5
5	2.5 [✓ ABOVE] / BELOW	[✓ OPEN] / CLOSED		7
6	0.5 [✓ ABOVE] / BELOW	[✓ OPEN] / CLOSED		1
7	1 ABOVE / [✓ BELOW]	OPEN / [✓ CLOSED]	2	
8	1.5 ABOVE / [✓ BELOW]	OPEN / [✓ CLOSED]	3	
9	2 ABOVE / [✓ BELOW]	OPEN / [✓ CLOSED]	4	
		TOTAL	9	19

ANALYSIS: WATER POINTS DIFFERENCE

Gained		Lost		Net
9	–	19	=	-10

RESULTS

1. In your analysis, did you find that the net water points result was positive or negative?

A. POSITIVE [✓ B. NEGATIVE]

2. Over the 9-day observation period, did your tomato leaf conserve more water than it lost or lose more water than it conserved?

A. CONSERVED MORE WATER THAN IT LOST [✓ B. LOST MORE WATER THAN IT CONSERVED]

CONCLUSIONS

Consider the equation for **photosynthesis** to answer the following questions.

$$6CO_2 + 6H_2O \rightarrow 6O_2 + C6H1_2O6$$

Carbon dioxide + Water → Oxygen + Sugar

3. What two chemical compounds do plants need to undergo photosynthesis? In other words, what are the two reactants in this chemical reaction?

   Carbon dioxide (CO_2) and water (H_2O)

   a. Which of the two chemical compounds listed above is available in increased abundance under climate change conditions?

      Carbon dioxide (CO_2)

4. Given your answer to question 2 regarding the amount of water conserved or lost by your tomato leaf, do you think that your tomato plant had enough water to photosynthesize efficiently?

   No

5. One of the products of photosynthesis is sugar, which is used as energy for the plant or to build other carbohydrates that make up plant structures such as leaves, stems, and fruit. If your tomato plant is not photosynthesizing efficiently, will it be able to build carbohydrates to produce tomatoes (the fruit of the plant)?

   A. YES [✓ **B. NO**]

   Why or why not?

   If the plant has insufficient water for photosynthesis, it will not be able to produce the sugars that are used as building blocks to make fruits and other structures.

A

Increased CO_2
Temperature **0.5°C above** historic level

OPEN STOMA

A

Increased CO_2
Temperature **0.5°C below** historic level

CLOSED STOMA

A

Increased CO_2
Temperature **1°C above** historic level

OPEN STOMA

A

Increased CO_2
Temperature **1°C below** historic level

CLOSED STOMA

A

Increased CO_2
Temperature **1.5°C above** historic level

OPEN STOMA

A

Increased CO_2
Temperature **1.5°C below** historic level

CLOSED STOMA

A

Increased CO_2
Temperature **2°C above** historic level

OPEN STOMA

A

Increased CO_2
Temperature **2°C below** historic level

CLOSED STOMA

A

Increased CO_2
Temperature **2.5°C above** historic level

OPEN STOMA

B

LOSE 1 WATER POINT

B

GAIN 2 WATER POINTS

B

GAIN 3 WATER POINTS

B

GAIN 4 WATER POINTS

B

LOSE 1 WATER POINT

B

LOSE 2 WATER POINTS

B

LOSE 3 WATER POINTS

B

LOSE 5 WATER POINTS

B

LOSE 7 WATER POINTS

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]
    - o Test tubes, caps, capsules, racks [1 set for every 4 students (or 8) students]
    - o 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
- *Washed Away* instructional video, optional introduction to the experiment for the instructor

« 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. If possible, watch the *Washed Away* instructional video for an introduction to the experiment.
2. 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.
3. 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."

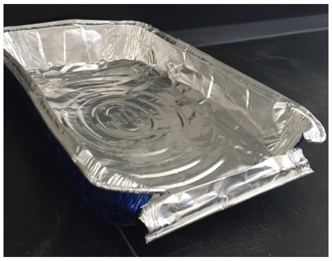

Figure 3. Soil pan, showing cut flap

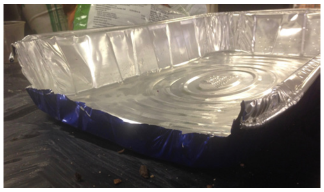

Figure 4. Catch pan, showing open side

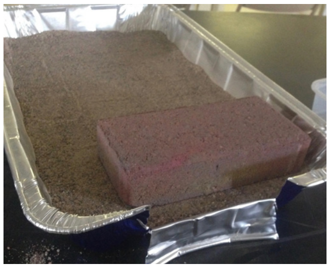

Figure 5. Lower layer of play sand in the soil pan, tamped down so that sand is flush with opening

Figure 6. Attachment of soil pan to catch pan

   b. Make enough soil solutions so that half of the groups in each class will receive a "topsoil" solution, and the other half of the groups in each class will receive a "lower layer" solution.
4. 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.
5. 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
6. 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.
   k. 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.
7. 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.
8. 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.
9. 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/>

Name ______________________________ Date ______________

Climate Change and Farmland Soil Quality

WASHED AWAY

As the climate changes, the frequency and intensity of extreme precipitation is likely to increase. While crops need adequate precipitation throughout their growing cycle, extreme precipitation can erode soil and degrade soil quality.

To determine soil quality, agriculture producers test the pH of soil and the level of nutrients such as nitrogen, phosphorous, and potash. These nutrients are necessary for crop health and production.

In this activity, you will examine the soil quality in an area of an imaginary farm before and after an extreme precipitation event has resulted in erosion of the topsoil.

PREDICTION

I predict that the:

- pH of the topsoil will be **HIGHER / LOWER** than the lower layer.
- Nitrogen of the topsoil will be **HIGHER / LOWER** than the lower layer.
- Phosphorous of the topsoil will be **HIGHER / LOWER** than the lower layer.
- Potash of the topsoil will be **HIGHER / LOWER** than the lower layer.

MATERIALS

- 4 tubes and caps
- 4 soil-testing capsules
- Tube rack
- 3 squeeze-bulb pipettes
- Paper towels
- Beaker of water
- Beaker of soil
- Soil solution
- Soil color chart
- Spoon

SOIL TESTING

1. Follow the instructions provided by your instructor to test your soil.
   a. Place a paper towel under your test tube while conducting the test.
2. Wait the specified time for the soil test to develop.

COMPARING SOIL ON AGRICULTURAL LANDS WITH SOILWEB

In this activity, you will investigate soil characteristics of agricultural land in three areas and at your location. These soil characteristics can help predict how agricultural producers in these areas may be affected by extreme precipitation events. Use a computer or tablet with internet access and follow the instructions below.

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.

SOIL VARIABLES

LATITUDE, LONGITUDE	21.5236, -158.0436	34.3823, -103.3695	36.4554, -120.1225	MY LOCATION
CITY, STATE	Wahiawa, Hawaii	Clovis, New Mexico	Five Points, California	
% SLOPE				
ORGANIC MATTER AT 0CM				
PH BY WATER EXTRACTION AT 0CM				
RUNOFF				

SOILWEB CONCLUSIONS

1. Organic matter comes from the tissues of plants, animals, or microorganisms that are currently or were once living. In the soil, organic matter can be a source of nutrients for crops. In general, areas with higher organic matter tend to have soils with higher levels of nutrients.

   Which location or locations likely have the highest nutrient levels for crops? How do you know?

2. Which location or locations have the highest potential for runoff, which could result in the erosion of soil by water?

3. Would the soil in your location likely have favorable nutrient content and pH for crop growth? Why or why not?

4. How could an agricultural producer use SoilWeb to help in the decision to purchase a piece of land as a potential crop field?

Return to Soil Testing

1. Examine the tubes and compare to the corresponding charts to determine pH and nutrient levels.
2. Complete your group's data table and the whole class data tables.

DATA & ANALYSIS

Your Group's Data Table

GROUP NUMBER ________				
SOIL LOCATION (topsoil or lower layer)	**PH** (number)	**NITROGEN** (high, medium, low, or very low)	**PHOSPHOROUS** (high, medium, low, or very low)	**POTASH** (high, medium, low, or very low)

CLASS DATA TABLES

pH: record the pH level of each group as a number.

TOPSOIL		LOWER LAYER	
GROUP NUMBER	PH	GROUP NUMBER	PH
MEAN		MEAN	

NUTRIENTS: record nutrient levels of each group as **high, medium, low, or very low**.

TOPSOIL				LOWER LAYER			
GROUP	NITROGEN	PHOSPHOROUS	POTASH	GROUP	NITROGEN	PHOSPHOROUS	POTASH
MOST COMMON LEVEL				MOST COMMON LEVEL			

RESULTS

1. pH was higher in the:

A. TOPSOIL **B. LOWER LAYER** **C. NEITHER (SAME)**

2. Nitrogen tended to be higher in the:

A. TOPSOIL **B. LOWER LAYER** **C. NEITHER (SAME)**

3. Phosphorus tended to be higher in the:

A. TOPSOIL **B. LOWER LAYER** **C. NEITHER (SAME)**

4. Potash tended to be higher in the:

A. TOPSOIL **B. LOWER LAYER** **C. NEITHER (SAME)**

SOIL TESTING CONCLUSIONS

1. How do you think the affected area of our imaginary farm changed physically? In other words, what changes in the way the area looked would we have seen before and after the extreme precipitation event?

2. Think about the nutrient levels in the lower layer of soil in the affected area of our imaginary farm after the extreme precipitation event. How were the resources, especially the nutrients, available for the crops affected by the precipitation event?

3. How would the crops in the affected area of our imaginary farm be impacted by the changes in nutrients after the extreme precipitation event?

4. How will the increasing frequency of extreme precipitation events affect agricultural producers? List any effects that you can imagine producers will experience as a result of extreme precipitation events.

5. Using your knowledge of climate change, list at least two other ways that our changing climate will impact agricultural producers.

ANSWER KEY

Climate Change and *Farmland Soil Quality*

WASHED AWAY

As the climate changes, the frequency and intensity of extreme precipitation is likely to increase. While crops need adequate precipitation throughout their growing cycle, extreme precipitation can erode soil and degrade soil quality.

To determine soil quality, agriculture producers test the pH of soil and the level of nutrients such as nitrogen, phosphorous, and potash. These nutrients are necessary for crop health and production.

In this activity, you will examine the soil quality in an area of an imaginary farm before and after an extreme precipitation event has resulted in erosion of the topsoil.

PREDICTION

I predict that the:

- pH of the topsoil will be **HIGHER / LOWER** than th ver layer.
- Nitrogen of the topsoil will be **HIGHER** han the lower layer.
- Phosphorous of the topso **ER / LOWER** than the lower layer.
- Potash of the topsoil will be **HIGHER / LOWER** than the lower layer.

student answers will vary

MATERIALS

- 4 tubes and caps
- 4 soil-testing capsules
- Tube rack
- 3 squeeze-bulb pipettes
- Paper towels
- Beaker of water
- Beaker of soil
- Soil solution
- Soil color chart
- Spoon

SOIL TESTING

1. Follow the instructions provided by your instructor to test your soil.
    a. Place a paper towel under your test tube while conducting the test.
2. Wait the specified time for the soil test to develop.

COMPARING SOIL ON AGRICULTURAL LANDS WITH SOILWEB

In this activity, you will investigate soil characteristics of agricultural land in three areas and at your location. These soil characteristics can help predict how agricultural producers in these areas may be affected by extreme precipitation events. Use a computer or tablet with internet access and follow the instructions below.

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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.

SOIL VARIABLES

LATITUDE, LONGITUDE	21.5236, -158.0436	34.3823, -103.3695	36.4554, -120.1225	MY LOCATION
CITY, STATE	Wahiawa, Hawaii	Clovis, New Mexico	Five Points, California	
% SLOPE	8-15%	1-3%	0-1%	
ORGANIC MATTER AT 0CM	3.5%	2.5%	1.3%	
PH BY WATER EXTRACTION AT 0CM	5.6	8.2	8.2	
RUNOFF	Medium	Low	High	

SOILWEB CONCLUSIONS

1. Organic matter comes from the tissues of plants, animals, or microorganisms that are currently or were once living. In the soil, organic matter can be a source of nutrients for crops. In general, areas with higher organic matter tend to have soils with higher levels of nutrients.

   Which location or locations likely have the highest nutrient levels for crops? How do you know?

   Wahiawa, HI (This answer assumes that your local site is not higher.)

2. Which location or locations have the highest potential for runoff, which could result in the erosion of soil by water?

   Five Points, CA (This answer assumes that your local site is not higher.)

3. Would the soil in your location likely have favorable nutrient content and pH for crop growth? Why or why not?

   Student answers will vary depending on local soil organic matter and pH values.

4. How could an agricultural producer use SoilWeb to help in the decision to purchase a piece of land as a potential crop field?

   The producer could examine the organic matter content, pH, and runoff values to determine whether the land likely has high soil quality and low runoff potential. This could save her or him some initial investment funds if the land was in need of little or no fertilizing or groundwork, for example.

Return to Soil Testing

1. Examine the tubes and compare to the corresponding charts to determine pH and nutrient levels.
2. Complete your group's data table and the whole class data tables.

DATA & ANALYSIS

Your Group's Data Table

GROUP NUMBER ________				
SOIL LOCATION (topsoil or lower layer)	**PH** (number)	**NITROGEN** (high, medium low, or	**OSPHOROUS** medium, low, or very low)	**POTASH** (high, medium, low, or very low)

student answers will vary

CLASS DATA TABLES

pH: record the pH level of each group as a number.

TOPSOIL		**LOWER LAYER**	
GROUP NUMBER	**PH**	**GROUP NUMBER**	**PH**
MEAN		**MEAN**	

student answers will vary

student answers will vary

NUTRIENTS: record nutrient levels of each group as **high, medium, low, or very low**.

TOPSOIL				LOWER LAYER			
GROUP	NITROGEN	PHOSPHOROUS	POTASH	GROUP	NITROGEN	PHOSPHOROUS	POTASH
MOST COMMON LEVEL				MOST COMMON LEVEL			

student answers will vary

student answers will vary

RESULTS

1. pH was higher in the:

A. TOPSO **WER LAYER** **C. NEITHER (SAME)**

student answers will vary

2. Nitrogen tended to be higher in the:

[✓ **A. TOPSOIL**] **B. LOWER LAYER** **C. NEITHER (SAME)**

3. Phosphorus tended to be higher in the:

These will usually be the case.

[✓ **A. TOPSOIL**] **B. LOWER LAYER** **C. NEITHER (SAME)**

4. Potash tended to be higher in the:

[✓ **A. TOPSOIL**] **B. LOWER LAYER** **C. NEITHER (SAME)**

SOIL TESTING CONCLUSIONS

1. How do you think the affected area of our imaginary farm changed physically? In other words, what changes in the way the area looked would we have seen before and after the extreme precipitation event?

   We would have likely seen evidence of soil erosion and topsoil removal. This could involve formation of channels, removal of crop plants, a change in soil color, and/or a change in soil texture.

2. Think about the nutrient levels in the lower layer of soil in the affected area of our imaginary farm after the extreme precipitation event. How were the resources, especially the nutrients, available for the crops affected by the precipitation event?

   If the nutrient-rich topsoil is eroded, we will have fewer nutrients available for crops.

3. How would the crops in the affected area of our imaginary farm be impacted by the changes in nutrients after the extreme precipitation event?

   With lower nutrient levels, crop plants would not be able to efficiently conduct the necessary processes for life functions, such as photosynthesis, production of energy molecules, production of genetic material, etc.

4. How will the increasing frequency of extreme precipitation events affect agricultural producers? List any effects that you can imagine producers will experience as a result of extreme precipitation events.

   - *Flooding*
   - *Soil erosion*
   - *Reduction in soil quality/nutrient levels*
   - *Damage to crops*

5. Using your knowledge of climate change, list at least two other ways that our changing climate will impact agricultural producers.

   Reduced productivity because of higher temperatures, drought, and extreme events

SOILWEB CONCLUSIONS

1. Organic matter comes from the tissues of plants, animals, or microorganisms that are currently or were once living. In the soil, organic matter can be a source of nutrients for crops. In general, areas with higher organic matter tend to have soils with higher levels of nutrients.

   Which location or locations likely have the highest nutrient levels for crops? How do you know?

   Wahiawa, HI (This answer assumes that your local site is not higher.)

2. Which location or locations have the highest potential for runoff, which could result in the erosion of soil by water?

   Five Points, CA (This answer assumes that your local site is not higher.)

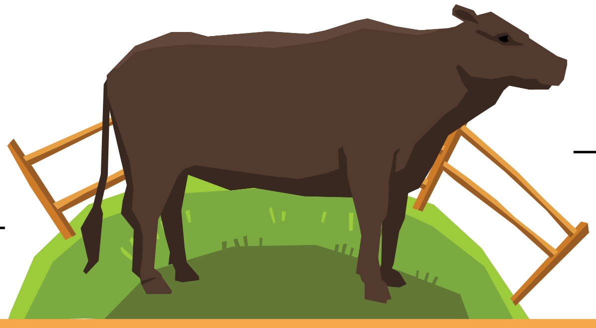
3. Would the soil in your location likely have favorable nutrient content and pH for crop growth? Why or why not?

   Student answers will vary depending on local soil organic matter and pH values.

4. How could an agricultural producer use SoilWeb to help in the decision to purchase a piece of land as a potential crop field?

   The producer could examine the organic matter content, pH, and runoff values to determine whether the land likely has high soil quality and low runoff potential. This could save her or him some initial investment funds if the land was in need of little or no fertilizing or groundwork, for example.

Criollo vs. Angus Cattle *in a Changing Climate*



GET OUT AND GRAZE (GO AG!)

DESCRIPTION

Students learn about heritage livestock as they play the roles of Angus and Raramuri Criollo cattle grazing on a rangeland under abundant and then limited forage conditions caused by climate change.

PHENOMENON

How does reduced forage availability due to climate change affect two different cattle types?

GRADE LEVEL
6 – 12

OBJECTIVES

Students will:
- Compare and contrast a traditional, British cattle type with a heritage breed from Mexico
- Model the grazing behavior of cows under abundant and then limited resources
- Analyze resource acquisition under different availability scenarios
- Discuss the advantages and disadvantages of heritage livestock types under climate change conditions

TIME
60 MINUTES

COMMON CORE STATE STANDARDS

English Language Arts Standards » Science & Technical Subjects » Grade 6-8
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.

CCSS.ELA-LITERACY.RST.6-8.7. Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

English Language Arts Standards » Science & Technical Subjects » Grade 9-10
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.

CCSS.ELA-LITERACY.RST.9-10.7. Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

English Language Arts Standards » Science & Technical Subjects » Grade 11-12
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
CSS.MATH.CONTENT.6.SP.A.2
Understand that a set of data collected to answer a statistical question has a distribution which can be described by its center, spread, and overall shape. [Extension Activity]

Grade 7 » Statistics & Probability
CCSS.MATH.CONTENT.7.SP.B.3
Informally assess the degree of visual overlap of two numerical data distributions with similar variabilities, measuring the difference between the centers by expressing it as a multiple of a measure of variability. [Extension Activity]

Grades 9-12 » Statistics & Probability
CCSS.MATH.CONTENT.HSS.ID.A.1
Represent data with plots on the real number line (dot plots, histograms, and box plots). [Extension Activity]

CCSS.MATH.CONTENT.HSS.ID.A.3
Interpret differences in shape, center, and spread in the context of the data sets, accounting for possible effects of extreme data points (outliers). [Extension Activity]

NEXT GENERATION SCIENCE STANDARDS

Middle School Performance Expectation

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.

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
Developing and Using Models (MS, HS) Analyzing and Interpreting Data (MS) Constructing Explanations and Designing Solutions (MS, HS)	ESS3.A Natural Resources (HS) ESS3.C Human Impacts on Earth Systems (MS, HS) LS2.A Interdependent Relationships in Ecosystems (MS, HS)	Cause and Effect (MS, HS) Systems and System Models (MS, HS)

AGRICULTURE, FOOD, AND NATURAL RESOURCES STANDARDS

AS.01.01. Evaluate the development and implications of animal origin, domestication and distribution on production practices and the environment.
    AS.01.01.01.c. Evaluate the implications of animal adaptations on production practices and the environment.
AS.01.03. Analyze and apply laws and sustainable practices to animal agriculture from a global perspective.
    AS.01.03.02.a. Research and summarize sustainability in animal systems.
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.).

BACKGROUND

The bloodline of Raramuri Criollo (pronounced krē-ō-yō) cattle originated in Spain. In 1493, Columbus brought a small group to the New World from the Andalusia region of southern Spain. In 1627, Jesuit missionaries introduced Criollo cattle to the Sierra Tarahumara Indians in the Copper Canyon area of Mexico, and the Tarahumara have maintained the cattle with minimal husbandry or cross-breeding with other cattle breeds into the present time. Raramuri Criollo have undergone generations of natural selection in arid, rugged landscapes in Mexico. As a result, they are well adapted to dry conditions.

Raramuri Criollo cattle have a different body type than breeds typically used by ranchers in the Southwest, such as Angus. Criollo are smaller, and they have a more slender hind end and larger shoulders. On average, mother cows are about 800-900 pounds. Their body type allows them to move over steep and rocky terrain.

Angus cattle, which originated from a British bloodline, tend to be much larger and stockier than Criollo. Angus mother cows tend to grow as large as 1,100 pounds. They prefer to move over flat terrain. They usually concentrate their grazing on nutritious patches of grasses that are closer to water.

Research has demonstrated that Raramuri Criollo will cover significantly greater distances than conventional Angus to find forage in the extensive pastures of the Chihuahuan Desert. Raramuri Criollo cattle were found to travel twice the distance from water compared to the conventional breed during the same time period. As a result, Raramuri Criollo tend to need less supplemental feed than Angus. Supplemental feed, such as hay and cottonseed cakes, can be costly for ranchers. In addition to needing less supplemental feed, Raramuri Criollo may have less impact on the ecosystem. Researchers have suggested that Raramuri Criollo spread their impact over the landscape to a greater degree, and their use could help reduce some of the problems associated with localized overgrazing in arid landscapes.

MATERIALS

- *Compare and Contrast* handout [1 per student]
- *Get Out and Graze* handout [1 per student]
- *Histogram Extension Activity* handout, printed single sided (optional) [1 per student]
- Labels for far and close "grazing site" bags (Figure 1)
- Location map for each grazing site station
- PowerPoint presentation
- Computer and projector
- 10 small paper bags, preferably 5 of each of 2 different colors if possible (Figure 1)
- Glue stick or scotch tape
- Packing tape
- 150 pennies, separated into two bags of 50 each and two bags of 25 each
- 5 green markers
- 5 blue markers
- 5 opaque bowls, cups, or plastic bags to serve as cow "rumens" during the game
- Optional: document camera
- *Get Out and Graze* instructional video, optional introduction to the game for the educator and students

Figure 1. Small paper bags with grazing site labels attached

PREPARATION

1. If possible, watch the *Get Out and Graze* instructional video for an introduction to the game. At 1:55, the video can be shown to students to provide an introduction on how to play the game.
2. Prepare the 5 close grazing sites and 5 far grazing sites by printing the labels, cutting out, and attaching one to each of the 10 small paper bags (Figure 1). Attach labels with a glue stick or scotch tape. If you have two different color bags, attach all of the "Close" labels to one color and all of the "Far" labels to the other color. Place a strip of packing tape inside the bottom of each paper bag to secure and cover up the bottom flap. The bag will be holding pennies, and when bags are not taped, the pennies tend to get trapped under the bottom flap during the game.
3. Locate a suitable space in the classroom or outside area, and then place the five close grazing sites and 5 far grazing site bags. Grazing site bags can be on tables or desks as long as there is adequate space for students to move freely between all 10 sites. Place the empty bags at the locations, open them, stand them up, and fold the top over so that the bags are closed. Figure 2 is a sample map for grazing site location placement (F= far grazing site bag and C=close grazing site bag).

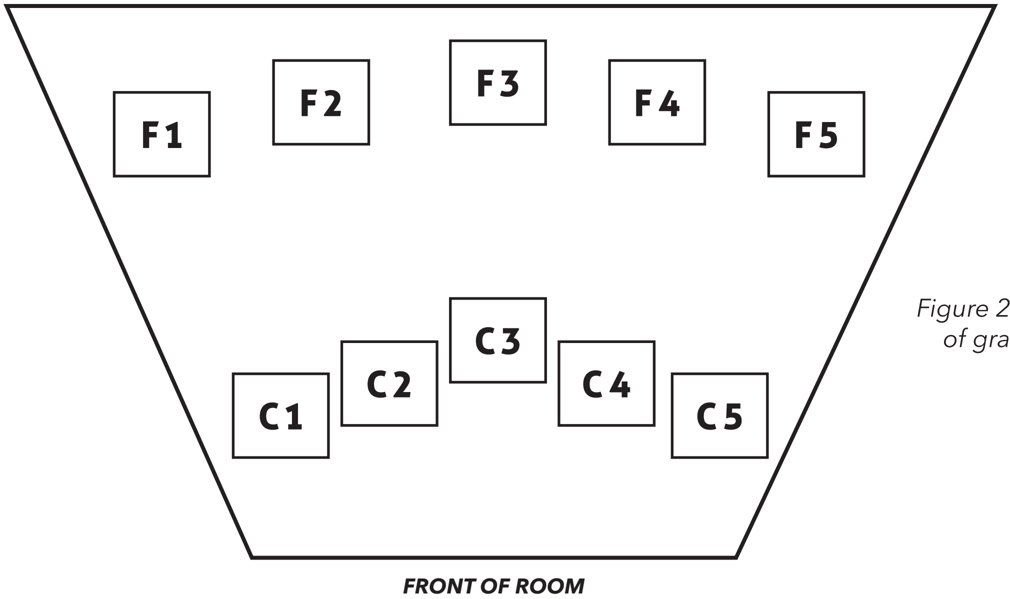


Figure 2. Sample map for placement of grazing sites, C=Close, F=Far

4. Print out the location map, and cut along the lines to separate the map into 10 sections. Place one section of the grazing site location map next to each grazing site. Lay them out so that they follow the numbering of the sample map (Figure 2).
5. Draw the location map on the board or prepare to show it with a document camera.
6. Draw the Angus and Criollo tables from page 1 of the *Get Out and Graze* handout on the board or prepare to show them with a document camera.
7. Set up a computer and projector and display the PowerPoint presentation.

PROCEDURES

INTRODUCTORY COMPARE AND CONTRAST ACTIVITY

1. Pass out a *Compare and Contrast* handout to each student.
2. Use the PowerPoint presentation to introduce Criollo and Angus cattle.
    a. **Slide 2**: we will be playing a game related to cattle foraging patterns on the range. The two cattle breeds pictured will be involved in our game; they are called Criollo (pronounced krē-ō-yō) and Angus.
        i. Examine these two photos and answer questions 1-3 on the *Compare and Contrast* handout. [Ask students to share their answers, and lead a discussion of the similarities and differences of the two breeds. Similarities may include: they are the same species (or both cattle) and they have all of the same main body parts. Differences may include: Criollo is much smaller/weighs much less, Criollo is skinnier/Angus is bulkier, Angus does not have horns, Criollo originated in Spain/Angus originated in Europe.]

GRAZING GAME EXPLAINING THE PROCEDURES AND MAKING PREDICTIONS

1. Pass out a *Get Out and Graze* handout to each student.
2. Explain the game using the PowerPoint presentation.
    a. **Slide 3**: we will play a game in which you will play the roles of two different types of cattle. We will start by assigning roles, and then we will talk about how to play the game [assign students to roles].
        i. Five students – Angus for scenario 1
        ii. Five students – Criollo for scenario 1
        iii. Up to four students - Food distributors
        iv. One or two students – Location mappers
        v. One or two students – Data collectors
    b. **Slide 4**: in this first part of the game, **five** students will play the role of **Angus cows** grazing on a rangeland.
        i. There are 10 grazing sites total: five grazing sites close to the water station, near the front of the room, and five grazing sites far from the water station.
        ii. The food resources in the game are represented by pennies. The five close grazing sites have a total of 50 food resources (pennies) divided randomly between feeding sites. The five far grazing sites also have 50 food resources divided randomly between feeding sites.
    c. **Slide 5**: Angus are **reliant on nearby water**, so for the purposes of our game, they are **unable to travel to the far grazing sites** to collect food. They can only travel to the close grazing sites in our game because research shows that they prefer to stay close to water. The first trial of the game will focus on Angus. The second trial will involve Criollo, which are less reliant on water and can graze at both close and far grazing sites.
    d. **Slide 6**: there will be six rounds in the Angus trial. It is not a race; each cow will have time to graze at the grazing site s/he visits.
        i. In each round, cows move to a grazing site and collect the appropriate number of food resources for that location.
        ii. Cows at CLOSE grazing sites can get a maximum of THREE food resources per round.
        iii. There is a cost of both time and energy for a cow to move to far grazing sites, so cows at FAR grazing sites can get a maximum of TWO food resources per round.
        iv. More than one cow is allowed to visit a grazing site during a round. If there are two or more cows at a site, they must take turns getting food resources, up to the maximum allowed at that site (three or two).
        v. We will note the number of Angus cows that do not collect at least 10 food resources at the end of the trial. Cows that do not collect at least 10 food resources will have to be supplemented with additional hay and cottonseed cakes, which results in increased expenses for the rancher.
    e. **Slide 7**: if there are no more food resources at a grazing site, the cow must wait patiently until it is time to switch to a new grazing site.
        i. After the cow has collected food resources, s/he will **mark a dot on the paper**

near the grazing site showing they were there. Angus cows will use blue markers, and Criollo will use green markers.

   ii. Cows must move to a different grazing site each round, but they may return to a grazing site once they have left it for at least one round.
   iii. We will conduct a total of six rounds.
   iv. At the end of all six rounds, each cow will count the number of resources s/he was able to collect. We will examine how the herd did as well as how each cow did throughout the grazing cycle.

f. **Slide 8**: in the second part of the game, **five** students will play the role of **Criollo** cows grazing on a rangeland.
   i. **Criollo** are able to **travel further from water**, so they can go to **either the close grazing sites or the far grazing sites**.
   ii. Remember, there is a cost of both time and energy for a cow to move to far grazing sites, so cows at FAR grazing sites can get a maximum of TWO food resources per round.
   iii. The five close grazing sites have a total of 50 food resources (pennies) divided randomly between feeding sites. The five far grazing sites have a total of 50 food resources divided randomly between feeding sites.
   iv. We will note the number of Criollo cows that do not collect at least 7 food resources at the end of the trial. Criollo cattle are smaller than Angus and need fewer food resources to fuel their lighter bodies. Cows that do not collect at least 7 food resources will have to be supplemented with additional hay and cottonseed cakes, which results in increased expenses for the rancher.
   v. The rest of the rules from the Angus trial also apply to the Criollo trial.

g. **Slide 9**: fill out the predictions box at the top of page 1 of the *Get Out and Graze* handout. Predict which cattle breed will need more supplemental feed because they will not collect enough food resources during the game, and then predict which breed will consume a greater percentage of the total resources available.

Grazing Game – Scenario 1 (abundant food)

1. While the rest of the class is **not** looking, have the food distributor(s) divide:
   a. 50 food resources (pennies) randomly in the close grazing site bags
   b. 50 food resources (pennies) randomly in the far grazing site bags

   Tell food distributors that there is no need to place exactly 10 pennies in each of the five bags. However, make sure there is a total of 50 pennies in close grazing sites and 50 pennies in far grazing sites. Once distributors have placed the pennies in the bags, they should fold the tops of the bags back down.
2. Pass out a "rumen" and a blue marker to each student playing the role of an Angus cow.
3. Get students started on trial 1 for Angus cows:
   a. **Slide 10**: using the rules and procedures explained before, the five **Angus cows** will now play the game. Remember that Angus cows **are reliant on nearby water**, so for the purposes of our game, they are unable to travel to the far grazing sites to collect food. In our game, they **can only travel to the close grazing sites** because research shows that they prefer to stay close to water.
      i. Prompt students who are playing Angus cows to choose a starting grazing site. Instruct them to graze, and remind them that they are to take three food resources at the close sites. If there is more than one cow at the grazing site, students will take turns getting resources up to a maximum of three per cow.
         1. Students will open the bag, and without looking in, collect three food resources. Then instruct students to close the bags by folding the tops back over.
         2. Students are to put the food resources into their rumens and wait patiently until it is time to switch.
         3. Tell students to be secretive about how many resources are available at each grazing site. If there are no resources left at a site, they should open the bag and act like they are taking resources and depositing them in their "rumens." They should not hint to other cows about the number of resources available at their site.
      ii. Instruct students to use the **blue** marker to make a dot on the paper at their grazing site to show that they were there.
      iii. Once all five Angus players have had the chance to graze at the first site, instruct students to switch. They must move to a different close grazing site.
         1. Remind students that cows can share a site; they will just take turns getting resources from the bag.
         2. Remind them that they must change locations, but they may return to a grazing site once they have left it for at least one round.

        iv. Repeat until Angus players have played six rounds.
4. Once the Angus players have been through all six rounds, have them count how many food resources they have collected.
5. Ask the data collector(s) to enter each cow's data on in the data table on the board (or use the document camera). Instruct each Angus player to call out their number of food resources one at a time. All students should fill in the Angus portion of the data table on page 1 of the handout.
    a. **Slide 11**: as the data collector(s) fill in the table on the board, you will fill in the Angus portion of the Abundant Resources data table on page 1 of the handout.
6. While students are filling in their table, have the food distributor(s) collect any remaining food resources from the close grazing sites.
7. Next, while the rest of the class is **not** looking, have the food distributor(s) randomly divide 50 food resources in the close grazing sites. There should still be 50 food resources randomly distributed in the far grazing sites. Tell food distributors to place the pennies in the bags and fold the tops of the bags back down.
8. Pass out a "rumen" and a green marker to each student playing the role of a Criollo cow.
9. Get students started on trial 2 for Criollo cows:
    a. **Slide 12**: using the rules and procedures explained before, the five **Criollo cows** will now play the game. Remember that Criollo are more likely to travel **further from water**, so they can go to either the **close grazing sites or the far grazing sites**. They may collect TWO food resources from far grazing sites and THREE food resources from close grazing sites.
        i. Prompt students who are playing Criollo cows to choose a starting grazing site. Instruct them to graze, and remind them that they are to take two food resources from far sites and three food resources at the close sites.
            1. Students will open the bag, and without looking in, collect two or three food resources, depending on the site. Then instruct students to close the bags by folding the tops back over.
            2. Students are to put the food resources into their rumens and wait patiently until it is time to switch.
            3. Tell students to be secretive about how many resources are available at each grazing site. If there are no resources left at a site, they should open the bag and act like they are taking resources and depositing them in their "rumens." They should not hint to other cows about the number of resources available at their site.
        ii. Instruct students to use the **green** marker to make a dot on the paper at their grazing site to show that they were there.
        iii. Once all five Criollo players have had the chance to graze at the first site, instruct students to switch. They must move to a different site, either close or far.
            1. Remind students that cows can share a site; they will just take turns getting resources from the bag.
            2. Remind them that they must change locations, but they may return to a grazing site once they have left it for at least one round.
        iv. Repeat until Criollo players have played six rounds.
10. Once the Criollo players have been through all six rounds, have them count how many food resources they have collected.
11. Ask the data collector(s) to enter each cow's data on in the data table on the board (or use the document camera). Instruct each Criollo player to call out their number of food resources one at a time. All students should fill in the Criollo portion of the data table on page 1 of the handout.
    a. **Slide 13**: as the data collector(s) fill in the table on the board, you will fill in the Criollo portion of the Abundant Resources data table on page 1 of the handout.
12. Have students calculate the total resources consumed, the percent of resources consumed, the mean resources per cow, and the number of cows that needed supplemental feed, and enter them at the bottom of the Abundant Resources data tables on page 1 of the handout.
13. Ask students to examine these data to help them make predictions about what might happen in Scenario 2 when there is a food shortage.

Grazing Game – Scenario 2 (food shortage due to higher temperatures and variable precipitation)

1. Use the PowerPoint presentation to explain that we will play the game again but under the condition of limited resources.
    a. **Slide 14**: in Scenario 2, average global surface temperatures continue to increase. Because Earth is warming, climate change is expected to increase the length and severity of drought in many rangelands in the semiarid western United States. Drought and increased evaporation will result in reduced water for plants. Therefore, our cows in Scenario 2 will encounter fewer and smaller grasses.
    b. **Slide 15**: fill out the predictions

box at the top of page 2 of the *Get Out and Graze* handout. Under limited resources conditions (half as many resources as Scenario 1), predict which cattle breed will need more supplemental feed because they will not collect enough food resources during the game, and then predict which breed will consume a greater percentage of the resources available.

   c. **Slide 16**: we will assign new students to the roles of the two types of cattle so that as many people as possible get to participate [assign students to roles].
      i. Five students – Angus for scenario 2
      ii. Five students – Criollo for scenario 2
   d. **Slide 17**: the Angus trial and the Criollo trial are played using the same rules as in Scenario 1 except that in these trials **there are only 25 food resources** scattered among the close grazing sites and **25 food resources** scattered among the **far** grazing sites.
      i. Angus may still travel only to the close grazing sites while Criollo may travel to either the close or the far grazing sites.
      ii. A cow may only collect THREE food resources at the close grazing sites and TWO at the far grazing sites.
2. If you are using a drawn table on the board, erase the data from scenario 1 and change the number of resources available to 25 and 50 in the bottom of the table, as shown on page 2 of the handout. If you are using a document camera, prepare to show the Limited Resources data tables on page 2 of the handout.
3. Repeat steps 1-11 from Scenario 1, this time with just 25 food resources instead of 50.
   a. **Slide 18**: as the data collector(s) fill in the table on the board, you will fill in the Angus portion of the Limited Resources data table on page 2 of the handout.
   b. **Slide 19**: using the rules and procedures explained before, the five **Criollo cows** will now play the game. Remember that Criollo will travel **further from water**, so they can go to either the **close grazing sites** or far grazing sites. They may collect TWO food resources from far grazing sites and THREE food resources from close grazing sites.
   c. **Slide 20**: as the data collector(s) fill in the table on the board, you will fill in the Criollo portion of the Limited Resources data table on page 2 of the handout.
4. Have students calculate the total resources consumed, the percent of resources consumed, the mean resources per cow, and the number of cows that needed supplemental feed, and enter them at the bottom of the Limited Resources data tables on page 2 of the handout.

Mapping

1. Have the location mapper(s) collect all 10 of the location map strips and put them into the correct order.
   a. **Slide 21**: the location mapper(s) will collect all 10 of the location map strips and put them in the correct order as shown here.
2. If you have a document camera, project the map so all students can examine it.
3. If you do not have a document camera or other way to project the results, have the location mapper(s) replicate the map on the board. The exact location of each dot is not important, but the relative number of blue and green dots in close vs. far grazing sites should be replicated as closely as possible given the amount of time left.
4. After students have examined the results from the game, show the figure from the paper by Peinetti et al. (2011).
   a. **Slide 22**: this figure is from a research paper. The researchers conducted a study on the movement of Angus and Criollo cows in relation to a water source, and the movement of cows is shown on these maps. Angus cows are represented by blue, and Criollo cows are represented by green. The dot at the bottom of the map shows the location of the water source. Did Angus cows tend to get as far away from the water source as Criollo? [Answer: no, because there are green marks that are further away from the water source in the map on the right. Remember, Criollo are well adapted for dry landscapes and are able to move further away from water to take advantage of food resources in more remote locations.]
5. Ask students: how closely does the movement pattern of cows in our game match the movement pattern of Angus and Criollo in this study?

Results and Conclusions

1. Optional: if time permits, conduct the *Histogram Extension Activity* with students at this time. It will take approximately 15 minutes. See the Extensions section below for instructions.
2. Ask students to use the data tables to answer the results and conclusions questions on pages 2 and 3 of the handout. Choose one of the methods below to answer and discuss the questions as time permits.
   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. **Histogram Extension Activity**:
   a. Pass out a *Histogram Extension Activity* handout to each student. It is preferable to print this handout single sided so that students can look at the pages side-by-side when creating their histograms.
   b. For questions 1 and 2 on page 1 of the handout, explain that students will look back at their data tables on pages 1 and 2 of the *Get Out and Graze* handout and summarize their results. In order to prepare to make histograms for all four trials, students will fill in these tables by grouping the number of cows by the number of resources that they consumed. Students will look at the number of resources consumed by each cattle breed under each scenario, and write the number of resources consumed **only once**. In other words, if two cows ate nine resources, for example, students will not record the number "9" twice; instead they will record the number "9" once in the number of resources column, and then record "2" for the number of cows. Please see tables 1 and 2 below for a complete example.

Table 1. Sample of student data from page 1 of the Get Out and Graze *handout.*

ANGUS	
COW	**NUMBER OF RESOURCES**
1	9
2	8
3	12
4	11
5	9
TOTAL	49

Table 2. Example of how to fill out the first table on page 1 of the Histogram Extension Activity handout given the sample data in table 1 above.

ANGUS	
NUMBER OF RESOURCES	**NUMBER OF COWS**
8	1
9	2
10	0
11	1
12	1

c. On page 2, instruct students to use the data tables on page 1 to create histograms for all four of the trials (Scenario 1, Angus and Criollo trials and Scenario 2, Angus and Criollo trials). In this case, histograms will show the number of cows by the number of resources consumed.

i. Instruct students to answer the conclusions questions at the bottom of page 2. Answers will vary based on student data.

OTHER EXTENSIONS

2. Ask students to brainstorm about conditions that may lead to scarcer or more abundant resources, and have them adjust the numbers of food resources accordingly. Play the game again.
3. Ask students to predict what would happen if the game was played with more cows of each breed during each scenario. Play the game again with 7-10 cows instead of 5 in both trials of each scenario.

ADDITIONAL RESOURCES

Articles with background information about Raramuri Criollo cattle:

Anderson, DM, Estell, RE, Gonzalez, AL, Cibilis, AF, and Torell, LA. 2015. Criollo cattle: Heritage genetics for arid landscapes. Rangelands 37(2): 62-67. Accessed online 9 Mar 2017. <http://www.sciencedirect.com/science/article/pii/S0190052815000152>.

Peinetti, HR, Fredrickson, EL, Peters, DPC, Cibilis, AF, Roacho-Estrada, JO, and Laliberte, AS. 2011. Foraging behavior of heritage versus recently introduced herbivores on desert landscapes of the American Southwest. Ecosphere 2(5): 1-14.

Spiegal, S., Estell, R., Cibils, A. F., James, D. K., Peinetti, R., Browning, D. M., Romig, K., and Gonzales, A. In review. Seasonal divergence in foraging behavior of heritage and conventional cattle on a heterogeneous desert landscape. Rangeland Ecology & Management.

Website with helpful information about Raramuri Criollo cattle:

The Jornada Rangelands Research Programs. Criollo Cattle on The Jornada. Web. Accessed 9 Mar 2017. <https://jornada.nmsu.edu/ltar/criollo-cattle>.

Name ____________________ Date ____________

COMPARE AND CONTRAST

TWO TYPES OF CATTLE

CRIOLLO

(pronounced krē-ō-yō)

Bos taurus · *800 pounds* · *Bloodlines from Spain*

ANGUS

Bos taurus · *1,100 pounds* · *Bloodlines from Europe*

1. What two similarities do you notice between Criollo and Angus?

2. What two differences do you notice between Criollo and Angus (**besides color**)?

3. Make a prediction about how **differences** might affect foraging behavior of the two cattle types on a western rangeland.

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COMPARE AND CONTRAST

TWO TYPES OF CATTLE

CRIOLLO

(pronounced krē-ō-yō)

Bos taurus · 800 pounds · Bloodlines from Spain

ANGUS

Bos taurus · 1,100 pounds · Bloodlines from Europe

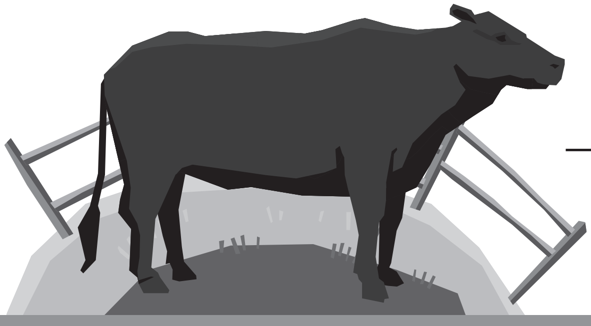
1. What two similarities do you notice between Criollo and Angus?
   May include:
   They are the same species (or both cattle), they have all of the same main body parts

2. What two differences do you notice between Criollo and Angus (**besides color**)?
   May include:
   Criollo is much smaller/weighs much less, Criollo is skinnier/Angus is bulkier, Angus does not have horns, Criollo originated in Spain/Angus originated in Europe

3. Make a prediction about how **differences** might affect foraging behavior of the two cattle types on a western rangeland.
   Example:
   Because Criollo is smaller and may be better adapted to dry climates due to its bloodline, it may be better suited to foraging on a western rangeland where water may be scarce.

Name ____ Date ________________

Criollo vs. Angus Cattle in a Changing Climate



GET OUT AND GRAZE (GO AG!)

Scenario 1 – Abundant Resources: Predictions

1. I predict that ____________________ cattle will need more supplemental feed because they will not collect enough food resources during the game.
   Angus / Criollo

2. I predict that ____________________ cattle will consume a greater percentage of the resources available.
   Angus / Criollo

Abundant Resources: Data

ANGUS	
COW	**NUMBER OF RESOURCES**
1	
2	
3	
4	
5	
TOTAL	

Total Number of Resources Available: 50

Percent of Total Resources Consumed:

(_________ ÷ 50) x 100 = __________%
Total

Mean Resources Per Cow:
(Total Resources Consumed divided by Number of Cows)

Number of Cows that Needed Supplemental Feed
(10 Resources or Less):

CRIOLLO	
COW	**NUMBER OF RESOURCES**
1	
2	
3	
4	
5	
TOTAL	

Total Number of Resources Available: 100

Percent of Total Resources Consumed:

(_________ ÷ 100) x 100 = __________%
Total

Mean Resources Per Cow:
(Total Resources Consumed divided by Number of Cows)

Number of Cows that Needed Supplemental Feed
(7 Resources or Less):

Scenario 2 – Limited Resources: Predictions

1. I predict that ____________________ cattle will need more supplemental feed because they will not collect enough food resources during the game.
   Angus / Criollo

2. I predict that ____________________ cattle will consume a greater percentage of the resources available.
   Angus / Criollo

Limited Resources: Data

ANGUS	
COW	**NUMBER OF RESOURCES**
1	
2	
3	
4	
5	
TOTAL	

Total Number of Resources Available: 25

Percent of Total Resources Consumed:

(_________ ÷ 25) x 100 = __________%
Total

Mean Resources Per Cow:
(Total Resources Consumed divided by Number of Cows)

Number of Cows that Needed Supplemental Feed
(10 Resources or Less):

CRIOLLO	
COW	**NUMBER OF RESOURCES**
1	
2	
3	
4	
5	
TOTAL	

Total Number of Resources Available: 50

Percent of Total Resources Consumed:

(_________ ÷ 50) x 100 = __________%
Total

Mean Resources Per Cow:
(Total Resources Consumed divided by Number of Cows)

Number of Cows that Needed Supplemental Feed
(7 Resources or Less):

RESULTS AND CONCLUSIONS

1. Use the data tables on pages 1 and 2 to complete the following.

   a. The ____________________ cattle needed more supplemental feed because they did not collect enough food resources during the game.
   Angus / Criollo

   b. The ____________________ cattle consumed a higher percentage of the resources available.
   Angus / Criollo

2. It is predicted in some places that climate change will cause increased temperatures and prolonged drought. This will reduce the availability of plants that cattle eat. Which type of cattle could better forage in these conditions? Why?

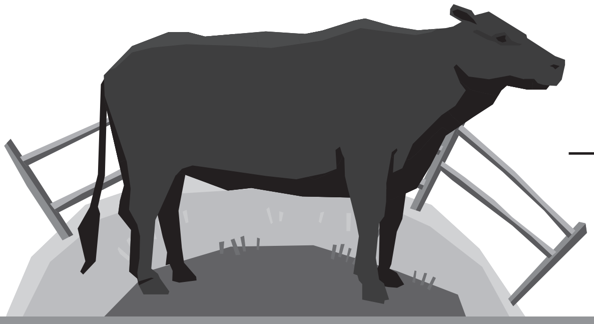
3. Increased temperatures and prolonged drought create a problem for cattle ranchers that rely on Angus cattle because they require more water and forage in a smaller area. Many ranchers are considering a transition to Criollo cattle.

   Identify two characteristics of Criollo that could make them a more sustainable alternative for cattle ranchers.

   -
   -

4. How would a transition to Criollo affect other parts of an ecosystem?

ANSWER KEY



Criollo vs. Angus Cattle in a Changing Climate

GET OUT AND GRAZE (GO AG!)

Scenario 1 – Abundant Resources: Predictions

1. I predict that ____________________ cattle will need more s ntal feed because they will
   Angus / Criollo
   not collect enough food resources during th

student answers will vary

2. I predict that ________________ attle will consume a greater percentage of the resources available.
   Angus / Criollo

Abundant Resources: Data

ANGUS	
COW	**NUMBER OF RESOURCES**
1	
2	
3	student answers will vary
4	
5	
TOTAL	

Total Number of Resources Available: 50

Percent of Total Resources Consumed:

(_________ ÷ 50) x 100 = __________%
Total

Mean Resources Per Cow:
(Total Resources Consumed divided by Number of Cows)

Number of Cows that Needed Supplemental Feed
(10 Resources or Less):

CRIOLLO	
COW	**NUMBER OF RESOURCES**
1	
2	
3	student answers will vary
4	
5	
TOTAL	

Total Number of Resources Available: 100

Percent of Total Resources Consumed:

(_________ ÷ 100) x 100 = __________%
Total

Mean Resources Per Cow:
(Total Resources Consumed divided by Number of Cows)

Number of Cows that Needed Supplemental Feed
(7 Resources or Less):

Scenario 2 – Limited Resources: Predictions

1. I predict that ____________________ cattle will need more su[illegible]ntal feed because they will
   Angus / Criollo
   not collect enough food resources during the g[illegible]

2. I predict that ____________________ [illegible] will consume a greater percentage of the resources available.
   Angus / Criollo

student answers will vary

Limited Resources: Data

ANGUS	
COW	**NUMBER OF RESOURCES**
1	
2	
3	
4	
5	
TOTAL	

student answers will vary

Total Number of Resources Available: 25

Percent of Total Resources Consumed:

(_________ ÷ 25) x 100 = __________%
Total

Mean Resources Per Cow:
(Total Resources Consumed divided by Number of Cows)

Number of Cows that Needed Supplemental Feed
(10 Resources or Less):

CRIOLLO	
COW	**NUMBER OF RESOURCES**
1	
2	
3	
4	
5	
TOTAL	

student answers will vary

Total Number of Resources Available: 50

Percent of Total Resources Consumed:

(_________ ÷ 50) x 100 = __________%
Total

Mean Resources Per Cow:
(Total Resources Consumed divided by Number of Cows)

Number of Cows that Needed Supplemental Feed
(7 Resources or Less):

RESULTS AND CONCLUSIONS

1. Use the data tables on pages 1 and 2 to complete the following.

   a. The ___Angus___ cattle needed more supplemental feed because they did not collect enough food resources during the game.
   Angus / Criollo

   b. The ___Angus___ cattle consumed a higher percentage of the resources available.
   Angus / Criollo

This will usually be the case.

2. It is predicted in some places that climate change will cause increased temperatures and prolonged drought. This will reduce the availability of plants that cattle eat. Which type of cattle could better forage in these conditions? Why?

   Criollo may be better suited to forage in drought conditions because they are more likely to roam further away from a water source and search for food resources.

3. Increased temperatures and prolonged drought create a problem for cattle ranchers that rely on Angus cattle because they require more water and forage in a smaller area. Many ranchers are considering a transition to Criollo cattle.

   Identify two characteristics of Criollo that could make them a more sustainable alternative for cattle ranchers.

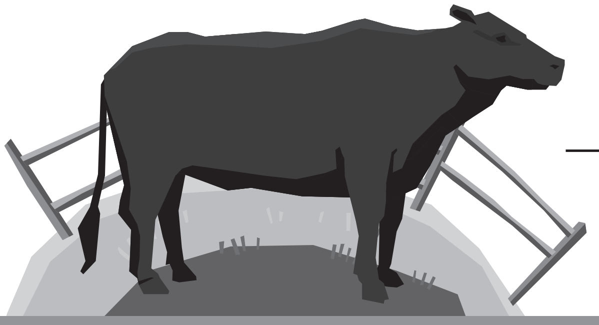
   - *Smaller, better adapted to move over difficult terrain*

   - *Able to move further from water source to forage*

4. How would a transition to Criollo affect other parts of an ecosystem?

   Criollo can spread their impact more widely over a grassland. They would be less likely to overgraze an area because their grazing would not be as concentrated. Therefore, plants would be more likely to survive and reproduce, and the effect of more abundant producers would likely be more abundant consumers.

Name ____ Date ____________________



Criollo vs. Angus Cattle in a Changing Climate

GET OUT AND GRAZE (GO AG!)

HISTOGRAM EXTENSION ACTIVITY

1. Refer to page 1 of the *Get Out and Graze* handout. When resources were **abundant**, how many cows of each breed consumed each number of food resources? In other words, group the number of cows by the number of food resources they consumed. For example, if two cows consumed four food resources each, in the number of resources column, write “4” and in the number of cows column, write “2.”

Abundant Resources

ANGUS	
NUMBER OF RESOURCES	NUMBER OF COWS

CRIOLLO	
NUMBER OF RESOURCES	NUMBER OF COWS

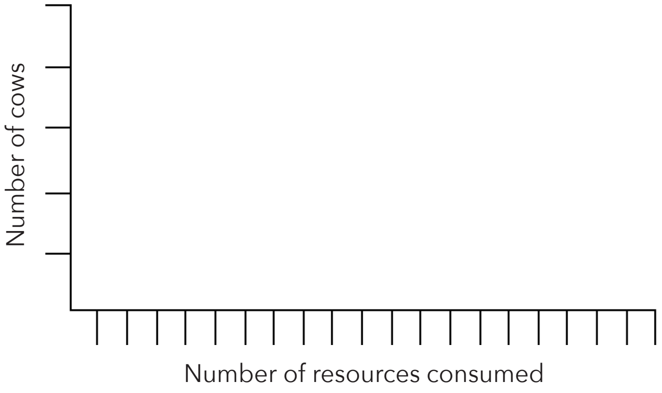
2. Refer to page 2 of the *Get Out and Graze* handout. When resources were **limited**, how many cows of each breed consumed each number of food resources?

Limited Resources

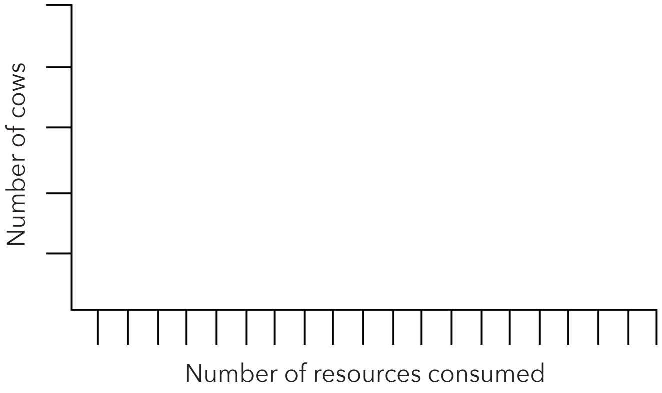
ANGUS	
NUMBER OF RESOURCES	NUMBER OF COWS

CRIOLLO	
NUMBER OF RESOURCES	NUMBER OF COWS

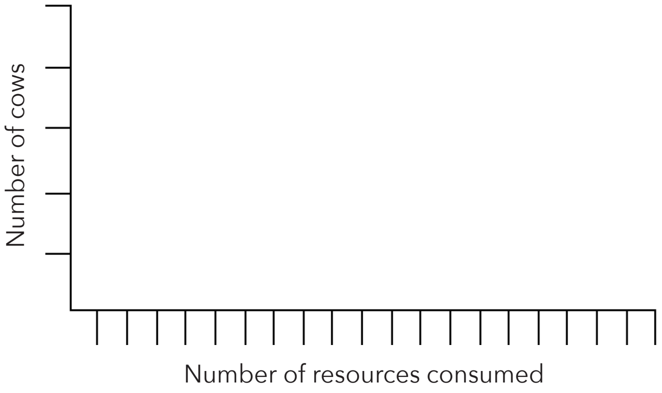
3. Use the data from questions 1 and 2 to create histograms, graphs of the number of cows by number of resources consumed.



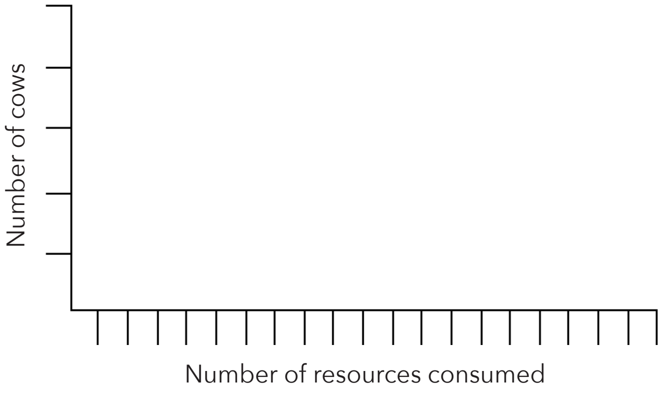
ANGUS
Abundant Resources



CRIOLLO
Abundant Resources



ANGUS
Limited Resources



CRIOLLO
Limited Resources

CONCLUSIONS

1. Describe similarities and differences in the way the data are distributed in the abundant resources and limited resources scenarios for **Angus cattle**. In other words compare and contrast how many **Angus** cows collected each number of resources in both scenarios.

2. Based on your answer to #1 above, in which scenario are Angus cattle less likely to need supplemental feed?

A. ABUNDANT RESOURCES **B. LIMITED RESOURCES**

Close

Grazing Site

(Get 3 Food Packs)

Far

Grazing Site

(Get 2 Food Packs)

Close

Grazing Site

(Get 3 Food Packs)

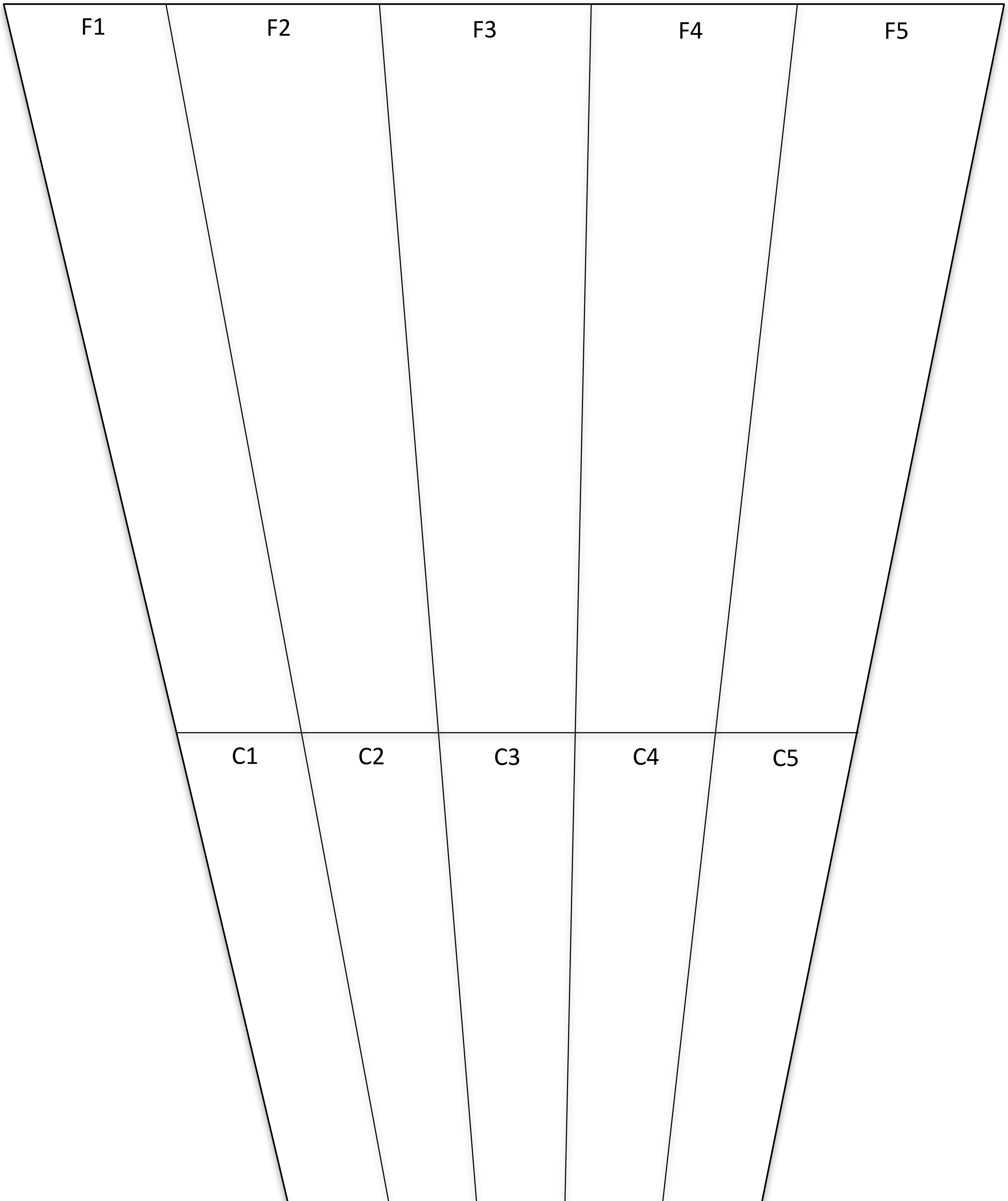
Far

Grazing Site

(Get 2 Food Packs)

Note: make copies of this page. You will need five "Close" labels and five "Far" labels.

Location Map



THE EFFECTS OF CLIMATE CHANGE ON AGRICULTURAL SYSTEMS

COMMON CORE STATE STANDARDS ACTIVITY CHARTS

These charts identify the Effects of Climate Change on Agricultural Systems activities that apply to each of the listed Common Core State Standards and are organized by Middle School and High School. Some standards are fully met by the activities, and some standards are addressed by the activities but require further teaching.

MIDDLE SCHOOL LITERACY

	Farms on the Table	Interacting Adaptations	Wilt it be Productive?	Washed Away	Get Out and Graze
CCSS.ELA-LITERACY.W.6-8.7		●			
CCSS.ELA-LITERACY.SL.6-8.1		●			
CCSS.ELA-LITERACY.R1.6.7		●			
CCSS.ELA-LITERACY.WHST.6-8.2.D			●		
CCSS.ELA-LITERACY.RST.6-8.3	●		●	●	
CCSS.ELA-LITERACY.RST.6-8.4	●		●	●	●
CCSS.ELA-LITERACY.RST.6-8.7					●
MIDDLE SCHOOL MATH					
CCSS.MATH.CONTENT.6.SP.B.5.A				●	
CCSS.MATH.CONTENT.6.SP.A.2					● **[EA]**
CCSS.MATH.CONTENT.7.RP.A.3			●		
CCSS.MATH.CONTENT.7.SP.B.3					● **[EA]**
HIGH SCHOOL LITERACY					
CCSS.ELA-LITERACY.W.9-10.7		●			
CCSS.ELA-LITERACY.SL.9-10.1		●			
CCSS.ELA-LITERACY.WHST.9-10.2.D			●		
CCSS.ELA-LITERACY.W.11-12.7		●			
CCSS.ELA-LITERACY.WHST.11-12.2.D			●		
CCSS.ELA-LITERACY.SL.11-12.1		●			
CCSS.ELA-LITERACY.RAT.11-12.7		●			
CCSS.ELA-LITERACY.RST.9-10.3	●		●	●	
CCSS.ELA-LITERACY.RST.9-10.4	●		●	●	●
CCSS.ELA-LITERACY.RST.9-10.7					●
CCSS.ELA-LITERACY.RST.11-12.3	●		●	●	
CCSS.ELA-LITERACY.RST.11-12.4	●		●	●	●
CCSS.ELA-LITERACY.RST.11-12.9	●				
HIGH SCHOOL MATH					
CCSS.MATH.CONTENT.HSS.ID.A.1					● **[EA]**
CCSS.MATH.CONTENT.HSS.ID.A.3					● **[EA]**

EA = Extension Activity

THE EFFECTS OF CLIMATE CHANGE ON AGRICULTURAL SYSTEMS

NEXT GENERATION SCIENCE STANDARDS ACTIVITY CHARTS

Performance Expectations

This chart identifies the Effects of Climate Change on Agricultural Systems activities that address each of the listed Next Generation Science Standards Performance Expectations.

MIDDLE SCHOOL					
	Farms on the Table	Interacting Adaptations	Wilt it be Productive?	Washed Away	Get Out and Graze
MS-LS1-6			●		
MS-LS2-1					●
MS-LS2-5	◗	◗	◗		◗
MS-ESS3-3	◗	◗	◗		
HIGH SCHOOL					
HS-ESS3-1	◗	◗	◗	●	●
HS-ESS3-4	●	●	●		

● = Activity fully addresses Performance Expectation
◗ = Fully addresses Performance Expectation when combined with other activities with this notation

THE EFFECTS OF CLIMATE CHANGE ON AGRICULTURAL SYSTEMS

NEXT GENERATION SCIENCE STANDARDS ACTIVITY CHARTS

Three Dimensions

This chart identifies the Effects of Climate Change on Agricultural Systems activities that address each of the listed three dimensions of the Next Generation Science Standards.

NGSS THREE DIMENSIONS					
	Farms on the Table	Interacting Adaptations	Wilt it be Productive?	Washed Away	Get Out and Graze
SCIENCE AND ENGINEERING PRACTICES					
Developing and Using Models	MS		MS, HS	MS, HS	MS, HS
Planning and Carrying Out Investigations			MS	MS, HS	
Analyzing and Interpreting Data			MS		MS
Constructing Explanations and Designing Solutions			MS	MS, HS	MS, HS
Engaging in Argument from Evidence		MS, HS			
Obtaining, Evaluating, and Communicating Information		MS, HS			
DISCIPLINARY CORE IDEAS					
ESS2.C The Roles of Water in Earth's Surface Processes				MS, HS	
ESS3.A Natural Resources		HS			HS
ESS3.B Natural Hazards				MS, HS	
ESS3.C Human Impacts on Earth Systems	MS, HS	MS, HS	MS, HS	MS, HS	MS, HS
LS1.C Organization for Matter and Energy Flow in Organisms			MS, HS		
LS2.A Interdependent Relationships in Ecosystems					MS, HS
PS3.D Energy in Chemical Processes and Everyday Life			MS, HS		
CROSSCUTTING CONCEPTS					
Cause and Effect				MS, HS	MS, HS
Systems and System Models	MS, HS		MS, HS	MS, HS	MS, HS
Energy and Matter			MS		

MS = Middle School
HS = High School