

Using Project WET to teach

Climate Resilience



project WET

WATER EDUCATION TODAY

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Resilience and a Changing Climate

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About this Lesson Plan

Climate change is a complex topic that can be controversial. However, understanding climate, and specifically the way that climate is changing, is crucial to making informed decisions and building resilience. The information in this section is meant to help educators understand the basic scientific evidence for climate change to allow them to effectively teach climate resilience.

This lesson plan will help educators teach about climate and climate change using interactive, objective, science-based activities that students will enjoy. Please note that none of the activities in this lesson plan are presented in their entirety. Access to the original activities is required for use. Each activity lists the publication or online location where educators can find the original activity, along with suggestions on using the Project WET activity to teach about climate resilience. Many of the activities are from the *Project WET Curriculum and Activity Guide 2.0* which is only accessible through an official Project WET training. For more information, contact your local Coordinator or Project WET Foundation headquarters at wetusa@projectwet.org.

Understanding the terms

“Climate change” and “global warming” are often used interchangeably, which can be confusing. While related, they are actually two separate processes. **Global warming** refers to a trend of increasing temperatures on Earth since the early 20th century. **Climate change** refers to many different phenomena that are occurring because of carbon emissions—mostly caused when fossil fuels are burned to heat our homes, power our cars, light our cities and otherwise operate our modern world. These emissions act like a blanket, trapping heat in the Earth’s atmosphere. One of the phenomena caused by carbon emissions is global warming. Others include sea level rise, loss of glaciers and ice mass, extreme weather events and changing plant and flower blooms.

Research clearly shows that global surface temperatures have increased over the last century by anywhere from 1.3-1.9 degrees Fahrenheit (approximately 0.74 degrees Celsius), with the rate of increase higher in the last 50 years. However, the warming trend is not uniform—the greatest trend in warming is over North America and Eurasia with

some places, such as the southeastern U.S., cooling slightly. Ocean temperatures have also increased, especially over the last 50 years. This warming trend, referred to as global warming, is just part of the whole picture of climate change.

The Greenhouse Effect

A greenhouse allows crops to be grown inside—even in the winter. Glass lets the warmth of the sun shine through into the structure and then traps the heat inside. If you think of the Earth as a greenhouse, the greenhouse effect describes a similar process here. In fact, the greenhouse effect helps regulate Earth’s temperature by capturing certain gases in the atmosphere that trap heat and warm the planet. Water vapor is the most abundant greenhouse gas, followed by carbon dioxide. Others include natural gases, such as methane and nitrous oxide, and synthetic (man-made) gases, such as chlorofluorocarbons (nontoxic, nonflammable chemicals used in the manufacture of aerosol sprays, foams and packing materials, as solvents, and as refrigerants). Without the greenhouse effect, the average temperature on Earth would be closer to zero degrees F, instead of its current average of approximately 57 degrees F. Since the greenhouse effect is a verifiable, natural process that plays an important role in temperature regulation, the question arises: How is it related to climate change? The issue is whether humans are altering the greenhouse effect by adding to greenhouse gases through fossil fuel combustion and deforestation.

Deforestation is the clearing or thinning of forests or stands of trees and other vegetation to make way for other non-forest uses such as housing, agriculture or industry. When done by burning, deforestation releases carbon directly into the atmosphere. Deforestation also increases CO₂ in the atmosphere because the removed trees, which absorbed CO₂, no longer exist. These human activities can cause more heat to be trapped, increasing the warming process of the Earth.

Weather versus Climate

Like “climate change” and “global warming”, the terms “weather” and “climate” are often confused and used interchangeably but are two very different concepts. **Weather** refers to atmospheric conditions that happen over the short term, such as rain, clouds, snow and storms. **Climate** is the long-term, regional or global average of temperature, humidity and precipitation patterns over seasons, years or decades. Weather is short-term and localized; climate is long-term and regional or global. Therefore, climate change cannot be tracked in one season but must be tracked and compared to years or decades-long trends.

Climate Resilience

Climate resilience is defined by the U.S. Climate Resilience Toolkit as “the capacity of a community, business, or natural environment to prevent, withstand, respond to, and recover from a disruption,” specifically from climate. For example, a resilient community will have flood mitigation procedures in place in the case of an extreme flooding event. Or a city may have water supply alternatives and water conservation



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measures in place to prepare for severe drought.

What is Changing with a Changing Climate?

Extreme Weather

Weather extremes are part of a varying climate, and an isolated extreme weather event, such as a hurricane, is not necessarily a reflection of climate change. (Remember that climate is measured in the longterm over a large geographical region). However, the frequency of extreme weather events is increasing in many places throughout the world. An extreme weather event is defined as a weather event that is rare (meaning less than a 10 percent likelihood at a particular place and/or time of year). In other words, an extreme weather event is something that falls outside of the normal weather patterns in an area. What is considered an extreme weather event may vary from place to place but can include flooding, drought, severe storms and dangerous heat. The Intergovernmental Panel on Climate Change (IPCC) has reported that the changing climate is leading to increasingly frequent and intense extreme weather events.

Oceans, Lakes and Rivers

Ocean temperatures are rising along with global temperatures, albeit a little more slowly than land temperatures. Nonetheless, the impact of the 0.18 F (0.1 degree C) rise in ocean temperature over the last century should not be minimized. The temperature rise has occurred where most marine life thrives—on the surface of ocean waters down to approximately 2,300 feet. This has most noticeably affected coral reefs, which are extremely sensitive to any sustained rise in temperature. The shift can cause coral bleaching, which can lead to reef die-off. The rising ocean temperatures are also affecting other ecosystems and species—including krill, which are an important food source for many ocean animals. Research shows that krill reproduce in smaller numbers at higher temperatures, which could have huge implications for the food chain and on animals such as penguins and sea lions that depend on krill.

Given the size and amount of the Earth’s surface that is covered by ocean water, it should not be surprising that any alteration, including higher temperatures, can have multiple impacts. For example, warming ocean temperatures can cause sea



levels to rise, because when water heats up, it expands. Higher water levels can impact coastal communities and ecosystems.

In addition to rising water in coastal communities, higher temperatures have resulted in polar ice melting, which can lead to ice shelf collapses. Stronger and more frequent storms are also linked to higher ocean temperatures: Warmer water on the ocean's surface dissipates more readily into vapor, making smaller storms into larger, more damaging storms.

Warmer waters are also associated with an increase in invasive species, organisms that become established in aquatic environments to which they are not native, causing detrimental effects on that ecosystem. When water temperatures rise, new species can thrive where they were unable to live previously. Whether plant or animal, these invasive species can cause a change in ecosystems and ultimately lead to the extinction of some species. This is true not only in oceans and seas but also in freshwater systems.

Freshwater species are especially sensitive to climate change for a variety of reasons: They are relatively isolated with limited abilities to disperse, are already heavily exploited by

humans and are at a disproportionate risk for loss of biodiversity. (Although freshwater covers only 0.6-0.8 percent of the Earth's surface, it is home to six percent of all species on Earth!)

Impact on Humans

Climate change impacts entire regions and continents which includes the humans who reside there. As coastlines disappear or alter, communities may be displaced. Warming waters affect fisheries. Alterations in the food chain can ultimately affect food supply, especially fish and seafood. These changes in food supply are not confined to oceans, lakes and streams. Agriculture is also highly dependent on climate. Increased drought and flood frequency and/or severity can pose real threats to farmers and ranchers. Changes in climate could make it more difficult to grow crops, raise animals and catch fish in the ways and places people have done in the past. Some places may be able to grow new and more diverse crops, while others may experience serious declines in yields.

In fact, UN-Water predicts that water is the primary way in which humans will feel the impact of a changing climate. Water availability will become less predictable, and changes

in water availability affect not only food security but also human health. Increases in the frequency and/or severity of existing health problems affected by weather and climate (such as extreme heat, flooding and storms) and new health problems in places where they did not occur previously (such as mosquito-borne illnesses moving farther north) can also impact human health. Weather and climate affect the distribution and behavior of many disease-carrying animals such as mosquitoes, ticks and rodents. Zika, Lyme disease and West Nile virus are examples of some of the diseases carried by animals. Extreme weather events such as storms and floods can also affect water quality, creating problems with water-borne illnesses if communities are not prepared for such events.

As the frequency of extreme weather events increases, communities and cities need to prepare for changes in water supply and distribution. In many areas, water demand will increase, while water supply will decrease. In other areas where water may be overly abundant, securing clean water will be a challenge, along with managing stormwater runoff, flooding and/or sea level rise.

Background Resources

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- National Oceanic Atmospheric Administration (NOAA). “Chlorofluorocarbons (CFCs)” <https://www.esrl.noaa.gov/gmd/hats/publicn/elkins/cfcs.html> (Accessed July 12, 2018)
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- “Is There a Strong Link between Extreme Weather Events and Climate Change?” *Scientific American*. <https://www.scientificamerican.com/article/climate-change-and-extreme-weather/> (Accessed July 11, 2018)
- UN Water. “Water and Climate Change.” <http://www.unwater.org/water-facts/climate-change/> (Accessed July 11, 2018)
- US Global Change Research Program. Climate and Health Assessment. <https://health2016.globalchange.gov/> [Includes a great graphic on U.S. effects in Chapter 1: Climate Change and Human Health: <https://health2016.globalchange.gov/climate-change-and-human-health>] (Accessed July 11, 2018)
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- Union of Concerned Scientists. <https://www.ucsusa.org/> (Accessed July 12, 2018)

Climate Resilience Lesson Plan

Climate change is complex, with many different components. However, it is also a defining issue for current and future generations, which means we must understand the actions we can take to help diminish negative impacts globally and locally.

Impacts on human health and survival explain why the topic of resilience is gaining traction among educators. Preparing children and communities for climate change can help mitigate potential problems. Understanding current vulnerabilities to climate- and weather-related health, environmental and infrastructural changes may lessen the impact of climate change in communities.

Climate resilience also applies to ecosystems. For example, coral reefs are proving less resilient to change than many other ecosystems and face serious threats to their survival. Educating people across the globe about how they can help prevent further damage to coral reefs is an important part of an ecosystem resilience plan.

Educators who plan to teach about climate change and climate resilience should be sure to emphasize the dif-

ference between climate and weather, understand what the greenhouse effect is and how it is changing, teach both local and global impacts of a changing climate, look at evidence (data) from the past 100 years and examine how their local communities can prepare for changes that are happening or will happen as a result of climate change.

This Lesson Plan contains instructions on how to use Project WET activities to teach about climate change and resilience. Each activity addresses a different aspect of climate change to help educators and students understand the larger picture. The last two activities are included in their entirety with a foreword about how they address climate change issues. At the very end of the lesson plan we have included suggestions for additional Project WET activities that can be used to teach about climate change and climate resilience.

Below are some additional resources that educators may find helpful to use with their students to help understand the larger issues and come up with positive actions that lead to resilience for water issues that result from climate change.

- Climate Change 101 with Bill Nye | National Geographic. <https://www.youtube.com/watch?v=EtW2rrLHs08> *Bill Nye the Science Guy gives a great overview on what climate change is including best practices for mitigating climate change.*
- National Geographic website on climate change for educators and students: <https://www.nationalgeographic.org/education/act-on-climate>
- NASA resource that shows a series of visualizations on how some of Earth's key climate indicators are changing over time: <https://climate.nasa.gov/interactives/climate-time-machine>
- National Geographic website with information and stories on various aspects of climate change: <https://www.nationalgeographic.com/environment/climate-change/>
- U.S. Climate Resilience Toolkit: <https://toolkit.climate.gov/>
- NASA quiz on extreme weather: <https://climate.nasa.gov/quiz-zes/extremeweather-quiz/>



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Climate Change Framework

To help shape Project WET’s Climate Resilience Lesson Plan and future climate change related activities, Project WET developed a Climate Change Framework that is broken down into two major categories: Earth Systems Impacts from Climate Change and Human Impacts from Climate Change. Under these categories are subcategories relating to water. Each activity falls within at least one area of the framework—some activities fall under multiple categories. In the sidebar of each activity you can find the framework category that the activity falls under. The framework is defined below for reference.



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Earth Systems Impacts from Climate Change

- Oceans
- Atmosphere
- The Arctic
- Freshwater
- Weather

Human Impacts from Climate Change

- Health and disease
- Stormwater
- Agriculture and food supply
- Water distribution and access
- Carbon footprint



High Water History

After damage costs are calculated, what are the real losses associated with a natural disaster like a flood or hailstorm?

Activity Location

Guide 2.0 - page 321

Grade Levels

Middle School (6-8)

Standards

Common Core:

ELA: RH.6-8.7; RST.6-8.2; RST.6-8.3; RST.6-8.4; RST.6-8.9; RST.9-12.9; SL.6-8.1; SL.6-8.4; WHST.6-8.7

MATH: 5.NBT.5

NGSS: MS-ESS2-2, MS-ESS3-2

Climate Change Framework

Earth Systems Impacts (Weather)

Human Impacts (Distribution and access)

Summary

By calculating economic loss that results from flooding in a specific area, students investigate how people are affected by floods and other weather events.

Climate Use Summary

The Annual Exceedance Probability (AEP), or the percent likelihood of a flood to occur, helps people to better understand 10-, 100 and 500 year floods, especially as the likelihood for major floods is expected to increase in many areas of the U.S.

Objectives

Students will:

- interpret how economic damage reports present individual and community losses from a natural disaster.
- differentiate between emotional and economic loss from a natural disaster.
- recognize why some natural events are classified as disasters.
- describe what it means to live in a 10-, 100- or 500-year floodplain.

Climate Specific Objectives

Students will:

- understand what the Annual Exceedance Probability means and how it equates to 10-, 100- or 500-year floods.
- examine trends in flooding over the past 100 years.
- research flood risk and historical flooding in their community.
- make predictions about flooding in the future.
- prepare a resilience plan for flooding in their community.

Connections to STEM

This activity asks students to calculate costs associated with flood loss then research flood damage and risk in their own communities. Students then must analyze flooding and precipitation trends to assess flooding risk into the future and develop resilience plans for their community. This real-world approach to learning about flooding and incorporating science, technology and math makes this an excellent STEM lesson.

Careers

Hydrologist – A hydrologist is a scientist who researches the distribution, circulation and physical properties of underground and surface waters. Surface water hydrologists study water sources such as streams, lakes, and glaciers. They may work with usage and precipitation data to estimate water levels in reservoirs. They also create flood forecasts and help develop flood management plans.

Insurance Adjuster – There are several types of claim adjusters (independent, staff and public) but they all have the same type of work—investigation

work. Once an insurance claim is filed for a disaster like a flood, a claims adjuster is called in to take over the process. The adjuster will investigate the damage the flood did, gather information about the event and determine a fair settlement for the individual, family or business affected by the flood.

Additional Materials

Warm Up

As written in the original activity.

Part I

- **Student Copy Page—AEP Calculations**

Part II

- **Student Copy Page—AEP Calculations**
- *Internet access*

Part III

- **Student Copy Page—Flooding Trends**
- *Internet access*

Additional Background Information

One of the effects of a changing climate is an increase in extreme weather events including extreme rainfall (from storms or hurricanes) or snowfall that results in flooding. However, flooding can also result from human factors such as failed dams or levees and increased impervious surfaces (such as pavement).

Large flood events are traditionally categorized as 10-year, 100-year and 500-year floods. However, many scientists are moving away from the terms 10-year, 100-year and 500-year floods because they can be misleading. The U.S. Geological Survey (USGS) uses the terms Annual Exceedance Probability (AEP) to describe the likelihood of having a major flood event. A 10 percent AEP means there is a 10 percent chance

of flooding in an area for any given year. This is the equivalent of a 10-year flood. Similarly, a 1 percent AEP means there is a 1 percent chance of flooding and 0.2 percent AEP means there is a 0.2 percent chance of flooding. These are the equivalent of 100-year and 500-year floods, respectively.

As the frequency of major flood events increases, the probability of a 100-year flood—or 1 percent AEP—occurring increases, shifting the definition of these floods and of floodplains. Another aspect that is worth noting when discussing climate change and flooding is that flooding is expected to increase in coastal areas due to rising sea levels. This is not necessarily due to weather events but remains an increased risk to coastal communities and should be considered when preparing for floods and considering resilience plans for communities.

Climate Resilience Procedure

Warm Up

As written in the original activity.

Procedure

Part I

As written in the original activity for Steps 1-6.

After Step 6:

7. Ask students to define these chances (1 of 10, 1 of 100 and 1 of 500) as percentages. Students should break into groups or pairs and work through the math in the chart in Question 1 on the **Student Copy Page—AEP Calculations**.
8. Ask students if they have ever heard of the term “Annual Exceedance Probability” (AEP). Explain that an AEP is the percent probability of a flood occurring

in any given year. Many agencies and organizations are no longer using the terms 10-year, 100-year and 500-year floods because it is confusing and are instead using AEP.

9. Have students complete question 2 on the **Student Copy Page—AEP Calculations** in their groups, defining a 10-year, 100-year and 500-year flood as 10 percent AEP, 1 percent AEP and 0.2 percent AEP. Table 1 shows the correct responses. (*Option:* Write this chart on the board and complete as a class.)

Table 1.

Flood event	Annual Exceedance Probability (AEP)
10-year flood	10%
100-year flood	1%
500-year flood	0.2%

Part II

As written in activity with the following modifications:

Before beginning **Part II** have students read the USGS publications, *The 100-Year Flood—It’s All About Chance* (available as a [PDF](#) or [online](#)) and *Significant Floods in the United States During the 20th Century—USGS Measure a Century of Floods* to help understand different types of floods and where major floods have occurred in the U.S. in the past.

Step 1. Have students label the correct AEPs under the 10-Year, 100-Year and 500-Year labels on the map, using their answers from Question 2 on the **Student Copy Page—AEP Calculations**.

Step 2. Students may use the **Student Copy Page—Map Calculations** (questions 3 and 4) to work through

the questions and math presented in the Guide. See the answer key in Step 5 in the Guide.

Steps 4-5. Use *Student Copy Page—Map Calculations* to help with calculations.

After Step 8:

9. Have students go to the National Flood Service website <http://www.floodtools.com/Map.aspx>. Look up your town or city. Have students identify where their school and home are located. Ask students to answer the following questions:
 - a. What is the flood risk for each of these locations?
 - b. What are the monetary flood losses in your community for the last 10 years according to this map?
 - c. What is the average damage claim for your area?
10. Click on “Historical Floods” on the webpage to see areas of your community that have flooded in the past. Discuss why flooding may have occurred in your area. Reflect on the USGS report, *Significant Floods in the United States During the 20th Century—USGS Measure a Century of Floods* to help understand why flooding occurs and where major floods have occurred in the U.S.

Part III

Building Climate Resilience

1. Have students look at Figures on the *Student Copy Page—Flooding Trends* (or go to the online report and figures for [Trends in U.S. precipitation over 100 years](#) and [Trends in flood magnitude Figure](#).)
 - a. Are extreme precipitation events (heavy rainfalls) increasing, decreasing or staying the same since the 1950s?



- (increasing!) How do students know this? Ask them to explain the graph and trends.
 - b. What areas of the county have trends for greater flooding? (Midwest and Northeast). What areas have trends for less flooding? (Southwest)
2. How do these precipitation and flood trends reflect the changing climate? (*Option:* Have students read the Huffington Post article, [Climate Change Has ‘Loaded The Dice’ On The Frequency Of 100-Year Floods](#).) Discuss as a class.
3. How many 10-year, 100-year and 500-year floods have you had in recent years? Use the [National Weather Service Flood Mapper](#) to help research this information (Note: this database is several years behind on data but is a good source of historical flood information.) What are some of the ways your local community has worked to prepare for major flood events?

Wrap Up

Climate Resilience Assignment

What can we do to better prepare for increasing major flood events? Divide class into groups to research and present on this. Are there ways to incorporate technology such as drones, Google Maps or Google Earth, social media, etc. to increase

flood preparedness and emergency response? Use the [NOAA, NWS flood safety website](#) to help guide some of the responses. List two things you should do to prepare for each of the following: before, during and after a flood.

Additional Educator Resources

Huffington Post article for *Part II* on Frequency of 100-yr and 500-yr floods increasing:

D’Angelo, Chris. 2017. Climate Change Has ‘Loaded The Dice’ On The Frequency Of 100-Year Floods. Huffington Post. https://www.huffingtonpost.com/entry/100-year-flood-climate-change-us_59a6ea3e-4b084581a14ea14

A summary of the 4th National Climate Assessment showing climate change by region:

Grist Magazine. 2018. <https://grist.org/article/we-broke-down-what-climate-change-will-do-region-by-region/>

Research article on frequency of 100-year floods in Iowa due to Climate Change:

Quintero, Felipe and Ricardo Mantilla et al. (2018) Assessment of Changes in Flood Frequency Due to the Effects of Climate

Change: Implications for Engineering Design. Hydrology. 5,19. www.mdpi.com/2306-5338/5/1/19/pdf

U.S. Geological Survey (USGS). The 100-Year Flood—It's All About Chance. Same information as the PDF recommended in *Part II*:

Holmes, R.R., Jr., Dinicola, K., 2010, 100-Year flood—it's all about chance: U.S. Geological Survey General Information Product 106, 1. <https://water.usgs.gov/edu/100yearflood-basic.html>

U.S. Geological Survey (USGS). “We had a “100-year flood” two years in a row. How can that be?” https://www.usgs.gov/faqs/we-had-a-100-year-flood-two-years-a-row-how-can-be?qt-news_science_products=0#qt-news_science_products

U.S. Geological Survey (USGS). “Does an increase in the 100-year flood estimate originate from climate or land-use change?” <https://www.usgs.gov/faqs/does-increase-100-year-flood-estimate-originate-climate-or-land-use-change>

U.S. Geological Survey (USGS). Floods: Recurrence intervals and 100-year floods. <https://water.usgs.gov/edu/100yearflood.html>

Article recommended for *Part II*:

U.S. Geological Survey (USGS). Significant Floods in the United States During the 20th Century—USGS Measure a Century of Floods. <https://pubs.usgs.gov/fs/2000/0024/report.pdf>

U.S. Global Change Research Program. 2014 National Climate Assessment. <https://nca2014.globalchange.gov/highlights/report-findings/extreme-weather#tab1-images>

From this report for Part III: Trends in U.S. precipitation over 100 years: <https://nca2014.globalchange.gov/highlights/report-findings/extreme-weather#graphic-20984>

Digital Tools

Interactive map showing risk zone of housing in coastal areas with a look at future flood risks to homes:

Climate Central. 2019. Ocean at the Door: New Homes and the Rising Sea. <http://www.climatecentral.org/news/ocean-at-the-door-new-homes-in-harms-way-zillow-analysis-21953>

Use this calculator to see the likelihood of experiencing different hazard events within a particular time frame. To start, choose a return period and type in an age. Then, you'll see the percent chance of experiencing that type of flood in a given year:

Global Facility for Disaster Reduction and Recovery. <https://www.gfdrr.org/en/100-year-flood>

Flood forecasts: National Weather Service (NWS). <https://water.weather.gov/ahps/forecasts.php>

Interactive flood map: National Weather Service (NWS). <https://www.weather.gov/safety/flood-map>

Where can I find flood maps?: U.S. Geological Survey (USGS). https://www.usgs.gov/faqs/where-can-i-find-flood-maps?qt-news_science_products=0#qt-news_science_products

Current flood information: U.S. Geological Survey (USGS). <https://water.usgs.gov/floods/>

“Water Watch” Flooding, drought, streamflow and runoff data from around the U.S.: U.S. Geological Sur-

vey (USGS). <https://waterwatch.usgs.gov/index.php?id=ww>

Background Resources

Holmes, R.R., Jr., Dinicola, K., 2010, 100-Year flood—it's all about chance: U.S. Geological Survey General Information Product 106, 1. <https://water.usgs.gov/edu/100yearflood-basic.html>

Kunkel, K. E. et al., 2013: Monitoring and understanding trends in extreme storms: State of knowledge. Bulletin of the American Meteorological Society, 94, doi:10.1175/BAMS-D-11-00262.1

Peterson, T. C. et al., 2013: Monitoring and understanding changes in heat waves, cold waves, floods and droughts in the United States: State of knowledge. Bulletin of the American Meteorological Society, 94, 821-834, doi:10.1175/BAMS-D-12-00066.1

U.S. Global Change Research Program. 2014 National Climate Assessment. <https://nca2014.globalchange.gov/highlights/report-findings/extreme-weather#tab1-images>

1. Convert the chance of having a 10-year flood, 100-year flood and 500-year flood into percentages. Use the table below to help you calculate percent.

	10-year flood:	100-year flood:	500-year flood:
Chance of flooding in any one year			
Expressed as a fraction			
Expressed as a decimal			
Expressed as a percent			

2. Scientists are now using the terms Annual Exceedance Probability (AEP) to define major flood events. Fill in the table below with the equivalent AEP terms for each of the flood events. (Hint: use your results from Question 1).

Flood event	Annual Exceedance Probability (AEP)
10-year flood	
100-year flood	
500-year flood	

3. In the event of a 10 percent AEP, how many houses may be damaged?
4. If each house is worth \$100,000 what is the total damage in dollars?
5. Fill in the table below:
 - a. How many houses are in the 1 percent AEP floodplain?
 - b. How many houses are in the 0.2 percent floodplain?
 - c. Calculate the potential losses of houses in dollars for each areas using \$100,000 value per home.

Flood event	Number of houses	Cost per house	Total loss (\$)
10% AEP			
1% AEP			
0.2% AEP			

Figure 1. Observed trends in heavy rainfall in the U.S. over the last 100 years.

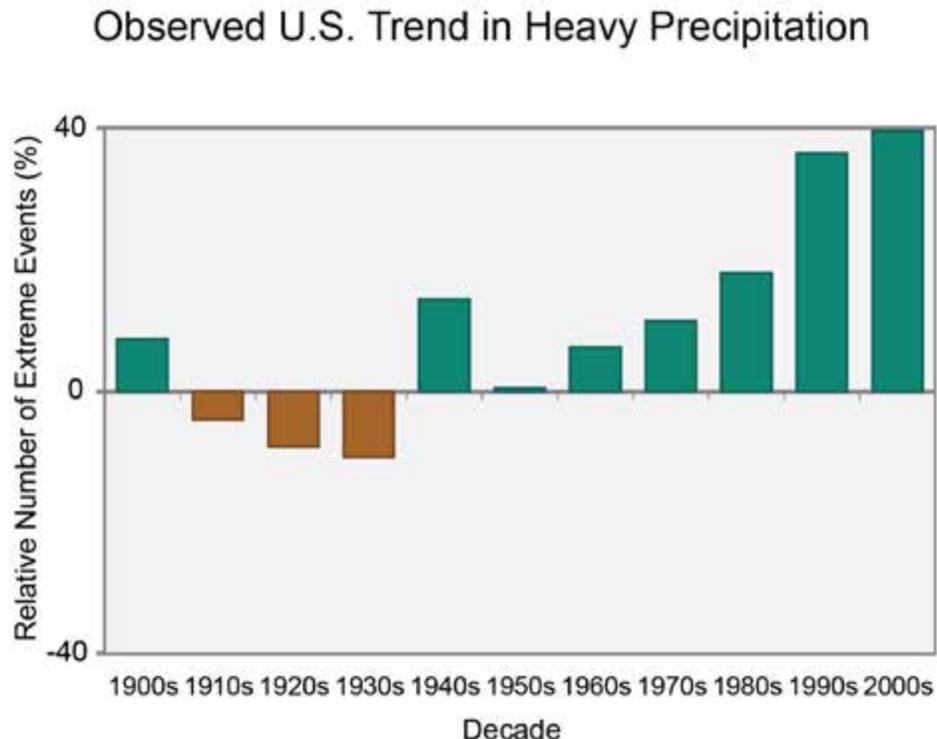


Figure source: U.S. Global Change Research Program. 2014 National Climate Assessment. Adapted from Kunkel et al. 2013

Figure 2. Observed trends in flooding in the U.S. over the last 100 years.

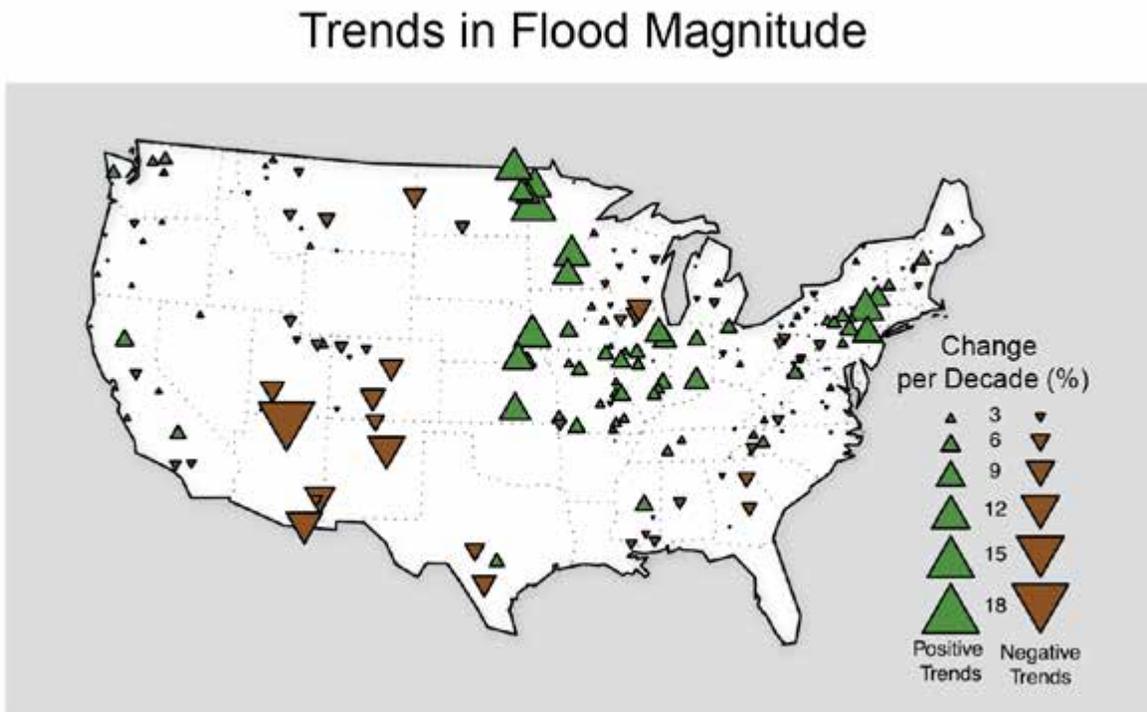


Figure source: U.S. Global Change Research Program. 2014 National Climate Assessment. Taken from Peterson et al. 2013



Super Sleuths

If you like mystery and intrigue, this activity is for you.

Activity Location

Guide 2.0 - page 113

Grade Levels

Middle School (6-8)

High School (9-12)

Standards

Common Core:

ELA: RH.6-8.7; RST.6-12.2;
WHST.6-12.7

NGSS: Supports as written:
MS-LS1-1, MS-LS2-1

Climate Change Framework

Human Impacts (Health and Disease)

Summary

Students learn about the diversity of waterborne diseases and the role of epidemiology in disease control by searching for others who have been “infected” with the same waterborne disease that they have.

Climate Use Summary

Use this activity to teach about waterborne diseases and water-related vector diseases in a changing climate. How can a changing climate affect the spread of these diseases?

Objectives

Students will:

- identify the role of water in transmitting diseases.
- compare symptoms of several waterborne diseases.
- analyze the characteristics of environments that promote the transmission of these diseases around the world.

Climate Specific Objectives

Students will:

- analyze the transmission of waterborne diseases that have spread or been introduced to new areas due to the effects of climate change.
- analyze how the characteristics of environments that promote the transmission of diseases around the world has increased, decreased or changed with a changing climate.

Connections to STEM

Careers

Epidemiologist- Epidemiologists investigate patterns, distribution and causes of disease. They play a significant role in public health as they seek to reduce the risk and occurrence of negative health

outcomes through research, community education and health policy. Epidemiologists need at least a master’s degree from an accredited college or university. Most epidemiologists have a master’s degree in public health (MPH) or a related field, and some have completed a doctoral degree in epidemiology or medicine.

Entomologist- An entomologist is a scientist who studies insects, their environments and their behaviors through observational, experimental, chemical and genetic techniques. They may specialize in a particular species or taxonomic group, or in the use of insects for particular applications or industries. Understanding the insects that act as vectors of diseases—such as mosquitoes, rats and ticks—is important in understanding how climate change affects these insects. Entomologists are also important in forensic science, agriculture and veterinary science among other fields. Many entomologists work with universities where advanced degrees are required.

Data

Incorporating real-world data into this activity makes it relevant to students

while integrating thinking across disciplines. Use the data found at the link below with the questions supplied in the activity, or deepen student thinking by having them create their own questions and analyze data to find the answers.

Access raw data and geospatial data on West Nile Virus, Zika, cholera and heat stroke at www.projectwet.org/climate.

Additional Materials

Part I

- Copies of Disease Descriptions provided in this lesson plan (one per student)
- Disease Symptom cards* for West Nile, Zika, heat stroke and Control (no disease) provided in this lesson plan, cut and put into envelopes as directed in the original activity.
- Common Waterborne Diseases & Symptom Cards for Typhoid Fever and cholera from the original activity (pg 118), cut and put into envelopes as directed in the original activity.
- Data for West Nile, Zika, cholera and heat stroke.

* Be sure there are enough Disease Symptom Card envelopes for each student. Make four copies of each for a class of 24, five copies for a class of 30, etc.

Additional Background Information

With global temperatures rising, tropical diseases are pushing north into areas previously unseen. This is true of both waterborne and vector diseases.

Waterborne diseases tend to increase with degradation of water quality such as during a flood or other natural disaster that allows sewage (i.e., feces) to leak into water supplies. As

the frequency of extreme weather events increases, the likelihood of waterborne diseases associated with such events also increases. Diseases such as cholera, hepatitis A and typhoid fever are some of the common waterborne diseases that occur where feces have contaminated drinking water as a result of natural disasters.

Vector transmission occurs from contact with infected insects or other animals that transmit certain diseases. Common examples of vector transmitted diseases are dengue fever, West Nile virus, Zika and malaria, all of which are transmitted through mosquitoes. Mosquitoes and other animals carrying diseases, such as ticks, will see a change in range and distribution with climate change. The mosquito that carries dengue fever and Zika virus, *Aedes aegypti*, is found throughout the southern United States. Its range is likely to expand with global warming creating more habitats that are suitable for it.

Some impacts on human health and disease will be more subtle than overt outbreaks of cholera or Zika virus. For example, people are likely to see an increase in frequency and/or severity of existing health problems that come from extreme heat, flooding and storms. Heat stroke, specifically, is of concern as global temperatures rise.

Scientists are only beginning to understand some of the effects that climate change may have on diseases. For example, soil moisture changes could alter the spread of the soil-borne fungi that give rise to the American Southwest's flu-like Valley fever. Diseases like *Bacillus anthracis*—the bacteria that cause anthrax—that lie in soil of permafrost



photo credit: pexel_pixabay

will also become a bigger concern as these areas thaw.

Proper sanitation and hygiene, along with healthy habits, can help prevent diseases from spreading.

For fecal-oral diseases these include the following healthy habits:

- Frequently wash your hands with soap and clean water, turning off all faucets after each use. (Hand washing is one of the most effective ways to stop the spread of disease.)
- During and immediately following natural disasters, be sure to purify drinking water and listen to government and health official warnings of disease outbreak.
- Maintain sewage systems properly. (Don't throw garbage, wet wipes, feminine hygiene product or diapers down toilets.)
- Get vaccinated. (This can boost natural immune defenses against many diseases, including some fecal-oral diseases, such as typhoid fever.)

- Wash fruits and vegetables to clean the food of any germs or bacteria from previous handlers.

Methods to prevent vector transmission from mosquitoes include:

- Remove stagnant water from around your home (this prevents the *Aedes* mosquito from laying her eggs around your home).
- Properly dispose of garbage and solid waste in closed containers to prevent female mosquitoes from laying their eggs.
- Wear long protective clothing to prevent insect bites.
- Use insect repellents or natural insecticides to prevent the presence of infected insects around you and your home.

Climate Resilience Procedure

Warm Up

As written in the original activity.

Procedure

Part I

Follow the instructions from the original activity making this adaptation in Step 2:

2. Hand out one symptom card envelope and one copy of Disease Descriptions to each student as directed in the activity in the Guide. Use the **Disease Description Cards** and **Disease Symptom Cards** included in this lesson plan plus the **Common Waterborne Diseases & Symptom Cards** for Typhoid Fever and cholera from the original activity (pg 118).

Part II

1. Ask each student to announce to the class what their disease is and why they came to that conclusion.
2. Discuss the control cards as a class. How do you know these

symptoms are not from one of the diseases affected by climate change?

3. Have students with the same disease form groups. Assign control card students to one of the disease groups.
4. Ask each group to research their disease and summarize how climate change may increase the frequency of occurrence, range and/or severity of that disease. As a starting point have students read Scientific American article(s) on increasing diseases:
 - <https://www.scientificamerican.com/article/our-planet-ourselves-how-climate-change-results-in-emerging-diseases/>
 - <https://www.scientificamerican.com/article/mosquito-borne-diseases-on-the-up-tick-thanks-to-global-warming/>.
5. Each group should present a summary of how climate change will affect their disease.

Part III

1. Have students access the data on West Nile, Zika, cholera and heat

stroke at www.projectwet.org/climate.

2. Ask students to graph the data by year for a given state(s), country(s) and/or overall using a line graph or bar graph. What patterns do they notice? Are any diseases increasing in frequency?
 - a. Which states have had the biggest increase in incidence of heat stroke over the last few years?
 - b. Which states are seeing the biggest increase in mosquito-borne diseases?
 - c. Which countries have seen spikes in cholera? (e.g., Haiti). Have students research what happened in those countries that year or years.
3. Have students examine the map of cases of each disease by state. What patterns do they notice? Which geographic areas are seeing the most mosquito-borne diseases? Which states have had the most cases of heat stroke?



photo credit: pexel_pixabay

Wrap Up

Building Climate Resilience

Discuss how climate change has affected and will affect waterborne and vector diseases in the U.S. and throughout the world. Using the research conducted in *Part II* and the evidence from *Part III*, have students make predictions about the range and frequency of the diseases presented in the future. How can people prevent these diseases from spreading? What measures should communities and the U.S. government have in place to prevent the spread of disease?

Climate Resilience Assignment

Ask students to come up with a climate resilience plan for one of the diseases. Students may work in groups or individually. Assign this as homework or have students work together in class to develop their plans.

Additional Educator Resources

Semenza JC, Höuser C, Herbst S, et al. Knowledge Mapping for Climate Change and Food- and Waterborne Diseases. *Critical Reviews in Environmen-*

tal Science and Technology. 2012;42(4):378-411. doi:10.1080/10643389.2010.518520. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3996524/>

Scientific American. These can be great reading assignments:

“As Earth Warms, the Diseases That May Lie within Permafrost Become a Bigger Worry.” <https://www.scientificamerican.com/article/as-earth-warms-the-diseases-that-may-lie-within-permafrost-become-a-bigger-worry/>

“Our Planet, Ourselves: How Climate Change Results in Emerging Diseases.” <https://www.scientificamerican.com/article/our-planet-ourselves-how-climate-change-results-in-emerging-diseases/>

“Mosquito-borne Diseases on the Uptick—Thanks to Global Warming.” <https://www.scientificamerican.com/article/mosquito-borne-diseases-on-the-uptick-thanks-to-global-warming/>

Wright, Pam. 2017. “Thawing Permafrost Could Unleash

Ancient, Dangerous Diseases, Scientists Say” <https://weather.com/science/environment/news/2017-11-08-thawing-permafrost-release-diseases>

World Health Organization. “Climate change and human health - risks and responses. Summary.” A great reading assignment: <http://www.who.int/global-change/summary/en/index5.html>

U.S. Climate Resilience Toolkit. “Changing Ecosystems and Infectious Diseases.” <https://toolkit.climate.gov/topics/human-health/altered-risk-infectious-diseases>

Digital Tools

Links to videos, interactive websites and other technological tools:

NASA. https://climate.nasa.gov/climate_resources/25/interactive-climate-time-machine/. *Interactive climate change map. Series of visualizations shows how some of Earth’s key climate indicators are changing over time.*



photo credit: Freemages.com_ Marcio Luiz Ingemio

KPBS – Kids PBS. Is Climate Change Aiding Spread Of Infectious Diseases? <https://www.youtube.com/watch?v=wPrZ7qiqqC0>. Interview that discusses how the change in global temperature will affect range of mosquitoes and diseases carried by vectors.

Discover News (Discovery Channel). How Global Warming Is Awakening Deadly Diseases <https://www.youtube.com/watch?v=UIAvavZCdfc>. A presentation on how melting Arctic climates and permafrost are releasing deadly bacteria and warming oceans are causing infections in humans to increase.

Background Resources

Centers for Disease Control: <https://www.cdc.gov/>

National Oceanic and Atmospheric Administration (NOAA): [Climate.gov](https://climate.gov)

Scientific American. “Mosquito-borne Diseases on the Uptick—Thanks to Global Warming.” <https://www.scientificamerican.com/article/mosquito-borne-diseases-on-the-uptick-thanks-to-global-warming/>

ScienceDirect. “Heat Stroke.” <https://www.sciencedirect.com/topics/medicine-and-dentistry/heat-stroke>

Welch, Craig. 2017. “Climate Change Pushing Tropical Diseases Toward Arctic.” National Geographic. <https://news.nationalgeographic.com/2017/06/vibrio-zika-west-nile-malaria-diseases-spreading-climate-change/>

World Health Organization. “Climate change and human health - risks and responses. Summary.” <http://www.who.int/global-change/summary/en/index5.html>

Wu, Xiaoxu, et al. 2016. “Impact of climate change on human infectious diseases: Empirical evidence and human adaptation.” Environment International. Volume 86, Pages 14-23. <https://www.sciencedirect.com/science/article/pii/S0160412015300489>



photo credit: Shutterstock_ ruigsantos

Heat Stroke

Heat stroke requires a rapid reduction of core temperature to 40 °C (104 °F), which is accomplished by physical cooling techniques. Immersion and evaporative (e.g., spray bottle and a standing fan) cooling are the most widely used cooling methods. When the body temperature reaches 40 °C, cooling measures should be discontinued to avoid hypothermic overshoot. Other adjunctive cooling methods include cooling blankets, cardiopulmonary bypass, peritoneal dialysis, and gastric/bladder lavage. Hypotension, caused by peripheral vasodilation, is common in heat stroke. Blood pressure usually rises with cooling and intravenous fluid administration. Airway management is critical in the resuscitation of any critically ill patients. Common early complications of heat stroke include seizures, rhabdomyolysis, hypokalemia, hypocalcemia, and shivering. All patients with heat stroke should be admitted for close observation and management.



Zika Virus

Zika is spread mostly by the bite of an infected *Aedes* species mosquito (*Ae. aegypti* and *Ae. albopictus*). These mosquitoes bite both during the day and night. An infected person can spread the disease by having a mosquito bite him or her and then bite someone else. Zika can also be passed from a pregnant woman to her fetus. This is especially dangerous because infection with Zika during pregnancy can cause certain birth defects such as microcephaly. Zika can also be passed through sex from one infected partner to another. Many people who contract Zika will not show symptoms or show very mild symptoms. Symptoms—such as fever, rash, muscle aches, red eyes and joint pain—can last for several days to a week. Once a person has been infected with Zika, they are likely to be protected from future infections. There is no vaccine or medicine for Zika but people rarely are hospitalized or die from Zika.



West Nile Virus

West Nile virus is most commonly transmitted through the bite of a mosquito. Mosquitoes become infected from feeding on infected birds then spread West Nile virus to people and other animals by biting them. The majority of people who contract West Nile Virus will not show symptoms. Mild symptoms such as a fever, rash, vomiting and/or diarrhea may last a few days although fatigue may last several weeks. One in 150 people may develop a severe illness affecting the central nervous system such as encephalitis (inflammation of the brain) or meningitis (inflammation of the membranes that surround the brain and spinal cord). These symptoms may include high fevers, neck stiffness, stupor, disorientation, coma, tremors, convulsions, muscle weakness, vision loss, numbness and paralysis.

Heat Stroke

Case background:

High Body Temp (103 F or higher)
Hot, red, dry, or damp skin
Fast, strong pulse
Head ache and/ or dizziness
Nausea
Confusion
Losing consciousness

Zika virus, caused by

Case background:

Fever
Rash
Headache
Joint pain
Red eyes
Muscle pain
Recently bitten by mosquitoes while traveling in South America

West Nile Virus, caused by

Case background:

Fever
Headache
Weakness and fatigue
Body aches and joint pains
Vomiting and/or diarrhea
Neck stiffness
Rash



Activity Location

Guide 2.0 - page 299

Grade Levels

Upper Elementary (3-5)

Middle School (6-8)

High School (9-12)

Standards

Common Core:

ELA: RI.3-12.2; RST.6-12.2;

RST.6-12.3; SL.3-12.1; SL.3-

12.4; SL.3-12.5; SL.3-6.2;

W.3-5.3; WHST.6-12.1

NGSS: HS-ESS3-1

Climate Change Framework

Human Impacts (Water Distribution and Access)

8-4-1, One For All

Eight water users, four common water needs...and one river to serve them all.

Summary

Representing eight different water users, students must safely carry one water container “downstream” and must navigate through four simulated water management challenges to reach the next community of water users on the same “river.”

Climate Use Summary

Students will analyze eight water users and how climate change will impact these users and the community, coming up with a plan to help solve water challenges related to climate change.

Objectives

Students will:

- identify water users and their water use or product.
- describe major water user categories and how each consumes water.
- list water users’ four common water needs.
- demonstrate the complexity of sharing water among all water users in a watershed.
- summarize how water managers use adaptive and integrated strategies to address river basin water challenges.

Climate Specific Objectives

Students will:

- Identify how changing weather patterns will stress existing water resources
- Demonstrate how water users can work together to manage stress placed on water resources

Connections to STEM

This activity looks at various water users in a community. This could also be tied to careers and who is responsi-

ble for monitoring these water uses or managing the water use of the water users. By discussing how climate change impacts various water users, students can brainstorm jobs or future careers needed to help mitigate climate change effects in the community.

Careers

Irrigation Specialist—Irrigation specialists are responsible for the sales, programming, operating and maintenance of irrigation systems to help farmers produce a more bountiful crop. They could potentially be pioneers of water conservation developing new irrigation strategies since agriculture is the biggest water user of all the categories.

Fish and Wildlife Manager—A fish and wildlife manager usually works for the state or federal government and studies animals in their natural environments to make decisions or recommendations on how to maintain habitat to be suitable for animal populations. They also supervise hunting on public land and keep track of the animal populations housed on these lands. Some wildlife managers collect data and prepare research to aid in decisions about how to manage wildlife.

Hydroelectric Power Operator—water creates energy through its movement. Hydroelectric dams allow humans to harness this energy for use. This type of energy may become more important in the future as we move away from fossil fuel. Understanding how hydroelectric power works and the tools required can be an asset for students in the future.

Public Lands Manager—there are several branches of government that manage public lands from the Bureau of the Land Management (BLM) to the National Forest Service to state Fish and Wildlife Agencies. All of these agencies are charged with maintaining public lands for use. This includes allowing people to boat, fish and swim on these lands. Maintaining safe water quality and quantity is an important responsibility for the employees of these agencies.

Water Resource Professional with Private Industries—Many corporations that work in commercial industries such as beverage companies, mining companies, textile/clothing companies and sanitation companies, to name a few, employ water experts to help them reduce, reuse and maintain high water quality within their company. This will become more important as demand for water increase and potential usable supply decreases in the face of climate change.

Additional Materials

Warm Up

- *White Board or chalkboard*

Activity

Use the materials suggested in the original activity.

Additional Background Information

The Earth's changing climate will result in reduced mountain snowpack

and warmer stream temperatures that will directly affect stream flow and stream health. In fact, basins in the Southwest are predicted to experience reduced stream flow runoff which will affect the people and industries that use water in rivers such as the Colorado and Rio Grande.

As extreme weather events occur more frequently, increased pressure will be put on our water resources. A changing climate will, in many places, result in increased demand for water in the face of a decreased water supply. In places where water supply may not be affected, water quality may be greatly reduced through flooding and increased runoff. Everyone relies on water for various reasons—changing climate conditions can put pressure on the existing usable water supply.

Coastal communities may see the most dramatic impacts as sea levels rise, potentially affecting ports and

Water Users Potentially Impacted by Changing Weather and Climate Patterns:	
Sector	Impact
Transportation	Ports, roads, airports and railways will be impacted by extreme weather and rising sea levels.
Fish & Wildlife	Rising temperature and changing habitats threaten species' survival and/or change species' range.
Agriculture	Prolonged drought, floods and changes in soil moisture will affect crop yields. Drought will also increase demands on water. Rising temperatures will affect where crops can be grown.
Industry	More demand on water means less water available for industrial use. This can impact industries' bottom line.
Earth Systems	Water will be distributed differently. More extreme weather events will occur such as floods, hurricanes and drought.
Energy	Increased drought and decreased stream flow can impact hydroelectric dams; increased temperatures will require more energy for air conditioning.
Municipal	Increased demand means less water available per person. Water quality may also be affected by extreme weather events.
Recreation	Decreased water quality in streams, lakes, rivers and oceans will impact people's use of water areas. Decreased stream runoff can impact use of streams in general and affect activities such as fishing.

harbors, harming coastal ecosystems and reversing freshwater flow that will biologically change estuaries.

As global temperatures rise, animals and people will demand more water for survival. This includes industries such as agriculture. Decreases in soil moisture could result in an increased demand for water to produce the food we eat. Other sectors—such as the energy, industry and mining sectors—may also be affected as demand for water resources increases.

Climate Resilience Procedure

Warm Up

- Have the class brainstorm different water users. Keep a list on the board of water users.
- Explain that in this lesson you will use the eight water users listed in the table *Water Users Potentially Impacted by Changing Weather and Climate Patterns*. You may want to list these eight on the board.

Procedure

Part I

1. Divide students into eight groups. Each group should be assigned one of the water users listed in the

Water Resource Issue	Obstacle for students
Increased water temp	Hop on one foot.
Changing precipitation patterns, intensifying of hurricanes	Hold one hand on head to “shield” from the storm.
Wetlands becoming dryer	Step from one manila folder to another (or other product that is like a stepping stone).
Salt water intrusion	Try to hold breath while in this section, symbolizing how fresh water fish interact with salt water.
Loss of high elevation snow melt	Bunny hop with feet together.

- table *Water Users Potentially Impacted by Changing Weather and Climate Patterns* (e.g., one group is focused on Agriculture). Hand out cards with the water users listed on them or count off by 8 and assign each group a water user.
2. Ask students to discuss why water is so important to their group. What would happen to them during a natural disaster (flood, hurricane, etc.)? How would they deal with prolonged drought? Should they be entitled to more water than other water users?
 3. Have students discuss right time, right quantity, right quality and right cost of water for their water user group.

4. Ask student to discuss how a changing climate may affect water use for each group. They can use the EPA Climate Change website with links to various sectors as a guideline: <https://19january2017snapshot.epa.gov/climate-impacts/climate-impacts-water-resources.html>

Part II

Follow *The Activity* as written in *Guide 2.0* with the following modification in Step 1 and adding in additional climate change obstacles.

1. Ask students to form groups of eight by having one student from each water user group form a new community. There should be eight different water users in each community. Extra students can choose a community to join and switch out with their water use counterpart as needed.

Using existing obstacles such as drought (duck under string), pollution (hanging strips), etc. incorporate additional climate change obstacles as defined in the table.

Part III

Building Climate Resilience

2. Ask students to discuss the following questions as a community, looking at water use through the lens of their particular water user role.



photo credit: Freeimages.com_Julia Freeman-Woolpert

- Without any challenges from a changing climate, how does your community share water resources?
 - How will your community deal with decreased stream flow from less mountain runoff?
 - How will your community deal with rising sea levels?
 - What do changing fish and wildlife ranges and, as a result, changing animal behaviors mean for your community?
 - How will prolonged drought affect the water users in the community?
 - How will your community handle extreme weather events that result in natural disasters such as floods or extreme heat?
 - What do warming water temperatures mean for the water users in your community?
 - What other effects of climate change could impact your community water users?
3. Have each community develop a plan with a list of potential solutions to address how each user group might work together to mitigate or adapt to water challenges in their community. They must consider how climate change

should be incorporated into those plans.

Wrap Up

Use the *Wrap Up* written in the original activity.

Climate Resilience Assignment

Have groups make a presentation to the class (or city!) about the plan to address water challenges from climate change. This should be a PowerPoint or other visual presentation that highlights the group's solutions.

Additional Resources

Nice visual: http://www.dwaf.gov.za/iwrm/contents/about/what_is_iwrm.asp

U.S. Global Change Resource Program. The Effects of Climate Change on Water Resources in US: https://www.globalchange.gov/sites/globalchange/files/Water_SAP_4.3_Letter.pdf

Environmental Protection Agency (EPA). Climate Impacts on Water Resources. <https://19january2017snapshot.epa.gov/climate-impacts/climate-impacts-water-resources.html>

U.S. Global Change Resource Program. <https://nca2014.globalchange.gov/report/sectors/water>

Digital Tools

NASA. https://climate.nasa.gov/climate_resources/25/interactive-climate-time-machine/Interactive-climate-change-map. *Series of visualizations shows how some of Earth's key climate indicators are changing over time.*

Climate Impact Lab. <http://www.impactlab.org/map/#u-smeas=absolute&usyear=1981-2010&gmeas=absolute&gyear=1986-2005>. *Shows average temperatures and changes in temperature over time.*

U.S. Global Change Resource Program. <https://nca2014.globalchange.gov/highlights/report-findings/future-climate#intro-section-2>. *Series of maps that show changes in temperature, soil moisture, precipitation, changes in consecutive dry days among other visual charts and graphs.*

BBC. http://news.bbc.co.uk/2/hi/in_depth/629/629/6528979.stm. *Clickable map to show climate change around the world.*



photo credit: Freeimages.com_ Denise Hunter



Stormwater

Where does stormwater come from? And where does it go?

Activity Location

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Grade Levels

Upper Elementary (3-5)
Middle School (6-8)

Standards

Common Core:

ELA: RST.6-8.1; RST.6-8.2;
RST.6-8.3; RST.6-8.4

MATH: 3.MD.2; 4.MD.2

NGSS: 3-5-ETS1-1,
3-5-ETS1-2, 4-ESS3-2,
5-ESS2-1, 5-ESS3-1,
MS-ESS3-3, MS-LS2-5,
MS-ETS1-2

Climate Change Framework

Human Impacts
(Stormwater)

Summary

Students learn how water travels through a community and how it can be managed. Students learn methods that city planners, water managers and land owners use that can reduce the impact of Storm Water runoff. Students use household sponges to simulate how storm water runoff can be captured, stored and released.

Climate Use Summary

Students consider how climate change is impacting their city or town, and learn what other cities in the United States are doing to be resilient.

Connections to STEM

Careers

Stormwater manager - Stormwater managers examine the effects of a city's runoff on the local watershed. They look at land use activities and often engage in education and outreach to help the community better understand the effects of their actions on the local watershed.

Additional Materials

Warm Up

Use the materials suggested in the original activity.

Activity

Student Copy Page—Stormwater Resilience Data Collection Sheet

Additional Background Information

In future years, an increase in extreme weather events such as storms and hurricanes is predicted for many areas in the United States. Even places where more drought is predicted may be impacted by serious rain events. Without permeable areas such as parks, wetlands and forests, communities face risks of flooding. Stormwater systems

Objectives

Students will:

- list ways that humans alter and modify the physical environment.
- identify how humans impact water quality.
- list, describe and compare solutions for managing storm water runoff.
- explain how storm water impacts a natural landscape and a human-made cityscape.
- describe how solutions that mimic nature can capture, store and filter water.

Climate Specific Objectives

Students will:

- identify and describe how climate change (including hurricanes, flooding, drought, wildfires, etc.) will impact storm water management.

help divert water from impervious surfaces to mitigate flood risks. As the frequency of extreme events such as severe droughts and floods occur, communities and urban centers need to prepare for changes in water supply and distribution. This includes preparing stormwater management systems to handle larger volumes of water.

In coastal cities, rising water levels can exacerbate the threat to stormwater systems and increase flooding potential. Understanding how cities can be engineered to help mitigate the effects of increased waterflow will help better prepare urban centers for the future.

Climate Resilience Procedure

Warm Up

As written with the following modifications:

- Go outside and look at storm drains on the school grounds and/or nearby streets. Do students know what the storm drains are for? Have they seen water flowing into them during a storm or snowmelt?
- Ask students if they know where the water in these drains go. Explain that a common misconception is that the water goes to the treatment plant. Stormwater enters these drains and actually goes directly to a nearby water source. What is that water source for your community?
- Have students brainstorm what sorts of contaminants may get flushed into storm drains and end up in the nearby water source. (*Option:* if you can't go outside you can look at Google Maps or Google Earth to see where the storm drains are).

Have students look for them on their way home or next time they are outside.

Procedure

Part I

As written in original activity.

Part II

As written in original activity with the following modifications:

After Step 3: Assign half of the groups to be an average event of precipitation and the other half to be an extreme precipitation event, such as a storm. Pair up each “average” group with an “extreme” group.

4. Give one student copy page to each group. Instruct students in the “normal precipitation” half to pour one cup (8oz, 237mL) of water on the top portion of the tray. Groups that represent extreme precipitation should pour 2 cups (16 oz/ 473 mL) of water on the top of their trays.
5. As written in the original activity: Distribute a set of BMP cards facedown for each student. Students should shuffle the cards and take turns drawing a card from the deck and reading the description of the BMP to the rest of the group. The student reading the card should ask the rest of

the group how they think this is beneficial.

6. Have students shuffle the cards again and place face down. Draw two or three BMP cards and follow the instructions for the number of sponges indicated on the card that should be removed, unwrapped and placed back into the tray. Student should record the BMPs they are implementing on the **Student Copy Page—Stormwater Resilience Data Sheet**.
7. Continue the activity as written with the “average” groups pouring 1 cup of water and the “extreme” groups pouring 2 cups of water on their trays. Use the **Student Copy Page—Stormwater Resilience Data Sheet** to record answers. (*Option:* record answers in a spreadsheet to see the results graphically. A template can be downloaded at www.projectwet.org/climate).
8. Make a class chart on the board comparing groups' results. Ask each group to write on the class summary chart the BMPs they used, along with their final volume. Each student group pair will have used a different set of BMPs. What would have happened if the tray was filled with BMPs (all



photo credit: Jchannel/Shutterstock

the sponges were unwrapped)?
(*Option*: compare an average and extreme precipitation event with all the sponges unwrapped and compare the two!)

9. What do students notice about the “extreme” precipitation versus “average” precipitation runoffs? Which BMPs allowed for the most absorption? What do city managers need to take into account when planning for increased precipitation from extreme weather events in the future?

Part III

Building Climate Resilience

1. Have students go to EPA Case Studies. Assign student groups various case studies from this list.
2. Have students report on the projects implemented in the location assigned to them.

Wrap Up

Reflect on what happens with stormwater runoff. Where does it go (local water source) and what sort of pollutants or materials are carried with it? What does this mean if there is a greater amount of stormwater runoff? Will all the water be able to exit your city through the storm drains?

Climate Resilience Assignment

Have students research and write a paragraph about what your city is doing. Is your city implementing BMPs? Is there a plan if flooding occurs/sea levels rise, etc?

Extensions

The *Extensions* in the Guide offer options to discuss how climate change may affect your local community. Use the *Extensions* as originally written as well as the following Extension suggestion:

Have students take photos around campus and use design software (or draw depending on resources avail-

able) to map out where BMPs would be best suited.

Background Resources

U.S. Environmental Protection Agency (EPA). Climate Adaptation and Stormwater Runoff
<https://www.epa.gov/arc-x/climate-adaptation-and-stormwater-runoff>

For Part II of the Activity:

U.S. Environmental Protection Agency (EPA). Case Studies for Climate Change Adaptation.
<https://www.epa.gov/arc-x/case-studies-climate-change-adaptation#tab-2>



photo credit: Project WET Foundation

Permeable	Impermeable
1.	
2.	
3.	

Runoff Data Collection Chart

Round	BMP(s)	Original Water (average)	Amount Runoff	Amount absorbed	Observations
1	-	8 oz/ 237 mL			
1	-	16 oz/ 473 mL			
2		8 oz/ 237 mL			
2		16 oz/ 473 mL			

Project WET's SMAP Activities

photo credit: NASA



“The Breathing Boreal Forest” and “Dirt to Dinner” were developed with funding from the NASA Jet Propulsion Laboratory (JPL). They were developed to be used in conjunction with NASA’s Soil Moisture Active Passive (SMAP) mission launched in 2015. Project WET worked with JPL scientists to develop these activities, using information they provided on the importance of collecting soil moisture and freeze-thaw data.

SMAP’s instruments were designed to examine the top 2 inches (5 centimeters) of soil, even through clouds and moderate vegetation cover, producing the highest-resolution, most accurate soil moisture maps ever obtained from space. It measures not only soil moisture but also freeze-thaw cycles, as it can only measure liquid water in the top layer of soil, not frozen water (ice). Scientists can measure soil moisture at different times of the year and compare when the ground is frozen (no data) to when it thaws.

Unfortunately, at launch the satellite proved unable to collect some of the data it was supposed to due to

a radar failure. However, the satellite remains in space collecting some data and NASA is hopeful it will collect some of its intended data, too.

Since their development, these two SMAP activities—one on soil moisture (“Dirt

to Dinner”) and one on freeze-thaw cycles (“The Breathing Boreal Forest”)—have been provided to educators free of charge on the Project WET store. They are included in this lesson plan as both activities teach concepts directly related to climate change.

“Dirt to Dinner” gives students a solid introduction to soil and water, how water can be stored underground and the importance of soil health and adequate water. This activity can be used to teach climate change by having students examine changing precipitation patterns and global temperatures over time to make predications for how these variables can affect soil moisture, groundwater, atmosphere and plants. Have students check out NASA’s Climate Time Machine and Trends in U.S. precipitation over 100 years, which allows users to see how variables that affect soil (like temperature and precipitation) have changed over the past 100-200 years.

“The Breathing Boreal Forest” addresses a changing climate by looking at the global carbon cycle

over time. The provided graph and data show evidence for increasing carbon emissions while showing how plants contributed to the carbon cycle.

Connections to STEM

The complex nature of these activities allows for deep systems thinking—a critical component of STEM. Furthermore, if coupled with data and information from the SMAP satellite, as originally intended, these activities integrate multiple disciplines and subjects (especially if reading on SMAP is assigned to students). Bringing in data as suggested in the *Extension* of “The Breathing Boreal Forest” and as suggested above for “Dirt to Dinner” will further enrich STEM connections.

Careers

Botanist - Botanists are biologists who specialize in studying plants. Botanists study various aspects of plants, ranging from algae to giant redwood trees. Understanding plant health in an ecosystem is important to environmental health as well as understanding the effects of a changing climate. Some botanists specialize in agriculture and understanding crops’ resilience to various environmental factors such as climate, disease and pest control.

Additional Educator Resources

Links to the SMAP satellite mission:

- <https://smap.jpl.nasa.gov/> - about SMAP mission, science and data
- <https://www.nasa.gov/smap> - NASA’s dedicated webpage to SMAP including links with ad-

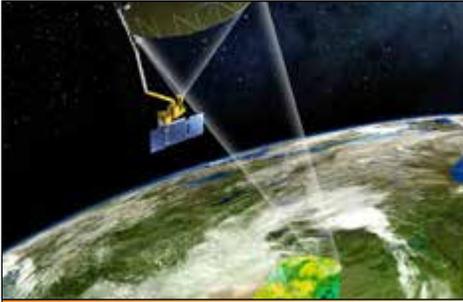
- ditional information on climate, earth, land and water.
- <https://smap.jpl.nasa.gov/science/objectives/> - a link to SMAP's science page including information on the carbon cycle and ecosystems, freeze/thaw and soil moisture.
- Graph of freeze/thaw data over a year during different years: <https://smap.jpl.nasa.gov/resources/50/>
- Trends in Precipitation over the last 100 years: <https://nca2014.globalchange.gov/highlights/report-findings/extreme-weather#graphic-20984>

Other resources:

- Data on freeze thaw from 1979-2016: <https://nsidc.org/data/nsidc-0477/versions/4>
- NASA's "Climate Time Machine." Students can explore several relevant links to Sea Ice, Sea Level and Global Temperature: <https://climate.nasa.gov/interactives/climate-time-machine>



photo credit: pexel_pixabay



The Breathing Boreal Forest

The vast Northern boreal forest “breathes” so we can all breathe a little easier.

Grade Level

Middle School

Subject Areas

Science, Math, Environmental Science

Duration

Preparation time: 30 minutes-2 hours (to freeze bread)

Activity time:

Warm Up: 5-10 minutes

Part 1: 10-20 minutes

Part 2: 30-45 minutes

Part 3: 20-30 minutes

Wrap Up: 5-10 minutes

Setting

Classroom, schoolyard, park

Skills

Gathering information (observing), Analyzing (identifying components and relationships, comparing, discussing), Interpreting (generalizing, drawing conclusions, relating, identifying cause and effect), Applying (decision making), Presenting (demonstrating, describing)

Vocabulary

Boreal forests, carbohydrates, carbon cycle, carbon dioxide (CO₂), coniferous trees, diurnal, dormancy, drought, fossil fuels, freeze/thaw cycle, frost events, greenhouse gas, hardy, photosynthesis, precipitation, sink, temperate climate, tender

Standards

NGSS: MS-LS2-1

Supports as written:

MS-LS2-4

Climate Change Framework

Earth System Impacts (Atmosphere)

Summary

In this activity students play the role of coniferous trees. First they learn about seasonal freeze/thaw cycles and dormancy through a game of tag. Students then juggle complex environmental factors to try to survive a growing season in a changing climate. Connections between freeze/thaw cycles, photosynthesis and the global carbon cycle are explored.

Charting the Course

Project WET’s *Molecules in Motion* activity is a fitting review of the physical states of water and the how they change. Project WET’s *SMAP Dirt to Dinner* Activity about soil moisture is a good lead up to this activity, especially Part 3 and 4. Project WET activities are found in the *Project WET 2.0 Curriculum and Activity Guide*. Project WET SMAP activities can be found online at: www.projectwet.org/SMAP.

Objectives

Students will:

- observe that materials containing water are subject to the same physical changes as water (e.g. freezing and thawing).
- demonstrate how seasonal freeze/thaw cycles affect trees.
- discuss that plants exhibit different behaviors/characteristics during growing season than during dormancy.
- analyze the effect of daily frost events on plants.

- explore how temperature and water fluctuation affect growing seasons of plants.
- explore how increased global temperatures affect growing seasons of plants.
- recognize that plants play a major role in the global carbon cycle.

Materials

Warm Up

- Two slices of bread—one normal, one frozen
- Whiteboard
- Marker

The Activity

Part 1

- **Freeze/Thaw Nametags** or costumes (Summer costume could be sunglasses and Winter costume could be hat and gloves)
- Boundary markers (cones, rope, etc.)

Part 2

- Boundary markers (cones, rope, etc.)
- **Tree Cards** (one per student)
- Survivor points—use small numerous objects such as paper squares, bright beads, poker chips, or noodles (you will need up to twelve per student)
- Container for survivor points
- **Spinners**
- Pencil
- Large paper clip
- **Growing Season Chart (15 Days)**

Part 3

- All materials from Part 2
- **Growing Season Chart (17 Days)**



Boreal forest covers vast reaches of Earth's Northern latitudes.

PHOTO CREDIT: Artipilot/iStockphoto

Wrap Up

- **Global Carbon Cycle** diagram
- **Atmospheric CO2 Concentration** diagram

Making Connections

Relatively tiny amounts of water in the soil make it possible for plants to grow on our planet. A few degrees difference in temperature can mean the difference between frozen and liquid water and can drastically affect how plants grow. The role of plants is larger than we may imagine—impacting the very air we breathe.

Background

Water changes states—from solid, to liquid, to gas—as temperatures fluctuate. We often visualize this as ice, liquid water and water vapor. When water is contained inside another material it is still subject to changes in state with change in temperature, and these state changes can affect the properties of the material. For example, when outside

temperatures drop below freezing, water inside plants and soil freezes, halting processes that require liquid water. When temperatures warm up above freezing again, the water contained in plants and soils melts and the plants and soil thaw out again. Throughout the year, in **temperate climates** (climates that vary significantly from winter to summer), annual **freeze/thaw cycles** occur seasonally (winter/summer), but **frost events** (warm days, freezing nights) can also occur **diurnally**—on a daily basis. This activity will explore the impacts of seasonal freeze/thaw cycles and daily frost events on soil, plants and global systems.

Soil is comprised of four components—mineral material, organic material, air and water. Water in soil is extremely important to plant growth. When this water freezes, it becomes unavailable to plants and limits growth. (See Project WET SMAP *Dirt to Dinner Activity* to further explore water in soil.)

Plants need the right amount of water to survive and grow—not too much and not too little. Plant tissue ranges from about 45 percent water (for woody parts such as tree trunks), to 95 percent water (for leaves). Plants get the water they need by absorbing it through their roots. The amount of water available to a plant can change depending on the temperature and precipitation, and these factors change throughout the growing season.

The amount and type of **precipitation** (rain, hail or snow) can affect plant growth. Floods bring excess water and can damage or kill plants. **Drought** (extended period of below-average precipitation) conditions might not provide enough water for plants to grow.

When temperatures drop below freezing, the water contained in plant tissue is subject to freeze. The amount of damage done to some plants by freezing temperatures depends on the type of plant (including where it

The Breathing Boreal Forest

normally grows and the temperatures it is used to), the age of the plant and the speed, degree and duration of the temperature drop. For some plants, one night when temperatures dip below freezing could kill the plant entirely, for example, citrus trees, avocado trees, succulents and bougainvillea. Other plants, for example trees such as **coniferous** trees (evergreen trees, like spruce or pine) that live in temperate climates have evolved the ability to become dormant to survive the winter. **Dormancy** means the plant's processes slow almost completely. When temperatures rise again snow melts, water in the soil melts and water in the trees melts causing liquid water to be available again. Plants that have been dormant "wake up" again and start to grow.

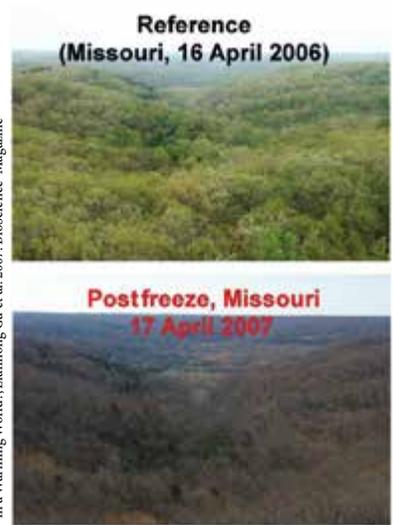
Warm temperatures also affect plants because as water heats up it evaporates more quickly. High temperatures can remove water from both the soil and plant tissue.

Growing season refers to the period of

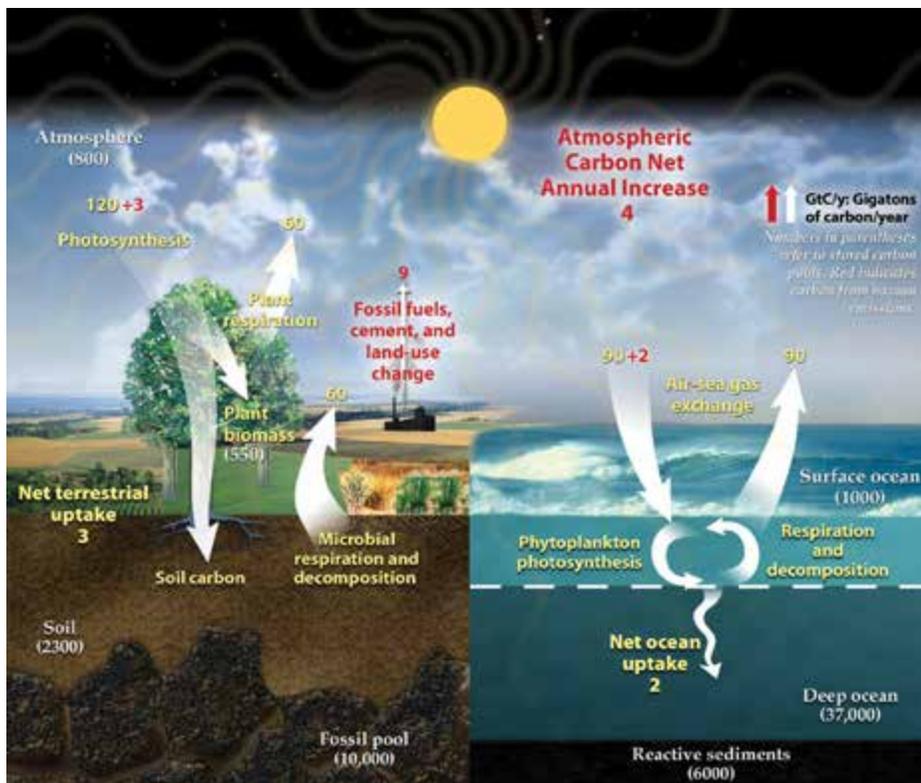
time that plants are able to grow. In warm climates, plants may be able to grow year round. In temperate climates, growing season is the time between the spring thaw and the fall/winter freeze. During the growing season, plant processes such as **photosynthesis** (the process through which green plants produce sugar for energy) occur.

Periods of transition occur as seasons change. For example, trees do not go into, or come out of dormancy overnight. Freezing or thawing first affects their leaves (or needles), then branches, then trunks and finally the soil over a period of one to three weeks. During these transition times, days are warm with thawing conditions during the afternoon and nights are cold with frozen conditions in the morning. A frost event occurs when vegetation is thawed and trees are growing and then suddenly temperatures drop below freezing potentially damaging the vegetation. In the spring, plants may start to grow during the

PHOTO CREDIT: The 2007 Eastern U.S. Spring Freeze: Increased Cold Damage in a Warming World?, Lianhong Gu et al. 2007. BioScience Magazine

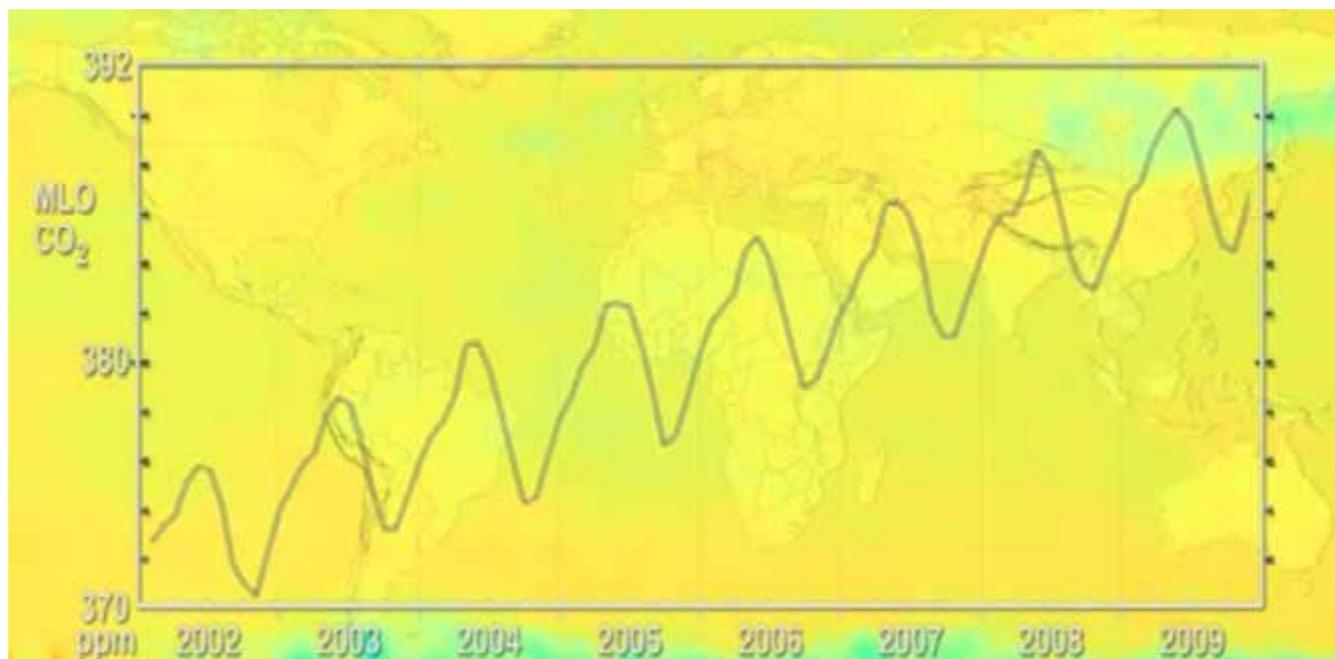


warm days only to be subjected to freezing temperatures at night. Plants are extremely vulnerable to frost events at the beginning of the growing season. New buds and flowers are their most vulnerable parts. These frost events can destroy new growth and lead to a year with no fruit or flowers, or kill plants and ruin crops entirely. For example, the first photo above was taken in Missouri in 2006 and then on the same date one year later in



The Global Carbon Cycle.

PHOTO CREDIT: U.S. DOE. 2008. Carbon Cycling and Biosequestration: Integrating Biology and Climate Through Systems Science; Report from the March 2008 Workshop, DOE/SC-108, U.S. Department of Energy Office of Science (genomicscience.energy.gov/carboncycle/).

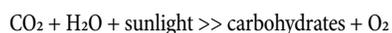


This graph shows how concentrations of carbon dioxide in the atmosphere change seasonally primarily driven by photosynthesis in boreal forests.

CREDIT: Aqua/AIRS Carbon Dioxide, 2002-2009, With Mauna Loa Carbon Dioxide Graph

2007 after a very fast and cold frost event that occurred.

The start of the growing season marks the beginning of photosynthesis, which occurs throughout the growing season until the plant becomes dormant again in the fall. During photosynthesis **carbon dioxide (CO₂)** (a colorless gas comprised of one carbon and two oxygen atoms) is absorbed from the atmosphere and combines with water (H₂O) and, driven by sunlight, produces **carbohydrates** (sugars), which provide food for plant growth and oxygen (O₂) which is released to the atmosphere.



When measured on a global scale, the impact of the removal of CO₂ from the atmosphere by plants during the growing season becomes evident. Plants play a role in the **carbon cycle**—the cycling of CO₂ in our atmosphere. For example, **boreal forests** (huge forests of coniferous trees mainly located in the Northern Hemisphere) act as carbon **sinks** (materials that absorb and remove carbon from the atmosphere) during

the growing season, which helps moderate the overall amount of CO₂ in the atmosphere naturally. The above graph shows seasonal change in levels of CO₂ in the atmosphere. The seasonal decrease in CO₂ is primarily driven by vegetation in the Northern Hemisphere. It's as if the forests are helping the planet to breathe in and out.

Why does this matter? CO₂ is a **greenhouse gas**. Greenhouse gases are gases that cause Earth's atmosphere to retain heat. More CO₂ in Earth's atmosphere leads to increased global temperatures. CO₂ is added to the atmosphere both through natural processes such as decomposition and ocean gas exchange, and by humans through the burning of **fossil fuels** (coal, oil and natural gas), waste and wood.

How does this all tie together? Temperature trends for approximately the past hundred years (since the industrial revolution) show an increase in global temperatures. Climate change has led to a longer growing season in the northern high latitudes. It has also led to more frost events that have the potential to kill forests. Northern boreal forests play

an important role in the global carbon cycle, but increasing frost events threaten their survival. The loss of these trees would mean the loss of an important CO₂ regulating mechanism for our planet.

Procedure

▼ Warm Up

- Gather the students and pass around a normal slice of bread. What makes up a slice of bread? (flour, sugar, water, etc.) Does this bread contain water? Explain to the students that although we cannot see liquid water in or on the slice of bread, the plants and materials making up the bread contain water.
- Now pass around a frozen slice of bread. Ask students to make observations about both pieces of bread and list their observations on the board in two columns. Are the properties of the frozen bread the same or different as the properties of frozen water? Does water contained inside a material change the materials properties as temperature changes? Leave the frozen bread out and

allow the students to continue to add to their list of observations as it thaws. (You could also toast the bread to represent very warm and dry conditions and observe changes).

▼ The Activity

Part 1

1. **Explain to the students that water in soil and water in plants is affected by changes in temperature, just like the slice of bread from the Warm Up.** Discuss that temperatures change in both seasonal (winter and summer) and daily (day and night) cycles. Ask students at which temperature water freezes. (32°F).
2. **Ask students to think of properties of soil in the summer (warm, soft, wet, muddy).** List them on the board. Ask students to think of properties of soil during the winter (hard, covered with snow, dry). List them on the board. Ask students to list properties of plants in the summer (you may want to choose a certain type of plant that the students are familiar with) (green, flexible, growing, flowers). Ask students to list properties of plants during the winter (dead, yellow, brittle, dry). Discuss how plants and soil change seasonally.
3. **Explain to students that seasonal freezing and thawing can have an effect on plants.** Do any plants survive the winter? (Yes, imagine trees and lilacs) Do any plants not survive the winter? (Yes, imagine vegetables in the garden that have to be replanted every year).
4. **Explain to students that they are going to be playing a tag game that demonstrates how plant growth can be affected by seasonal freeze/thaw cycles.** The game will demonstrate how plants that survive the winter freeze and thaw—the process of entering and emerging

from dormancy. Explain that students will represent coniferous trees for this activity. Ask students what they think happens to this type of tree during the winter. Do they die? Explain that trees become dormant during the winter and their processes slow virtually to a stop.

5. **Set up boundaries for a tag game appropriate for your group size.**
6. **Choose two students to be “it”.** One represents Summer and the other Winter (give each student a **Freeze/Thaw Nametag** or costume). Summer is trying to keep as many trees growing as possible, while Winter is trying to keep as many trees dormant as possible. Explain to students that if they are tagged once by winter their needles (fingers) freeze and they must fold them into a fist but can keep running, if tagged again by winter their branches (arms) freeze and they must run around with their arms at their sides. If tagged a third time by winter their trunk (whole body) freezes and they must remain where they are. Summer can “thaw” stationary frozen trees by tagging them several times. If tagged once their needles thaw and they regain the use of their fingers. If tagged twice their branches thaw and they can move their arms, and three times thaws their trunk and they can run around again.
7. **Play several rounds of the tag game so different students can be “it”.**
8. **When the game ends, discuss what happened to students as trees.** When winter comes, trees freeze from the outside in (leaves, branches, trunk, soil) and become dormant. As summer starts, they begin to thaw from the outside in (leaves, branches, trunk, soil). These periods of thawing can last a few weeks and are called transition periods.

Part 2

1. **Students now understand seasonal freezing and thawing of trees, and the transition periods in-between.** They will now focus on the growing season of plants and how fluctuations in temperature and precipitation can affect plant growth.
2. **Ask students to think about what happens when spring begins and plants start to grow.** Ask them to list things that could affect plant growth and discuss how each might affect plants (e.g. temperatures—warm and cold, hail, rainstorms, flooding, etc). Ask students if they have ever experienced a warm spring day when temperatures then dropped below freezing at night. They may have seen frost on the grass after a night like this. This is called a frost event. Frost events can occur during and after transition periods as summer begins and ends. Frost events can be very dangerous to plants—especially young plants just starting to grow.
3. **Now ask the students to think of other factors that could affect plant growth as the growing season (summer) continues and discuss how each might affect plants (e.g. hot temperatures, rainstorms, dry conditions).** These factors can also be dangerous to plants.
4. **Just how dangerous environmental changes are for plants depends on the type and age of plant.** The speed, degree and duration of the temperature change and the amount of water available to the plant are also influential.
5. **Explain to students that they are going to be playing a game similar to, but more complicated than “Red Light, Green Light” that demonstrates how plant growth can be affected by various factors**

during the growing season.

6. In the game, students will again represent coniferous trees. However, not all trees and plants are affected by environmental factors in the same way. Plants that are more **hardy** (capable of surviving harsh conditions), are more likely to survive more frequent, longer and extreme cold or hot temperatures than more **tender** (less capable of surviving harsh conditions) plants. Coniferous trees are hardy plants, but even the same type of plants vary in their ability to survive harsh conditions. Older, more mature plants often fair better than younger plants. Each student will receive a **Tree Card** that will tell them if they will be a young, middle-aged or mature coniferous tree. In this game, different-aged trees have different “survivor powers” based on how hardy they are. The more likely a plant is to be able to survive changing environmental conditions, the more “survivor points” it will start out with. Points are represented by your choice of small objects. Each student starts with six survivor points because coniferous trees are hardy plants. They then receive additional points based on their maturity. For example, a student who is a “mature tree” receives six additional points to start the game with twelve points, whereas a student who is a “young tree” only receives two additional points and starts the game with eight. Based on this system, each student should receive the appropriate number of “survivor points” to use during the game (use of these points is explained in detail below). **Tree Cards** have a tear-off coupon to redeem for the appropriate number of survivor points. Distribute the appropriate number of survivor points to each student (six plus however many their **Tree Card** gets



PHOTO CREDIT: bozhdb/iStockphoto

Frost events, especially in the springtime early in the growing season, can be trouble for plants.

them).

7. Other factors that affect a plant’s ability to survive through the growing season include how cold or hot it gets (temperature), how long it stays cold or hot (duration), how fast the temperature changes (speed) and the amount of water available to the plant (which is also affected by temperature).

Different sets of spinners will be used to determine the environmental conditions throughout the growing season.

8. Set up two boundaries in a large open space (it may take some experimentation to determine how far apart to place the boundaries). Line the students up along one of the boundaries. Explain that this

boundary represents the start of the growing season—trees have survived their transition period from winter to spring and are ready to grow.

9. **Explain that the other boundary represents the end of the growing season.** The goal is for trees (students) to survive the growing season and make it to the other side.
10. **Explain that you, the instructor, will be announcing the environmental conditions for fifteen days throughout the growing season—five early in the early summer, and ten in the middle to late summer.** Conditions for each day will be determined by several spinners (see **Spinner** pages). The first set of spinners is designed to represent typical early season conditions in a temperate climate when temperatures can fall below freezing at night. If this condition occurs, other spinners are used to determine the speed and duration of the temperature drop. A fourth spinner determines precipitation and water availability. Each factor on a spinner includes directions for students to move forward (grow) or backwards (become stressed). Explain to students that they (trees) will only be able to move forward (grow) when the weather is the right temperature and the right amount of water is available. The plant will be stressed if the temperatures are too hot or cold, or if there is not enough or too much water available. Warm weather will promote growth, however if it gets too hot for too long the tree might become stressed. For each day, the instructor will spin the spinners, announce the instructions and the students will move accordingly. Also, the instructor (or a volunteer) should record each day's conditions on the **Growing Season Chart (15 days)**.

11. **Throughout the game, anytime students are asked to move back, they have the option of “spending” their “survivor points” so that they don’t have to move back (or move back as far), thus, taking advantage of the characteristics that make them more hardy.** For example, if the temperature spinner dictates that students should move forward seven steps, and a severe thunderstorm on the precipitation spinners causes them to take three steps back, they can “spend” three “survivor points” and maintain their position. When a student runs out of survivor points he/she must take the step option. If a student steps back far enough to reach the starting line, he or she (tree) has been stressed too much to survive and will not grow anymore during that growing season. Students who are “out” can sit at the starting line or help with the spinners and condition recording. As conditions are established through the spinners, students may raise their hands at any time to cash in “survivor points”.
12. **Play fifteen rounds of the game, representing five early summer days and ten mid-late summer days.** Use the Early Summer Spinner set for the first five rounds and the Mid-Late Summer Spinner set for the last ten rounds. Some students should end up back at the start, while others will make it to the end, depending on how all the factors play out.
15. **After fifteen rounds, gather the students to discuss what happened.** Review the conditions from the growing season by referring to the **Growing Season Chart (15 days)**. What factors and conditions affect the growth of plants? (type and age of plant, day and nighttime temperatures, frost events, the speed and duration of below freezing

temperatures, precipitation and water availability) What factors help plants survive a growing season? (hardy, mature plants, not too much or too little water, few or no frost events) What factors make it more difficult for a plant to survive through a transition period? (tender young plant, too much or too little water, extreme temperatures, frost events)

14. **Play the game again allowing students to become a different aged-tree for each round.**

Part 3

1. **Increasing temperatures have been recorded all around the planet for many years.** Scientists have seen an overall earlier spring thaw in the northern high latitudes (areas North of 45 degrees North).
2. **To demonstrate this, play the game from Part 2 again, with students in the same tree age roles they just had, but move the beginning boundary further away from the end (to represent a longer growing season).** This time, play seventeen rounds—seven days of early summer and ten days of mid-late summer. Record conditions on the **Growing Season Chart (17 days)**.
3. **At the end of the game gather students to discuss any differences this change might have introduced.**

▼ Wrap Up

- Use the **Global Carbon Cycle** and **Atmospheric CO₂ Concentration** diagrams and what the students learned through this activity to inspire a discussion about plants role in the carbon cycle and how increased global temperatures might affect it.

Assessment

Have students:

- make observations about materials

<p>frozen and thawed that contain water and compare and contrast to the physical properties of frozen and thawed water. (Warm Up)</p> <ul style="list-style-type: none"> • demonstrate the effect of seasonal freeze/thaw cycles on trees. (Part 1) • discuss the concept of dormancy and what it means for plants in relation to seasonal/freeze thaw cycles. (Part 1) • explain what a frost event is and how it can affect plants. (Part 2 and Part 3) • discuss ways in which a variety of factors including plant type, plant age, daytime temperatures, nighttime temperatures, temperature change (speed and duration) and precipitation might affect the growing season of plants. (Part 2 and Part 3) • explore how increased global temperatures affect growing seasons of plants. (Part 3, Wrap Up) • recognize that plants play a major role in the global carbon cycle. (Part 3, Wrap Up) <p>Extensions</p> <p>Follow weather reports for a temperate location to try to capture real data for daytime and nighttime temperatures, frost events, and precipitation events during a growing season. Watch for news stories or warnings about impacts on plants.</p> <p>Compare historical weather data to determine if growing season lengths are getting longer for a specific temperate region.</p> <p>Teacher Resources</p> <p>Videos</p> <p>NASA SMAP eClips Videos:</p> <p>Our World (elementary school level): http://bit.ly/1iXxQ4I</p> <p>Real World (middle school level): http://bit.ly/18DrZux</p> <p>Launchpad (high school level): http://bit.ly/IFYOU6Qb</p>	<p>Websites</p> <p>https://smap.jpl.nasa.gov/</p>	
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Summer

Winter



Young Coniferious Tree



PHOTO CREDIT: aloha78/iStockphoto

2 Survivor Points

Middle-aged Coniferious Tree



PHOTO CREDIT: Popkov/iStockphoto

4 Survivor Points

Mature Coniferious Tree



PHOTO CREDIT: underworld111/iStockphoto

6 Survivor Points

Young Coniferious Tree



PHOTO CREDIT: aloha78/iStockphoto

2 Survivor Points

Middle-aged Coniferious Tree



PHOTO CREDIT: Popkov/iStockphoto

4 Survivor Points

Mature Coniferious Tree



PHOTO CREDIT: underworld111/iStockphoto

6 Survivor Points

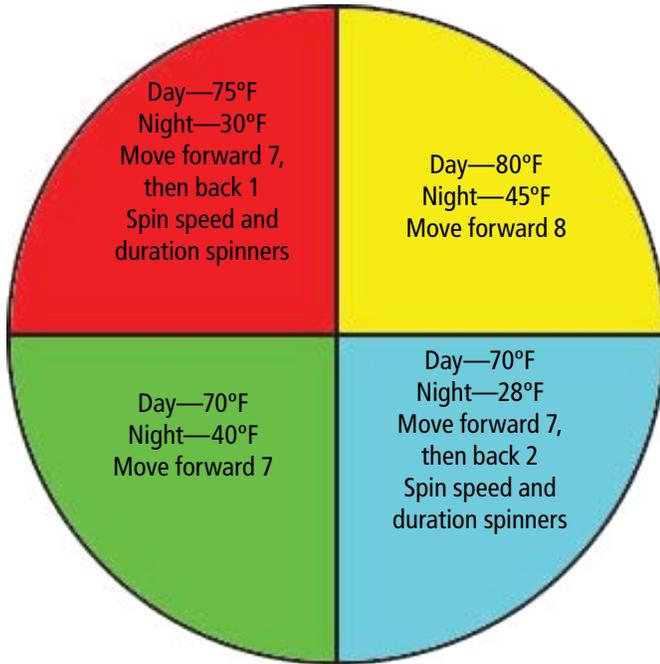
Early Summer Spinners

- Use to determine conditions for first five days.
- Spin 1 and 2 for each day (and record results).
- Use 3 and 4 if directed.

Directions for Spinners

- Lay spinner page on flat surface.
- Place a large paper clip so one end circles the spinner center.
- Hold a pencil vertically so that the point is inside the paperclip at the spinner center.
- Flick the paperclip with your finger to spin.

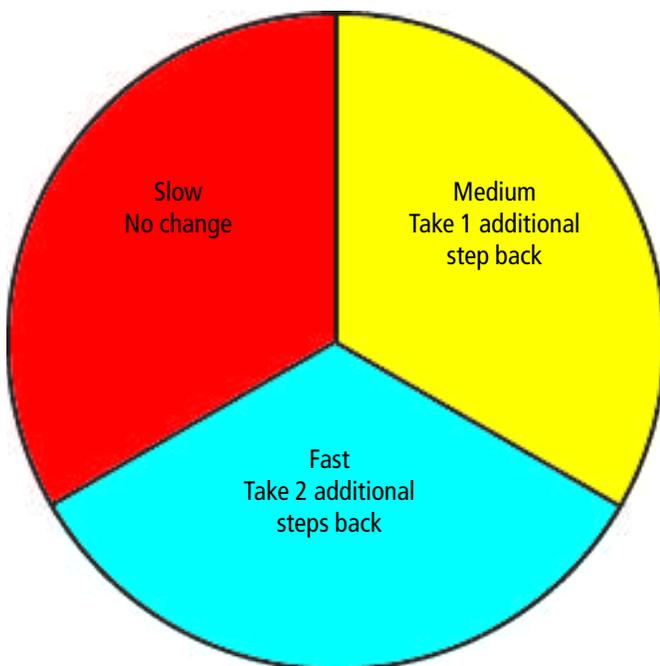
1. Day/Night-time Temperatures



2. Early Summer Precipitation



3. Speed of Temperature Drop



4. Freezing Temperature Duration

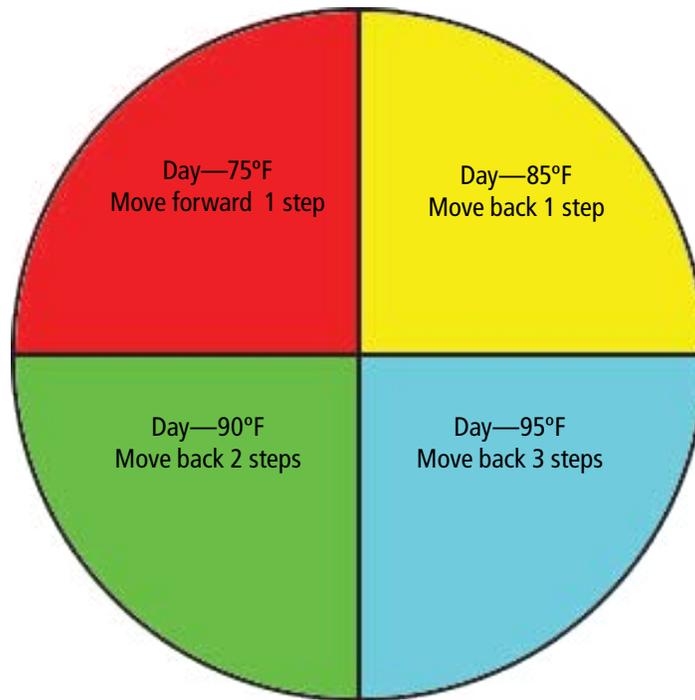




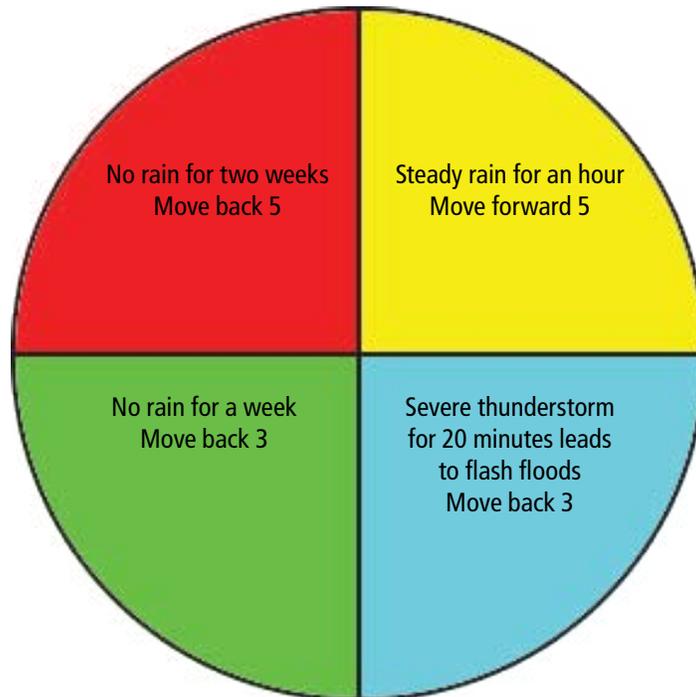
Mid-Late Summer Spinners

- Use to determine conditions for the last ten days.
- Spin and record results for both 1 and 2 for each day.

1. Daytime Temperatures



2. Mid-Late Summer Precipitation



Growing Season Conditions (15 days)							
Day	Daytime Temperature (°F)	Nighttime Temperature (°F)	Speed	Duration	Precipitation		
1							
2							
3							
4							
5							
6		above freezing					
7		above freezing					
8		above freezing					
9		above freezing					
10		above freezing					
11		above freezing					
12		above freezing					
13		above freezing					
14		above freezing					
15		above freezing					
Early Summer				Mid/Late Summer			



Growing Season Conditions (17 days)							
Day	Daytime Temperature (°F)	Nighttime Temperature (°F)	Speed	Duration	Precipitation		
1							
2							
3							
4							
5							
6							
7							
8		above freezing					
9		above freezing					
10		above freezing					
11		above freezing					
12		above freezing					
13		above freezing					
14		above freezing					
15		above freezing					
16		above freezing					
17		above freezing					
Early Summer				Mid/Late Summer			

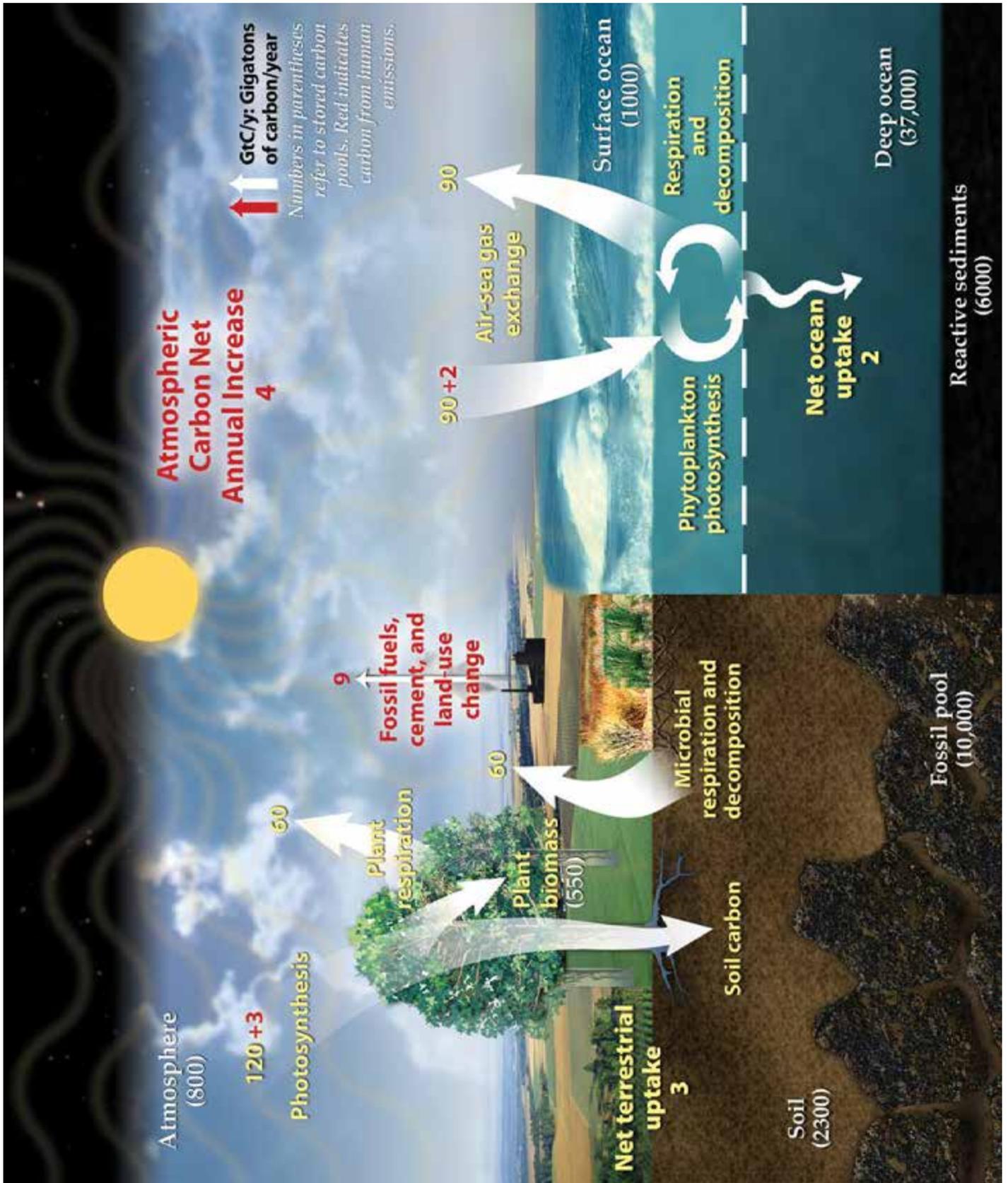
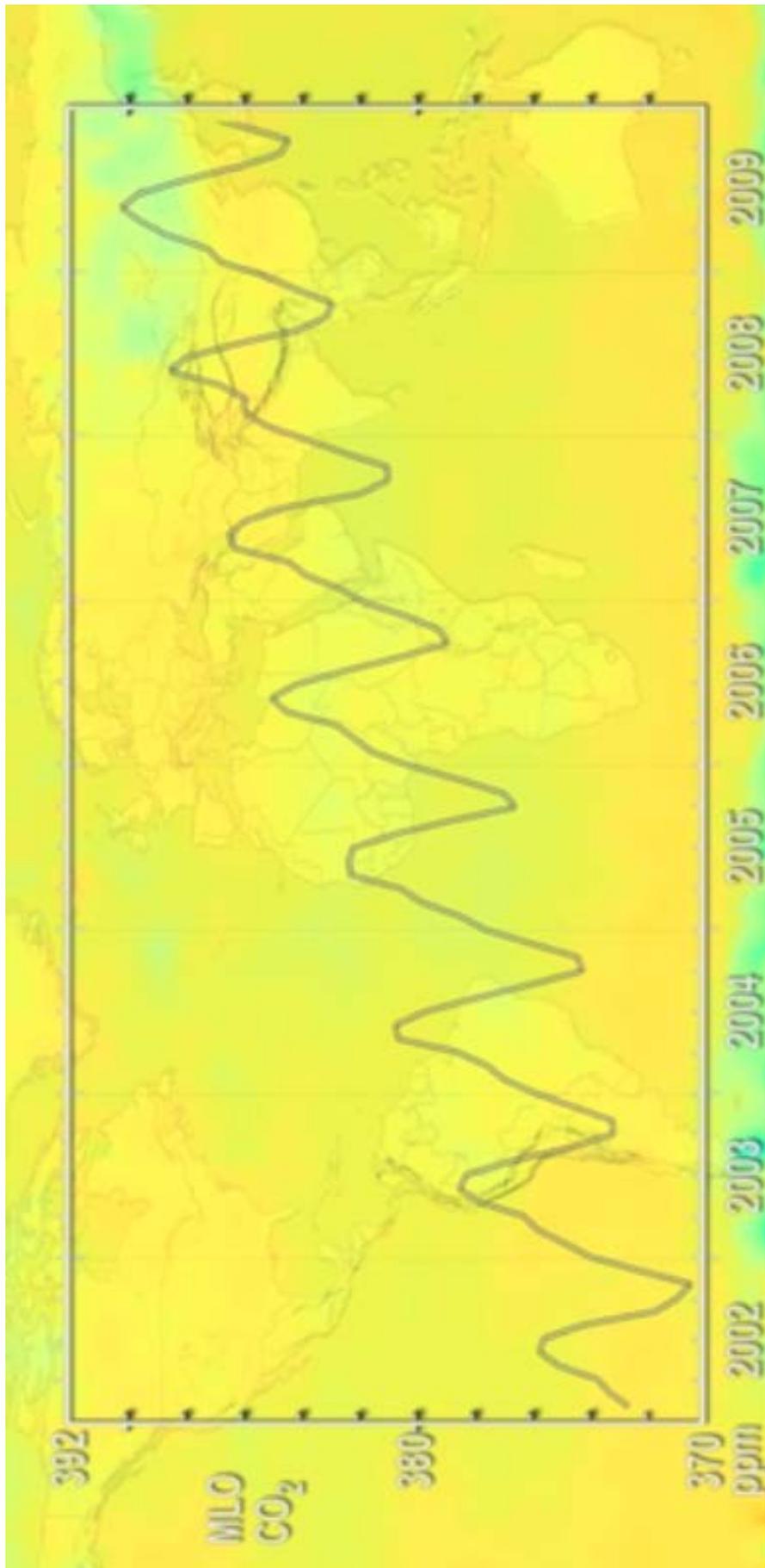
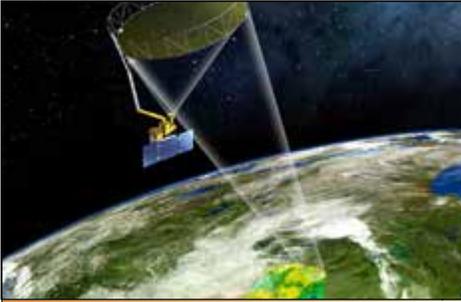


PHOTO CREDIT: U.S. DOE. 2008. Carbon Cycling and Biosequestration: Integrating Biology and Climate Through Systems Science; Report from the March 2008 Workshop, DOE/SC-108, U.S. Department of Energy Office of Science (genomicscience.energy.gov/carboncycle/).



CREDIT: Aqua/AIRS Carbon Dioxide, 2002-2009, With Mauna Loa Carbon Dioxide Graph



Dirt to Dinner

*How does 0.001 percent of Earth's water keep you from going hungry?
Soil moisture!*

Grade Level

Middle School

Subject Areas

Science, Math, Agriculture

Duration

Preparation time: 45-60 minutes

Activity time:

Warm up: 10-20 minutes

Activity: One-two 50 minute classes

Wrap Up: 30-45 minutes

Setting

Classroom, gymnasium, schoolyard, park

Skills

Gathering (observing), Organizing (charting), Analyzing (identifying components and relationships, discussing), Interpreting (relating, identifying cause and effect, making models), Applying (predicting), Presenting (writing, demonstrating)

Vocabulary

Adhesion, capillary water, cohesion, combined water, decomposed, drought, elevation, evaporation, experimental control, free water, gravitational water, hydrologic, hygroscopic water, infiltration, mineral material, organic material, pore spaces, precipitation, runoff, saturation, slope, soil moisture, soil texture, soil-water balance, surface tension, topography, transpiration, water table

Climate Change Framework Earth System Impacts (Groundwater)

**Human Impacts
(Agriculture and food)**

Summary

This activity gets students up and moving in a tag game format to learn about how water moves into, through and out of soil. Students use whole-body movement to model water, with soil, ground water, atmosphere and plants interactions.

Charting the Course

Prior to this activity you may want to review the water cycle with students. Project WET's *The Incredible Journey* ties in soil's role in the water cycle. Also visit www.DiscoverWater.org/water-cycle.

Properties of water, including surface tension (cohesion) and adhesion are explored in Project WET's *H2Olympics*. In Project WET's *Get the Ground Water Picture* students model water movement through sand, silt and clay. All of these activities can be found in Project WET's *Curriculum and Activity Guide 2.0*.

Objectives

Students will:

- list the four components of soil—minerals, organics, water and air.
- model processes by which water moves into and out of soil due to gravity, evaporation and absorption by plants.
- compare gravitational (free) and capillary soil moisture.
- explore how different environmental factors (precipitation, soil texture, vegetation, topography and temperature) affect soil moisture.

Materials

Warm Up

- Small plastic bag of soil
- Mixing bowl
- Sheet of paper (optional)
- Slice or loaf of bread
- Minerals—rocks and/or mineral samples
- Organics—twigs, leaves, grass
- Bottle of water
- Mixing spoon
- Magnifying glasses

Part 1

- Rope to mark boundaries
- Earth's Surface sign (**Soil Moisture Signs**)
- Soil Particle nametags
- Water Table sign (**Soil Moisture Signs**)
- Copies of *Dirt to Dinner Student Copy Page* (one per student)
- Pens or pencils
- Copy of *Answer Key*

Part 2 and 3

- All materials for Part 1
- Whiteboard and dry erase marker or large sheet of paper and marker
- Blue paper squares (or other objects, i.e. poker chips, total of sixty squares)
- Permanent marker
- Paper or plastic cup labeled "Atmosphere"
- Paper or plastic cup labeled "Surface Runoff"

Part 4

- All materials for Part 2
- Paper or plastic cups labeled "Soil Particle" (10)
- Paper or plastic cups labeled "Plant" (one per student)



Soil is comprised of mineral material, organic material, air and water.

PHOTO CREDIT: simplytheyu/iStockphoto

Demo Option

- Copy of *Dirt to Dinner Demonstration*
- Two egg cartons, one dozen each (optional)
- Markers
- Blue construction paper squares (at least thirty, approx. 0.5 inches square)
- Drinking straws (one per student)

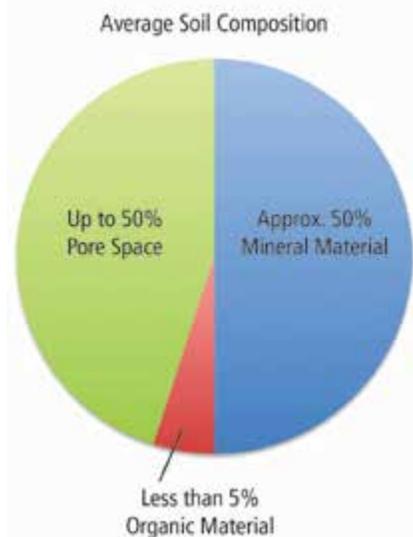
Making Connections

Do you ever think about soil when you are sitting at the dinner table? How about water? Perhaps you should start—you have soil moisture (the water in soil) to thank for all of the food on your plate! Soil moisture plays an important role in the food web. Soil moisture provides the water plants need to grow—plants which become ingredients in bread or feed the chicken or beef that end up feeding you. You may not realize it, but your life depends on soil moisture!

Background

We all know what soil is, but have you ever stopped to think about what soil is made

out of and why it is so important? Soil is the top layer of Earth's surface and it contains four main components—mineral material, organic material, water and air. **Mineral material** in soil varies mainly depending on what types of rocks are found in the area. Rocks break down to form sand, silt and clay, which have different sized particles (sand particles are larger than silt particles, which are larger than clay particles). The composition of soil varies based on sand, silt and clay content and particle size. **Organic material** includes **decomposed** (broken down) twigs, leaves and other plant and animal matter from the surrounding plants and animals. An average soil contains about fifty percent mineral materials by volume. Less than five percent of soil is comprised of organic materials. Spaces between the soil particles called **pore spaces** contain air, which can account for up to half of the soil by volume. Water content in soil varies over time and space due to a variety of factors that will be explored in depth in this activity. Water in soil is called **soil moisture**. Soil moisture



accounts for about 0.001 percent of the total amount of water on Earth, yet without it, plants would not be able to grow.

Soils play a role in Earth's **hydrologic** or water cycle. Water enters soil from above as **precipitation** (rain or snow) or snow melt, and from below as ground water rises. The top surface of the ground water is called the **water table**. Soils store some water, and

release most to ground water, plants, or the air. Water is absorbed through plant roots, moves through plants, and evaporates back into the atmosphere through a process called **transpiration**. Water in soil is subject to freezing, thawing or evaporating as temperatures fluctuate, which effects plant growth.

There are four types of soil moisture.

Gravitational water or **free water** is water that stays in the soil a short time. It usually enters the soil as precipitation and filters through to ground water below due to gravity. At times, all of the pore spaces in the soil may fill with water before drainage and **evaporation** (the conversion of liquid water to vapor) cause it to dry out again. This condition when all the air in soil is replaced by water is called **saturation**. Gravitational water is only available to plants while it is in the soil, before it filters to the ground water below or evaporates. Gravitational water plays a role in moving finer particles downward through the soil creating coarser topsoil and denser subsoil.

Capillary water is leftover after gravitational water drains out. Capillary water is the relatively small amount of water that is held between the soil particles due to the forces of **cohesion** (**surface tension**—the attraction of water molecules to other water molecules) and **adhesion** (the attraction of water molecules to other surfaces) that are stronger than gravity. Capillary water is the primary source of water for plants, which makes it extremely important in relation to our food supply.

The other two types of soil moisture account for a very small amount of the total water in soil, and though important for other reasons, will not be addressed in this activity.

Hygroscopic water forms a very thin film on soil particles due to adhesion. Plants are unable to access much hygroscopic water.

Combined water is water that chemically bonds with soil particles. The chemical bonds are too tight for this water to be available to plants. It is only released through additional chemical reactions.

The amount of capillary water in soil greatly affects the soil's ability to support plant life. Data about soil moisture can help crop growers produce the most robust yields. Soil moisture data also helps us better understand and predict weather and climate changes, early **drought** (an extended period of below-average precipitation that affects crop production and water supplies) warning signs, the extent of flooding and even help to identify possible spread of diseases caused by insects that breed in standing water.

Soil moisture is affected by a variety of factors including **soil texture** (particle size), precipitation, vegetation (amount and type) and **topography** (landforms—hills, valleys, etc.). In general, soil particle size and soil moisture are inversely related. Soil layers made up of large particles retain less soil moisture. This is mainly due to gravitational water **infiltrating** (permeating through open spaces) easily through the larger pore spaces between larger particles. More



Many factors, such as precipitation and topography influence the soil moisture available to plants.

PHOTO CREDIT: Joss/iStockphoto



Lack of soil moisture due to high temperatures can lead to loss of crops.

PHOTO CREDIT: saints 4757/iStockphoto

precipitation potentially means more soil moisture, but the type and intensity of the precipitation affect the amount of soil moisture, too. Long, moderate rainfall has opportunity to soak into the soil, increasing soil moisture content in soil layers. Short intense periods of precipitation can cause flash floods because the soil cannot absorb the precipitation fast enough. Topography also influences soil moisture content. For example, soil moisture varies with **elevation** (height on a hill) and **slope** (degree to which a surface is tilted). Higher elevations generally have lower soil moisture, while lower elevations generally have higher soil moisture. This is because water flows downhill due to gravity. For the same reason steeper slopes generally hold less soil moisture than flatter areas. The amount of vegetation cover also plays a role in soil moisture content. More vegetation cover leads to more organic ground cover, which protects the surface soil

from evaporation and retains soil moisture. Less vegetation cover leaves the soil exposed for soil moisture to evaporate.

On the ground, soil moisture for an approximately one square meter area can be measured using a theta probe like this



PHOTO CREDIT: Delta-T Devices

one, but with satellites we can measure soil moisture for much larger areas efficiently. NASA's new SMAP satellite will be able record soil moisture data for the first 5 cm depth of surface soil layer for areas between

3 to 36 square kilometers at a time, and will collect data for the entire planet once every two to three days.

Note to educators: The Warm Up for this activity reviews the composition of soil. Part 1 of this activity explores the types of soil moisture and the relationship between soil texture/particle size and soil moisture. Part 2 focuses on how precipitation and topography affect soil moisture. Part 3 adds temperature as a factor and Part 4 introduces the relationship between plants and soil moisture. The lesson builds upon itself, but the Warm Up and Parts 1-4 may also be used to teach each concept separately.

Procedure

▼ Warm Up

- Prior to the warm up, place a plastic bag of soil in the bottom of a mixing

bowl. You may want to cover it with a piece of paper or other item to hide it from sight.

- Tell students they will be learning about soil in the following activity. Then show them the slice or loaf of bread and ask them if they can explain how it is connected to soil. They will likely discuss how soil is necessary for growing plants, but not elaborate on how soil and plants interact or soil moisture.
- Discuss how bread is made from various ingredients such as flour, sugar, water, etc. Discuss how water is necessary to grow the plants from which these ingredients are made (water is needed to grow wheat to make flour and sugarcane to make sugar). Discuss soil moisture's importance to plants and hence, students' food supply.
- Tell the class that instead of baking a loaf of bread you are going to explore the recipe for soil.
- Ask students what ingredients they think you need to make soil.
- Into the bowl add: minerals (rocks); organics (leaves and twigs); a bottle of water (just place the entire bottle in the bowl); and air (you can pretend to mix in air from around you)
- Stir—remove soil sample and pass around.
- Let kids touch the soil and look at it with magnifying glasses.
- Explain that soils vary depending on their “recipe”—amounts of minerals, organics, water and air.
- Ask students to discuss how the amounts of the “ingredients” might affect the soil “recipe”.

▼ The Activity

Part 1

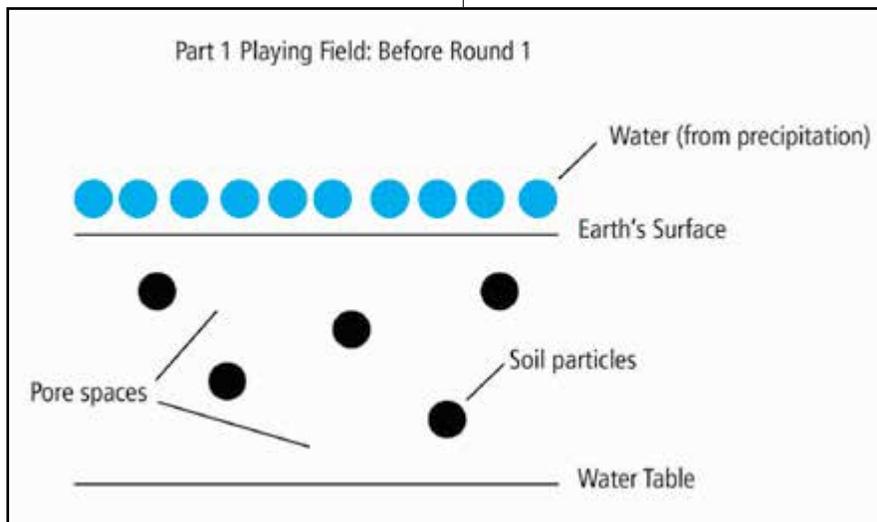
1. Explain to students that the group will now focus in on water in soils, or soil moisture. The group will

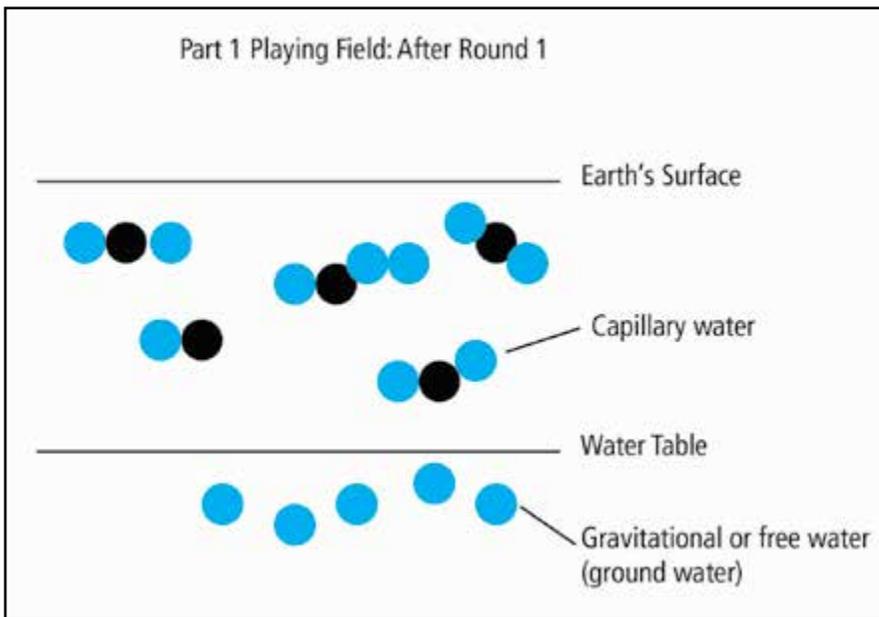
explore ways in which water moves into, through and out of soils, as well as environmental factors that affect the amount of soil moisture.

2. **First, students will play a game of tag to learn about how water moves through soil and important types of soil moisture.**
3. **Set up a playing field where one boundary represents the Earth's surface (mark with Earth's Surface sign), and the other parallel boundary represents the water table (don't mark with Water Table sign yet—the concept of the water table will be explained as the game progresses).**
4. **Choose five students to represent soil particles (both organic and mineral) and have them wear the soil particle nametags.** Students representing soil particles should stand between the Earth's surface and water table boundaries, facing the Earth's surface boundary. They should be scattered throughout the space so that they are near each other, but not touching. They will remain stationary but can lean and stretch to tag the other students. *(Note: it is critical that the five students representing soil particles fit into the defined playing field at such a density that some of the students representing*

water will be tagged. Be careful not to space the students representing soil particles out too far, or make the playing field too large. Adjust the size of the field accordingly.)

5. **All of the other students represent water.** These students will demonstrate infiltration of water from precipitation through the pore spaces (area surrounding the soil particles) in the soil.
6. **On your mark, they will run from the Earth's surface boundary to the water table boundary.** This represents water raining onto the Earth's surface and then infiltrating (permeating through open spaces) through the soil. The role of each of the soil particles is to attempt to tag and capture one or two of the students representing water. If a student is tagged, he/she links arms with the soil particle. Each soil particle can catch two waters—one for each arm. Students who are caught by soil (adhesion) can attempt to catch other waters (cohesion). Water captured represents capillary water.
7. **Allow the students to run across once.** Several students should be caught as capillary water. Pause the game and ask students to explain what happened (some of the water





that came from precipitation was retained by soil particles due to the attraction of water to water (cohesion) and water to other surfaces (adhesion) as it filtered through the pore spaces in the soil). Explain to the students that the water caught by soil particles is called capillary water. The amount of capillary water is the soil moisture content. Count how many students became capillary water for this round. Explain that capillary water is the main source of water for plants. Explain that the rest of the water that filtered through as gravitational or free water has crossed the water table (top most surface of the ground water) and has become ground water—most plants’ roots don’t reach deep enough to tap into the ground water. Place the Water Table sign at the water table boundary.

8. Explain that the size of pore spaces can affect how much water filters through the soil. For the next round, have the five soil particles spread out further across the field to represent large pore spaces. Was more or less capillary water retained than when the pore spaces were smaller? Less water should be caught during this

round and soil moisture content should be lower. Explain that this is an example of what might occur in a sandy soil where the particles are coarser or larger and so are the pore spaces which allows water to filter quickly through.

- 9. For a third round, decrease the size of the field and have the soil particles stand closer together.** This time more water should be caught than in either of the previous rounds. Explain that this is an example of what might occur in a clay-rich soil where particles are finer or smaller and pore spaces are smaller and water filters more slowly.
- 10. Hand out a copy of the Dirt to Dinner Student Copy Page to each student.** Have students label the diagram for Part 1 and make notes about how the soil moisture changed with changes in soil texture (you can discuss as a group—refer to **Answer Key** for explanations). Set **Dirt to Dinner Student Copy Pages** aside.

Environmental Factor	Characteristics	Game Setup
Precipitation	Average	30 waters
Soil Texture	Silty	5 particles, moderately spaced
Topography	Flat	Boundaries are straight and parallel

- 11. Reset the game and play several rounds to allow students to try various roles.**

Part 2

- 1. Now that students have a basic understanding about how water moves into and through soil, Part 2 will focus the effects of some environmental factors on soil moisture.**
- 2. Explain to students that other environmental factors besides soil texture affect the soil moisture.** Part 2 will focus on two of these factors: precipitation and topography. Write precipitation on the board. Discuss what precipitation means and brainstorm ways in which precipitation could affect soil moisture.
- 3. Explain to students that this first round will serve as an experimental control, or basis for comparison for additional rounds.** They will experiment in changing one factor affecting soil moisture in each additional round. The soil for the control round has the characteristics listed in the chart below (write them on the board—you can change each factor as it is addressed).
- 4. Set up the game again, pointing out how the control factors are represented.**
- 5. Choose five students to represent soil particles (both organic and mineral).** Students representing soil particles should stand between the Earth’s surface and water table boundaries, facing the Earth’s surface boundary. They should be scattered throughout the space so that they

are near each other, but not touching (same spacing as first round, Part 1). They should stand holding their hands out, palms upturned to collect water (blue paper squares) from the other students. Explain to everyone that for each round, you will secretly tell soil particles how many waters they may collect based on the environmental factors for that round. As soon as a soil particle gets that amount, they should put their hands down by their sides. All extra squares will be carried through to the ground water.

6. **The other students line up along the Earth's surface boundary.** They will be bringing the precipitation from the atmosphere into the soil. They should each gather blue squares that represent water from a cup labeled "atmosphere". For the first round the cup will contain thirty water squares (representing average precipitation). Divide the thirty squares by the number of students (minus the five soil particles) and instruct the students in how many squares each should take based on the class size—all thirty squares should be used (some students may have more than others).
7. **Explain to students that when the game starts, they will walk into the playing field.** Each soil particle will only be able to accept a certain number of water (in this case two squares each), but the other students won't know how many. (Secretly tell the soil particles that they can collect two squares each during this round.) As soon as a soil particle gets two squares, they should put their hands down by their sides. All extra squares will be carried through to the ground water.
8. Start the game. When all students have passed through to the ground

water, pause the game and have the soil particles count the amount of water they retained. This number will be the value for soil moisture content for the control round. Each additional round will examine how different factors affect the amount of soil moisture in comparison to the control round.

9. **Collect all the blue squares from the students.**
10. **Ask students to retrieve their Dirt to Dinner Student Copy Page.** Have them record their observations and soil moisture value for the control round in Part 2. Explain that for each factor each student will make and record a prediction as to whether the environmental change will increase, decrease or not change the soil moisture compared to the control round, and the reasons behind why they made that prediction. Then ask them to write down a prediction for the next round—how will a long, slow rainstorm affect soil moisture and why? For each round the instructor will also need to make adjustments to the game according to the **Answer Key**. Don't explain the changes you make to the students—they will predict how changes affect soil moisture and collect data to test their predictions.
11. **Set up for the next round using the Answer Key to guide the setup.** Place the cup labeled "atmosphere" outside of the Earth's surface boundary. Explain to the students that in this round, everything else will stay the same, but there will be a long slow rainstorm. This time, put sixty blue squares into the atmosphere cup to represent more available moisture. Secretly tell the soil particles they can retain four squares this time. Play the game the same as before, but this time students must

crabwalk to represent a slow rain. When all the students have reached the other boundary, have the soil particles count and report the new soil moisture content—it should be higher than the control round.

12. **Collect the blue squares from the students.**
13. **Have students record the soil moisture value for this round on their Dirt to Dinner Student Copy Page.** Then ask them to write down a prediction for the next round—will a short, intense rainstorm increase, decrease or not change the soil moisture as compared to the control?
14. **Set up for the next round. Explain to the students that in this round, everything else will stay the same, except precipitation.** There will be a short, intense rainstorm. Place the cup labeled "Surface runoff" near the Earth's surface boundary. Put sixty blue squares into the atmosphere cup to represent more available moisture. Explain that during an intense rainstorm there is not enough time for all the water to be absorbed by the soil and much ends up as **runoff** (precipitation that flows over the land surface)—even flash floods. To demonstrate and represent surface runoff take twenty squares out of the atmosphere cup and put them in the surface runoff cup where they are unavailable to students (there should be forty squares left for students in the atmosphere cup). Explain that the surface runoff cup represents water that cannot soak in to the soil fast enough during the intense storm. Secretly tell the soil particles that they can retain three squares each. Play the game the same as before. When all the students have reached the other boundary, have the soil particles count and report the new soil moisture content—it should be

higher than the control round, but lower than the long rainstorm round.

15. **Collect the blue squares from the students and remove the surface runoff cup.**
16. **Have students record the soil moisture value for this round.**
Discuss the relationship between precipitation and soil moisture. Return to your notes on the board. Discuss ways this model might be used to test other hypotheses about precipitation and soil moisture (e.g. how does snowmelt affect soil moisture? A fast snow melt, a slow snowmelt?).
17. **Now write the word topography on the board.** Discuss what topography means and specifically discuss elevation (top and bottom of a hill) and slope (gradual vs. steep). Explain that the soil on the top of the hill has less available moisture because water flows downhill due to gravity.
18. **Now have students study the topography diagram on the Dirt to Dinner Student Copy Page page.** Ask them to write predictions relating to each area of the diagram as to whether each area has higher, lower or the same amount of soil moisture as the control soil (flat).
19. **Discuss student predictions and actual soil moisture for topography factors.** Use the **Answer Key** for explanation.

Part 3

1. **When students have finished the topography section of the Dirt to Dinner Student Copy Page, return to the playing field.** This time we will experiment with changing the temperature. Ask students to think about what happens to water as temperature increases (it evaporates) and decreases (it freezes). Explain that water in soil is subject to these

same processes and that temperature has an effect on soil moisture. Explain that over time, soil loses capillary water through evaporation.

2. **Students will play a new control round to account for the addition of evaporation.**
3. **Set up the playing field as before with two boundaries, five soil particles spaced moderately.**
Precipitation will be average so put thirty squares in the atmosphere cup. Play the game the same as before, students must walk and the soil particles can each collect two squares. When all the students have reached the other boundary, pause the game. Ask the soil particles to count their waters and give a soil moisture content value. This should be the same as the initial control from Part 2. Now introduce the idea of evaporation. Explain that to some degree, evaporation is occurring all the time. The instructor, who represents evaporation from the soil, enters from the surface and removes one water square from each soil particle and returns it to the atmosphere. Now have the soil particles count and report the new soil moisture content. This number will represent the new control factoring in evaporation at the moderate temperature of 65°F. Collect all water squares. Have students record this soil moisture content on the **Dirt to Dinner Student Copy Page**.
4. **Set up for the next round. Explain to the students that in this round,**

everything else will stay the same, but the temperature will be 90°F.

Ask students to predict whether soil moisture will increase, decrease or remain the same as in the control round they just played. Put thirty blue squares into the atmosphere cup to represent average precipitation. Secretly tell the soil particles that they can retain two squares each. Play the game the same as before with students walking. When all the students have reached the other boundary, pause the game. Explain that due to the high temperatures, there is increased evaporation from the soil. The instructor, who represents evaporation from the soil, enters from the surface and removes eight of the ten water squares from the soil particles and returns them to the atmosphere. Now have the soil particles count and report the new soil moisture content. It should be lower than the control. Ask students to discuss the concept of drought.

5. **Reset the game the same as above.** This time, explain that temperatures have dropped below 32°F for several days. The soil and water has frozen and no one can move. Discuss what the consequences of freezing temperatures might be for soil and for plants.

Part 4

1. **Explain to students that in Part 4 they are going to learn why soil moisture is vital to plants, and therefore to humans.** Review that along with water, humans need food

Environmental Factor	Characteristic	Game Setup
Precipitation	Average	30 waters
Soil Texture	Silty	5 particles, moderately spaced
Topography	Flat	Boundaries are straight and parallel
Temperature	Average	65°F

to survive. Humans depend on plants as part of the food web to sustain themselves (humans eat plants and animals that eat plants).

2. **Explain to students that for this part of the activity, they will now become plants.** The field remains the same, but soil particles are now represented by ten soil particle cups, and the capillary water the plants need is represented by blue paper squares inside the cups. These cups are scattered throughout the playing field. Each cup contains five squares of water.
3. **The students line up along the Earth’s surface boundary.** Each student receives a cup labeled “plant”. They should choose a location to place their plant cup along the Earth’s surface boundary.
4. **Explain to students that when the game starts, they will represent their plant’s roots.** They will run into the playing field, locate a soil particle with capillary water, take one piece of paper, and return to their cup to deposit it. They will then run into the field looking for more water, collecting it one piece at a time. As long as their plant cup contains water, the plant stays alive.
5. **Explain to the students that plants are also constantly losing water to the atmosphere through transpiration.** This will be represented by the instructor systematically, and continually removing water one square at a time from each of the plant cups, and placing them into the cup labeled “atmosphere”.
6. **Tell the students they should continue to retrieve water from the soil and place it in their plant cup until they can’t find any more.** At that point they should return to their plant cup. Transpiration will continue

to occur. As the remaining water in their cups disappears, students should “wilt” (collapse on the ground) to represent the plant wilting.

7. **Ask the students to discuss how soil moisture affects plants, and how plants can affect soil moisture.** Assign students to write a paragraph on their **Dirt to Dinner Student Copy Page** addressing how soil moisture affects plants and plants affect soil moisture.

▼ **Wrap Up**

- Students have now examined a variety of factors that influence the amount of water in soil, or soil moisture. The balance between the amount of moisture maintained and lost as water goes into, through and out of soil is called **soil-water balance**. Students should understand that soil moisture is complicated, but they should also have some idea about how various factors specifically affect it.
- Gather the group with their **Dirt to Dinner Student Copy Pages** to discuss factors affecting soil moisture using the discussion prompts on the **Answer Key**. (Alternatively, you may choose to discuss each factor as you finish each part of the activity. It is not necessary to complete all activity parts for students to understand that many environmental factors influence soil moisture.)
- Discuss the importance of soil moisture in the food web. (Along with water, humans need food to survive. Plants are able to grow because of soil moisture. Humans depend on plants

as part of the food web to sustain themselves. Humans eat plants and animals that eat plants).

- Discuss seasonal changes in soil moisture based on temperature.
- Discuss diurnal changes in soil moisture based on temperature.
- Discuss ways in which multiple environmental factors could affect soil moisture at the same time. For example, discuss soil moisture scenario outlined in the chart below.
- Discuss additional scenarios varying more than one environmental factor.

Demo Option

1. **Complete the Warm Up to help students understand of the components of soil.**
2. **Use the Dirt to Dinner Demonstration provided, or create a three-dimensional model of the demo using two egg cartons (the advantage to using egg cartons is the demo can be displayed vertically for context).**
3. **Show students the model of the atmosphere, plants, soil and groundwater.**
4. **Start the demo by placing three squares of paper in each atmosphere cell and two squares in each ground water cell.** Explain that there is always water in the atmosphere and underground as ground water.
5. **Ask students what happens when it rains (water soaks into the soil).** Have students help you move paper squares from the atmosphere into the soil (you may want to demonstrate a

Environmental Factors	Characteristics
Precipitation	Intense 30 minute thunderstorm
Soil Texture	Sandy
Vegetation	Some vegetation cover
Topography	Steep slope
Temperature	Average

little water running off the surface—talk about puddles, storm water, etc.).

- 6. Once there are three squares in each soil cell, explain that some of the water that soaks into the soil filters through the pore spaces in the soil and becomes ground water.**

Have students move one square from each soil cell down to the ground water. Explain that the ground water has been recharged (you could talk about the water table and how it moves up and down here, too).

- 7. Explain that the leftover water in the soil is called capillary water and it is the water plants use to grow.**

- 8. Now, assign each student a plant cell—they will represent a plant.** If using the **Dirt to Dinner Demonstration** sheet, you can have each student write their name in their cell. They will use their straw to represent plant roots and use it to remove capillary water from the soil and move it to the plant. The plant with the most water will grow the largest. Plants can only get water from the soil cells (not the ground water). Explain that plants also transpire meaning water evaporates from their leaves. The instructor will systematically remove one square at a time from each plant to represent transpiration.

- 9. The game ends when there is no more capillary water to collect.** You can stop and see which plant grew larger (which plant had more water).

- 10. Create additional scenarios demonstrating factors affecting soil moisture (precipitation events, soil texture, vegetation cover amount, topography and temperature).**

Assessment

Have students:

- list the four components of soil. (**Warm Up**)

- draw and label a diagram comparing capillary and gravitational or free soil moisture. (**Part 1**)
- draw and label a diagram describing how topography affects soil moisture. (**Part 2**)
- describe what happens to soil moisture at high, moderate and low temperatures. (**Part 3**)
- discuss and/or model how soil moisture impacts plants and how plants impact soil moisture (**Part 4**)
- predict how multiple environmental factors (precipitation, soil texture, vegetation, topography and temperature) might affect soil moisture. (**Wrap Up**)

Extensions

Have students randomly select environmental factors to describe a soil and have each student write a paragraph describing how these factors might affect the soil moisture for their unique soil sample.

Have students collect soil samples from one or more local sites and describe environmental factors that might affect soil moisture for each sample.

Teacher Resources

Videos

NASA SMAP eClips Videos:

Our World (elementary school level):

<http://bit.ly/1iXxQ4I>

Real World (middle school level): <http://bit.ly/18DrZux>

Launchpad (high school level): <http://bit.ly/IFYOU6Qb>

Websites

<https://smap.jpl.nasa.gov/>



Earth's Surface

Water Table



Soil Particle

Soil Particle

Soil Particle

Soil Particle

Soil Particle



Dirt to Dinner Student Copy Page

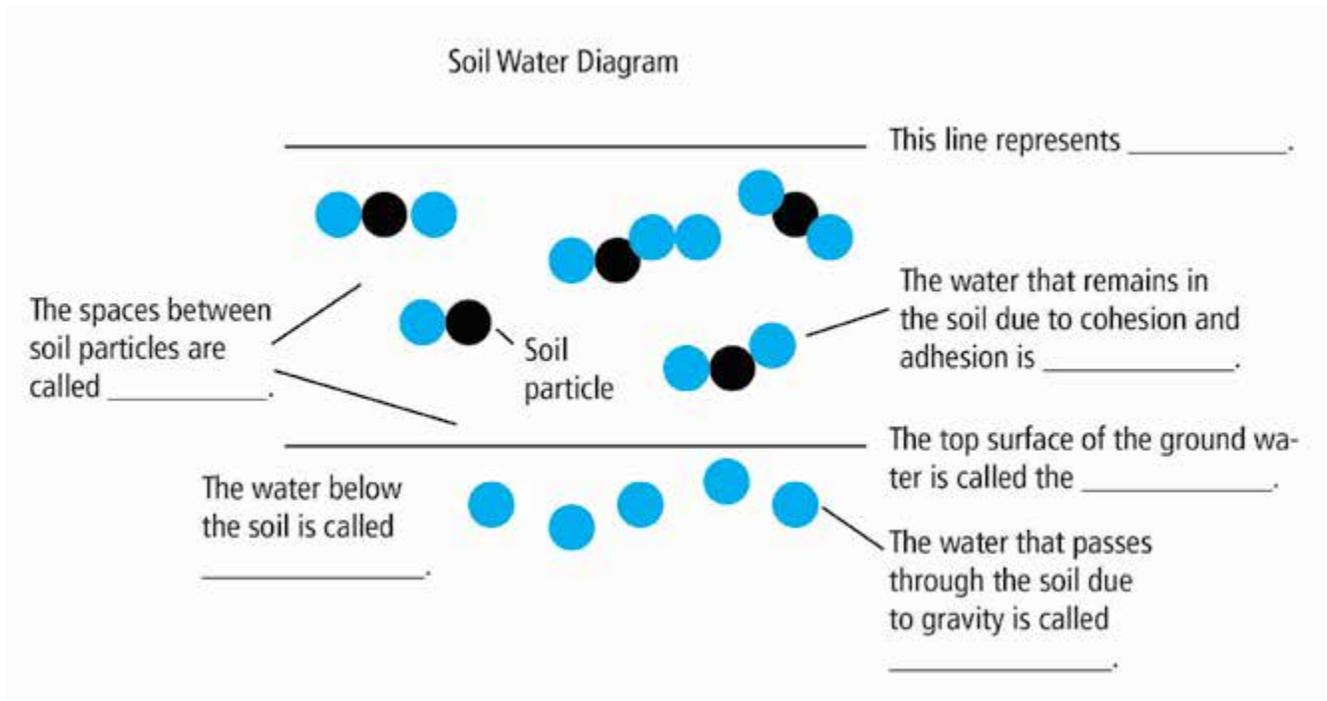
KIM Vocabulary Chart

As you encounter new vocabulary words throughout this activity, add them to this chart along with information including definition and a drawing or other memory cue to help you remember the word and its meaning.

Key (Vocabulary word, part of speech, synonyms, etc)	Information	Memory Cue

Part 1

Label the diagram.





Record observations about how different soil textures affect relative pore space and capillary water.

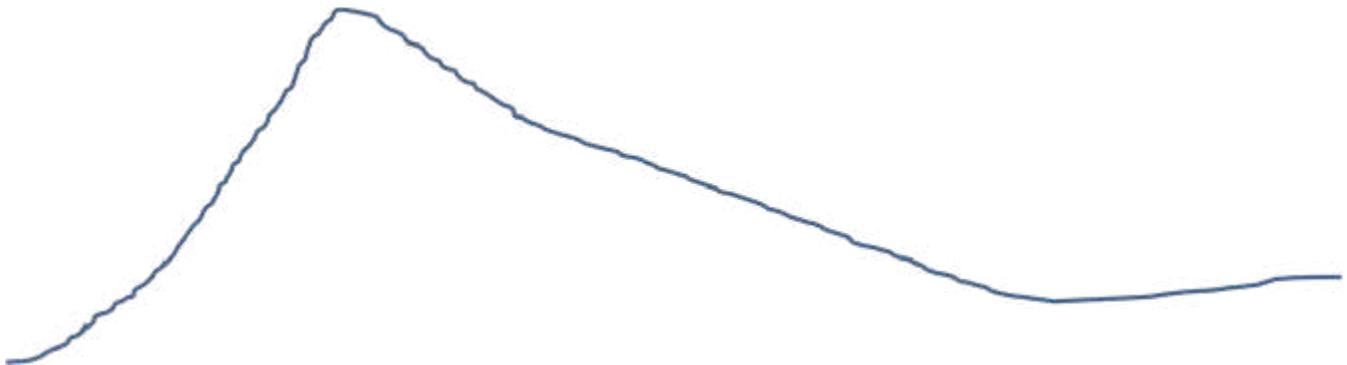
Part 1	Soil Texture	Pore spaces	Capillary water
	Silty		
	Sandy		
	Clay-rich		

Part 2

Precipitation

Part 2	Environmental Factor	Soil Moisture Prediction	Reason for Prediction	Actual Soil Moisture	Was your prediction correct? Explain.
	CONTROL: Precipitation—average	n/a	n/a		n/a
	Precipitation—long, gentle rainstorm				
	Precipitation—short, intense rainstorm				

Topography



Part 2	Environmental Factor	Soil Moisture Prediction	Reason for Prediction	Was your prediction correct? Explain.
	Topography—top of hill			
	Topography— bottom of hill			
	Topography— gradual slope			
	Topography—steep slope			



Part 3

	Environmental Factor	Soil Moisture Prediction	Reason for Prediction	Actual Soil Moisture	Was your prediction correct? Explain.
Part 3	Temperature—moderate	n/a	n/a		n/a
	Temperature—high				
	Temperature—low, below freezing				

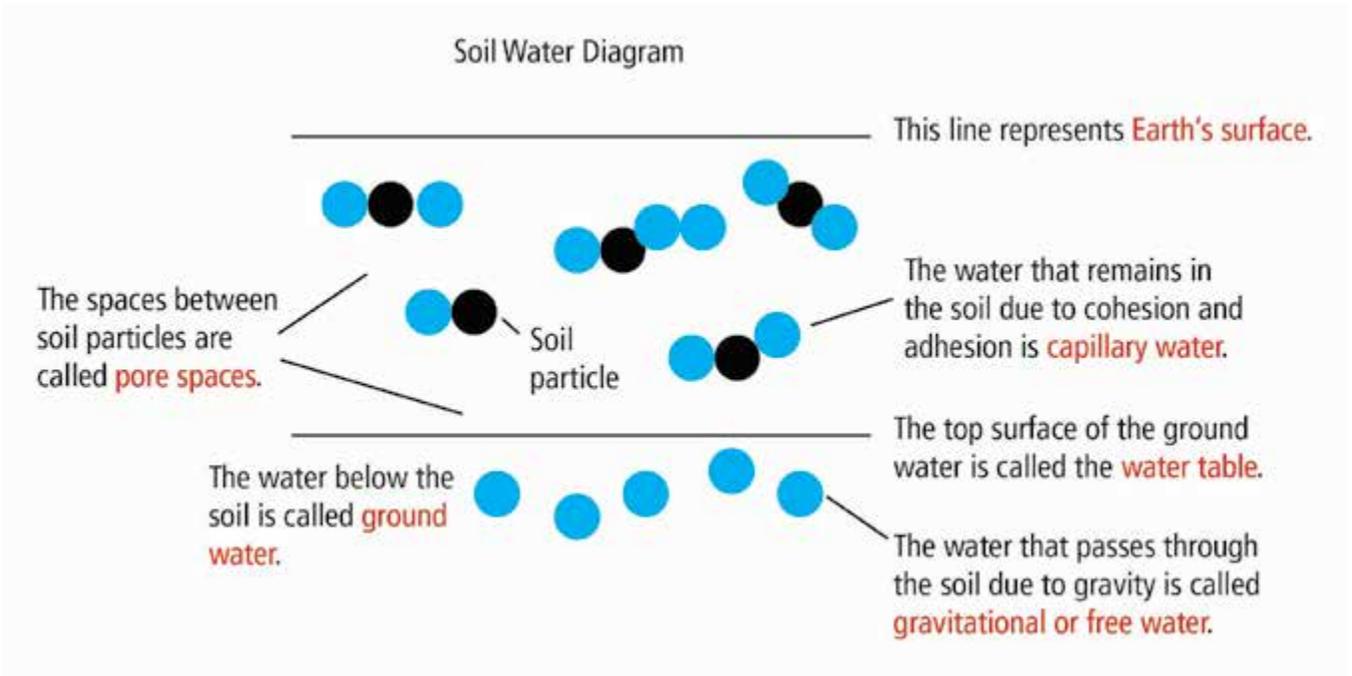
Part 4

Write a paragraph explaining how plants can affect soil moisture and how soil moisture can affect plants.



Dirt to Dinner Answer Key

Part 1



	Soil Texture	Pore spaces	Capillary water	What's going on here?
Part 1	Silty	Moderate	Moderate soil moisture	Silt particles are moderate in size compared to sand or clay.
	Sandy	Large	Less soil moisture	Because sandy soil contains larger soil particles and larger pore spaces (than silty soil), gravitational water filters more quickly through it, so less is retained as capillary water. Therefore, compared to the control soil a sandy soil will have lower soil moisture.
	Clay-rich	Small	More soil moisture	Because clay-rich soil contains smaller soil particles and smaller pore spaces (than silty soil), gravitational water filters more quickly through it, so more is retained as capillary water. Therefore, compared to the control soil a clay-rich soil will have higher soil moisture.



Part 2

Precipitation

Note to educator: Values below should hold true for any group size if five students play the role of soil particles and the number of paper squares to start with is divided evenly among the rest of the group.

	Environmental Factor	Atmosphere (start)	Soil Particles	Soil Moisture	What's going on here?
Part 2	CONTROL: Precipitation—average	30	2 squares each	10	Observed—Moderate
	Precipitation—long, gentle rainstorm	60	4 squares each	20	Long, slow precipitation event allows most of the water to soak into the soil. Some will filter through as gravitational water, but this will recharge capillary water. Control soil will have higher soil moisture content after this event than before.
	Precipitation—short, intense rainstorm	60	3 squares each	15	Short, intense precipitation event does not allow time for most of the water to soak into the soil. Some water will soak in, but most will remain on surface. Control soil will have a slightly higher soil moisture content after this event than before.

Topography

	Environmental Factor	Soil Moisture Prediction	Reason for Prediction
Part 2	Topography— top of hill	Less than control	Due to gravity, any precipitation that falls on a hill will flow downhill making less moisture available to soil at the top of a hill than would in a flat area. Therefore, less soil moisture is retained by a soil at the top of a hill than in a flat area.
	Topography— bottom of hill	More than control	Due to gravity, any precipitation that falls on a hill will flow downhill making more moisture available to soil at the bottom of a hill than would be in a flat area.
	Topography— gradual slope	Less than control	Due to gravity, any precipitation that falls on a gradual slope will flow downhill faster than precipitation that falls on a flat surface making less moisture available to soil on a gradual slope than on soil on a flat surface.
	Topography— steep slope	Less than control and less than gradual slope	Due to gravity, any precipitation that falls on a steep slope will flow downhill much faster than precipitation that falls on a flat surface making less moisture much less available to soil on a steep slope than on soil on a flat surface.



Part 3

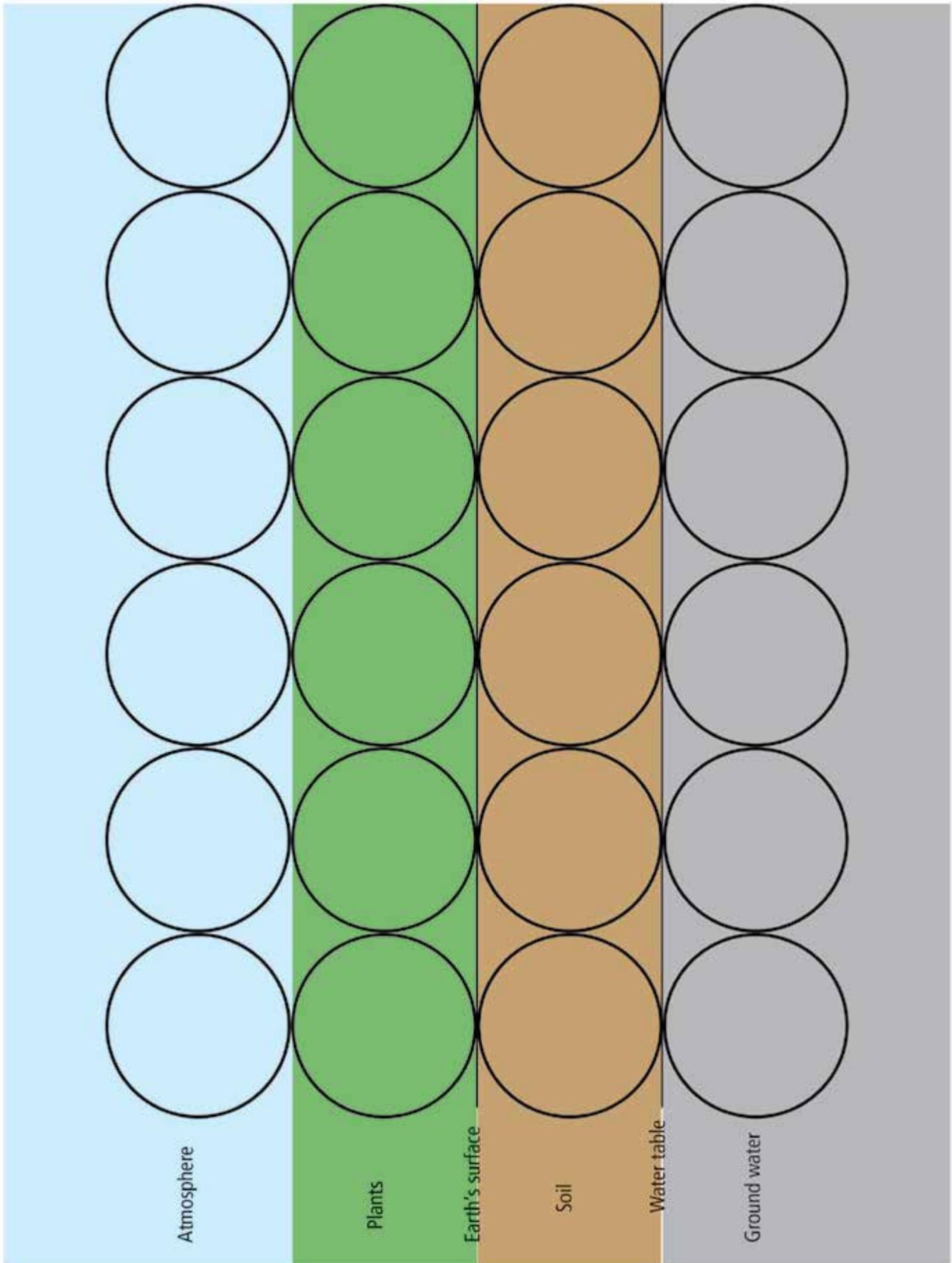
Note to educator: Values below should hold true for any group size if five students play the role of soil particles and the number of paper squares to start with is divided evenly among the rest of the group.

	Environmental Factor	Atmosphere (start)	Soil Particles	Lost to Evaporation	Soil Moisture	What is going on here?
Part 3	Control	30	2 squares each	5 squares	5	All other factors being the same as before, soil moisture decreases when evaporation increases.
	High Temperature	30	2 squares each	8 squares	2	High temperatures cause more water to evaporate from soil and transpire from plants. A soil subjected to high temperatures will have a lower soil moisture content than a soil in average temperatures.
	Low Temperature	30	2	0-freezing	10—but not available	Low temperatures cause less water to evaporate from soil and transpire from plants. A soil subjected to low temperatures will have a lower soil moisture content than a soil in average temperatures. However, the soil moisture in a soil subjected to freezing temperatures will freeze and all processes will stop until the soil thaws.

Wrap Up

Discussion Prompts

- Does soil texture affect soil moisture? (yes) How? (In general, water filters more quickly through larger particles, which means water moves more quickly through sand than silt or clay).
- Does precipitation affect soil moisture? (yes) How? (In general, more precipitation means more soil moisture and less means less soil moisture.)
- Does type of precipitation event affect soil moisture? (yes) How? (long slow storms increase soil moisture much more than short intense storms.)
- Does elevation (top or bottom of a hill) affect soil moisture? (yes) How? (Because water flows downhill due to gravity, the soils at the top of a hill are drier than those at the bottom).
- Does temperature affect soil moisture? (yes) How? (In general, higher temperatures increase evaporation and lower soil moisture content while lower temperatures and less evaporation help retain soil moisture. Freezing temperatures freeze water in the soil and in plants and slow or stop the movement of soil moisture to plants).
- Does precipitation affect plant growth? (Yes, in general more precipitation means more water available for plants, and less precipitation means less water available for plants).
- Does vegetation cover affect soil moisture? (yes) How? (More vegetation cover means more soil moisture because the organics protect the soil from evaporation.)



Additional Activity Suggestions

Many of Project WET's activities can be used to teach about climate change and climate resilience by extending or adapting the activities. In this lesson plan we provided step by step instructions on how to do this with four activities in the *Project WET Curriculum and Activity Guide 2.0*. Below is a list of other recommended Project WET activities to use in a climate change unit. The suggested grades for which the activity are marked in the chart.

Activity	Publication	How to use this activity to teach about climate change	Grade Level Use		
			3 - 5	6 - 8	9 - 12
Blue River	Guide 2.0	Find local stream flow data on USGS website to look at historical flow over time. https://waterdata.usgs.gov/nwis/sw (Watch the tutorial here.)	•	•	
Snow and Tell	Guide 2.0	This activity looks factors that influence the rate of snow melt. Examine how these these factors are impacted by a warming planet.	•	•	•
Get the Ground-water Picture	Guide 2.0	Part 3 of the activity could address how a changing climate adds to the problem of use and recharge. Find local data from USGS to localize: https://waterdata.usgs.gov/nwis/sw		•	
Discover the Waters of Our National Parks	Guide 2.0	Explore how a changing climate will affect our National Parks.	•		
Invaders!	Download-Guide 2.0 Portal	How do warming waters affect native species and the influx of invasive species? Will existing native or invasive species in your area thrive with warmer waters or will you see new invasive species entering local waterways?		•	•
Macroinvertebrate Mayhem	Guide 2.0	Macroinvertebrates can help indicate the changes in stream conditions that result from climate change. What stressors may occur due to changing water temperatures or rising/falling water levels?	•		
Piece It Together	Guide 1.0	Students analyze and plot global temperature and precipitation distributions to determine climate patterns and how they influence human lifestyles. Focus on how patterns are changing or are predicted to change. What effect will climate change have on lifestyles?	•	•	
Wet Vacation!	Guide 1.0	Analyze temperature and precipitation trends over the last 50-100 years locally and/or at vacation spots. Use USGS data to add evidence: https://waterdata.usgs.gov/nwis/sw . What will these vacation spots look like in the future?	•	•	
Ocean Habitats	Guide 2.0	Look at rising ocean temperatures and changes in acidification of the oceans—how will these changes impact the different zones and organisms in them? Students may also look at how the ocean acts as a sink for CO ₂ , changes in pH and the effect on calcium uptake for shell development.		•	
Nature Rules!	Guide 2.0	With warming oceans and the increasing greenhouse effect, changes are triggered in the jet stream and precipitation patterns to bring more frequent weather extremes to areas across the globe. Students will simulate a TV newscast through role-play that is dominated by the extreme weather events and will communicate the underlying influence on those events.		•	



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