

FARMING THE DESERT: THE SCIENCE BEHIND DESERTIFICATION

Subject Area: Science

Grade Levels: 6-10

Purpose and Overview:

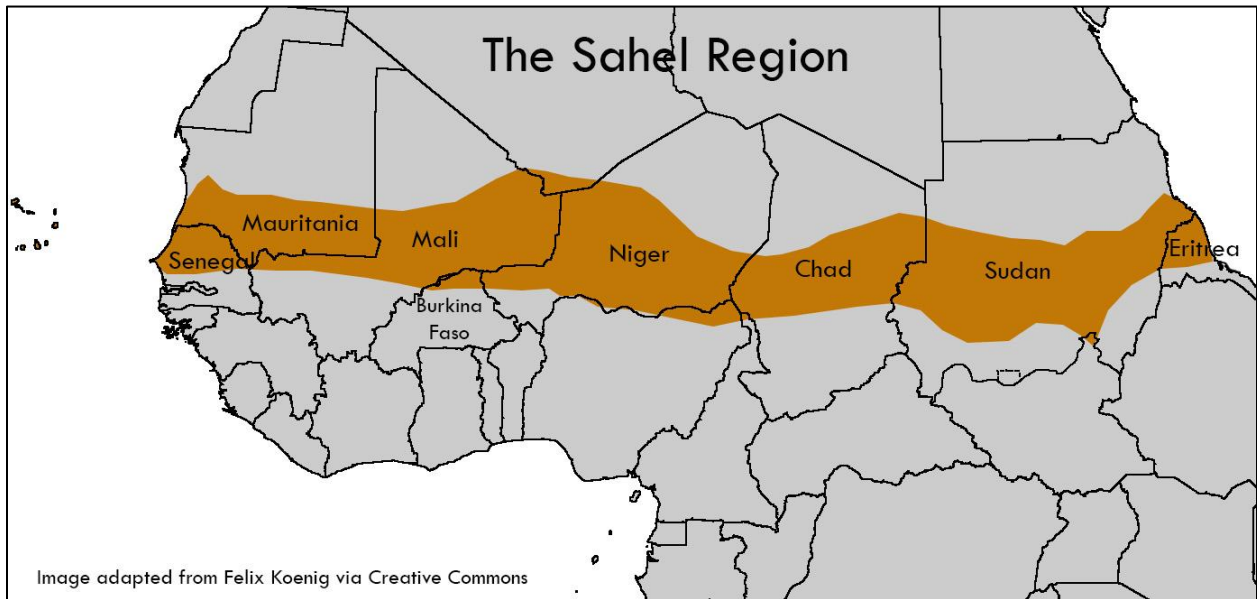
The purpose of these activities is to introduce students to the factors that contribute to desertification and solutions that have been implemented in the Sahel region of West Africa. The lessons correspond with a PBS LearningMedia video called [“Farming the Desert”](#) from the EARTH A New Wild series. In addition to the video viewing, the lesson includes an in-depth analysis of NASA data related to rainfall and desertification, an investigation of desertification vulnerability and population density, and a student-led microclimate investigation that relates back to the modifications that Yacouba Sawadogo, the main character of the video, made to his own farmlands.

Time:

- Part 1 (Video viewing and accompanying worksheet on desertification): Two 45-minute class periods. An additional 1-2 class periods for the extensions.
- Part 2 (Microclimate investigation): One 45-minute period for the investigation. One 45-minute period for the analysis and discussion.

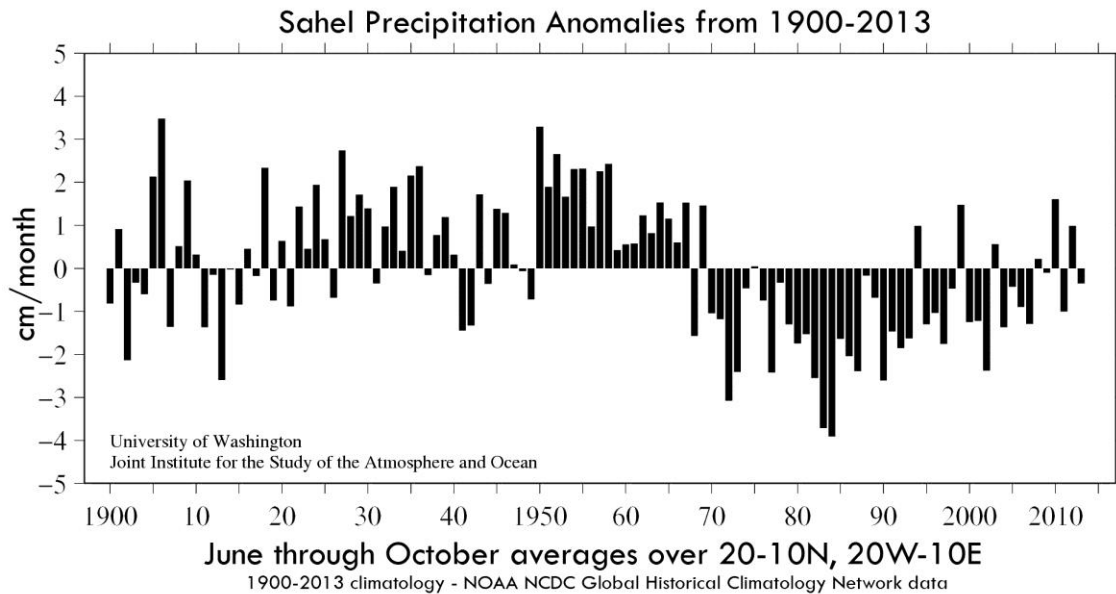
Introduction:

The Sahel region is a unique part of Africa that exists as a thin band bordered on the North by the Saharan desert and on the South by more lush, tropical savannas. In the image below, the Sahel region is represented by the brown band that stretches from west to east and includes eight African nations. The Sahel is considered to be one of Africa’s most productive regions; however, it is prone to highly erratic rainfall, which can lead to severe drought.



This lesson plan accompanies a video about Yacouba Sawadogo, who lives and farms in the part of Burkina Faso that lies in the Sahel region. Burkina Faso has four seasons: from mid-November to February the weather is dry and cool with temperatures around 60°F, from mid-February to June the weather is hot and dry with winds that blow from the Saharan Desert named “harmattan” and temperatures around 100°F, the rainy season is from June to September, and from September to mid-November is an intermediate season between the rainy and dry times. The difference in rainfall amounts (during the rainy season) can vary widely between Northern Burkina Faso, which lies in the Sahelian Zone and Southern Burkina Faso, which lies in the Sudanic zone. The annual rainfall amount in the North is less than 10 inches, compared to the South where the annual rainfall can reach up to 40 inches. It is important to note that dry seasons are a normal part of the climate of the region and are not to be confused with periods of drought.

Drought can occur when the precipitation during the rainy season is less than normal. Several consecutive years of rainfall anomalies can lead to severe droughts that have long-lasting effects. The graph below shows rainfall anomalies in the Sahel from 1900-2013. The bars that are positive indicate more rainfall than the June-October (rainy season) average and the bars that are negative indicate less rainfall than average. Rainfall fluctuation is a normal occurrence in the Sahel, and the graph depicts several consecutive years having positive rainfall anomalies leading up to the 1970's. Beginning in the 1970's, however, the Sahel experienced several consecutive years with negative precipitation anomalies. This prolonged deviation from the average rainfall led to a serious drought in the 1970's, which had dire consequences for people living in the region.



One of the consequences of prolonged drought is desertification. Desertification is a process by which land that was once productive can no longer support the same plant growth it had in the past. In addition to drought, other main causes of desertification include poor farming practices, deforestation, overgrazing, and fire.

If plants are removed from an area, either through overgrazing or deforestation, the nutrient rich topsoil can blow away, leaving farmlands less productive and making it harder for more plants to grow. Dry conditions can cause the soil to change to a hard, crusty surface that rain can't penetrate, perpetuating the dry conditions. If the factors that caused desertification are stopped and the land doesn't return to a productive state, then the land is “desertified.”

Vocabulary:

Anomaly: something different from the normal or the expected.

Desertification: land degradation in dry areas resulting from various factors, including human activities and climactic variation. Desertification is when land cannot return to its productive state.

Ecosystem: a community of living organisms that includes the living (biotic) and nonliving (abiotic) components interacting as a system.

Microclimate: the climate of a small area, especially when it differs from the surrounding area.

Sahel: a thin strip of land that lies South of the Saharan desert and North of the more humid savannahs below.

Part 1: Desertification

Time: Two 45-minute class periods with an additional 1-2 class periods for the extension activities

Materials:

- Internet, computer, projector
- Copies of student worksheet for Part 1: Desertification
URL: <http://www.pbslearningmedia.org/resource/d04430d2-7a58-4ed2-8a90-b9ea082116f7/farming-the-desert-science-part-1-student-worksheet>
- Farming the Desert | EARTH A New Wild Video
- URL: <http://www.pbslearningmedia.org/resource/f484ad16-6818-42bb-8e1d-c191bbd3fbd6/farming-the-desert-earth-a-new-wild/>
- Printouts of the following files (or students can access the online version):
 - NASA Earth Observatory’s online article “Defining Desertification”
Page 1: <http://earthobservatory.nasa.gov/Features/Desertification/>
Page 2: <http://earthobservatory.nasa.gov/Features/Desertification/desertification2.php>
 - USDA Global Desertification Vulnerability Map (printable full-size image is on page 15 of this lesson plan)
http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/nedc/training/soil/?cid=nrcs142p2_054003
 - USDA Global Population Density Map (printable full-size image is on page 16 of this lesson plan) http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/edu/?cid=nrcs142p2_054015

Objectives:

The student will...

- Define desertification and describe its causes.
- Describe the changes Yacouba Sawadogo made to his land to combat desertification.
- Summarize how the improvements Yacouba Sawadogo made altered the conditions of his farmland.
- Define vegetation index and describe how scientists use satellite data to discover desertified lands.
- Analyze graphical data to determine rainfall anomalies in the Sahel and discover consecutive years of drought that could lead to desertification.
- Compare and contrast maps that indicate global desertification vulnerability and population density.
- Evaluate the relationship between global desertification vulnerability and population density and describe the implications of high population density on desertified areas and vice versa.
- Identify states in the U.S. that are at risk for desertification and research the leading causes of desertification in a particular state.
- Examine and describe visualizations of rainfall and vegetation in the Sahel.
- Make inferences about rainfall and the vegetation index for a particular area.
- Read and summarize a primary source on the positive effects of termites on agriculture.
- Describe the positive and negative ecosystem effects of the Saharan Dust Plume.

Next Generation Science Standards:

Disciplinary Core Ideas

- LS2.A: Interdependent Relationships in Ecosystems
- LS2.C: Ecosystem Dynamics, Functioning, and Resilience
- LS4.D: Biodiversity and Humans

Cross-Cutting

- Patterns
- Cause and Effect
- Stability and Change

Science and Engineering Practices

- Analyzing and Interpreting Data
- Constructing Explanations and Designing Solutions
- Engaging in an Argument from Evidence

Performance Expectations

Middle School

- MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

High School

- HS-LS4-5. Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.
- HS-LS2-6. Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.

Common Core English Language Arts – Science and Technical Subjects

Grades 6-8

- CCSS.ELA-LITERACY.RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts.
- CCSS.ELA-LITERACY.RST.6-8.2 Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.
- CCSS.ELA-LITERACY.RST.6-8.6 Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text.

Grades 9-10

- CCSS.ELA-LITERACY.RST.9-10.1 Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.
- CCSS.ELA-LITERACY.RST.9-10.2 Determine the central ideas or conclusions of a text; trace the text's explanation or depiction of a complex process, phenomenon, or concept; provide an accurate summary of the text.
- CCSS.ELA-LITERACY.RST.9-10.6 Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text, defining the question the author seeks to address.

Suggested Flow:

1. Have students complete the “getting started” portion of the [student worksheet for Part 1](#).
2. Go over questions 1 and 2 from the worksheet with the students and generate a class list of the causes of desertification on the board.
3. Watch the [Farming the Desert | EARTH A New Wild Video](#) (4:39 minutes) and have students answer the guiding questions on their worksheet as they watch.

Student Worksheet Part 1 Section A Answer Key:

1. What do you think “desertification” means?
Answers may vary. Students may answer that it means “to become a desert” or “to create a desert”.
 2. What might cause desertification?
Answers may vary. Students might answer that desertification is caused by lack of rain, drought, hot weather, intense sunlight, and/or creeping of sand dunes.
 3. In the video, why did people clear the trees from the land?
New farms, firewood, construction
 4. What does the narrator describe as causes of desertification?
Drought, deforestation, degraded land
 5. What were the results of all of Yacouba Sawadogo’s efforts?
In year 1, Yacouba Sawadogo had a great harvest. Twenty years later his arid lands had been transformed into 30 acres of forest with over 60 species of trees.
 6. How did Yacouba Sawadogo’s tree-planting activities affect the microclimate on his land?
 - More shade led to lower temperatures
 - Less erosion because the trees provided more windbreaks
 - Water table raised
 7. What unanswered questions do you have after watching the Farming the Desert video?
Answers may vary. Students may wonder if Yacouba Sawadogo was the person that invented these farming techniques. They may wonder how many other people use these techniques.
4. Check in with students to see if there are things that could be added to the desertification causes list on the board after viewing the video. Have them add to the list on their worksheet as needed.

5. After watching the video, have students complete the graphic organizer for question 8.
8. In very impoverished areas like the Sahel, high-tech solutions to increasing agricultural yields are not feasible. In the video, Yacouba Sawadogo harnesses nature to help him increase his crops and the trees on his land. In the graphic organizer below, indicate how Sawadogo's strategies helped his land.

<u>What did Yacouba Sawadogo do?</u>	<u>How did this help?</u>
worked land in dry season	<ul style="list-style-type: none"> • prepared land BEFORE rain so it could catch water when it rained
dug zai pits	<ul style="list-style-type: none"> • helped capture water during rainy season
put organic material (leaf litter, dung) in pits	<ul style="list-style-type: none"> • (this is not discussed in the film - so you will have to ask students why you think he did this) • dung attracts termites • materials act as compost and mulch, which provides nutrients and and retains moisture
put termites in pits	<ul style="list-style-type: none"> • termites created underground tunnels that were like an irrigation network • water could flow through tunnels when it rained
built stone walls	<ul style="list-style-type: none"> • prevents surface water from flowing away when rains
planted trees	<ul style="list-style-type: none"> • tree roots held down soil & prevented it from blowing away • roots helped soil retain water

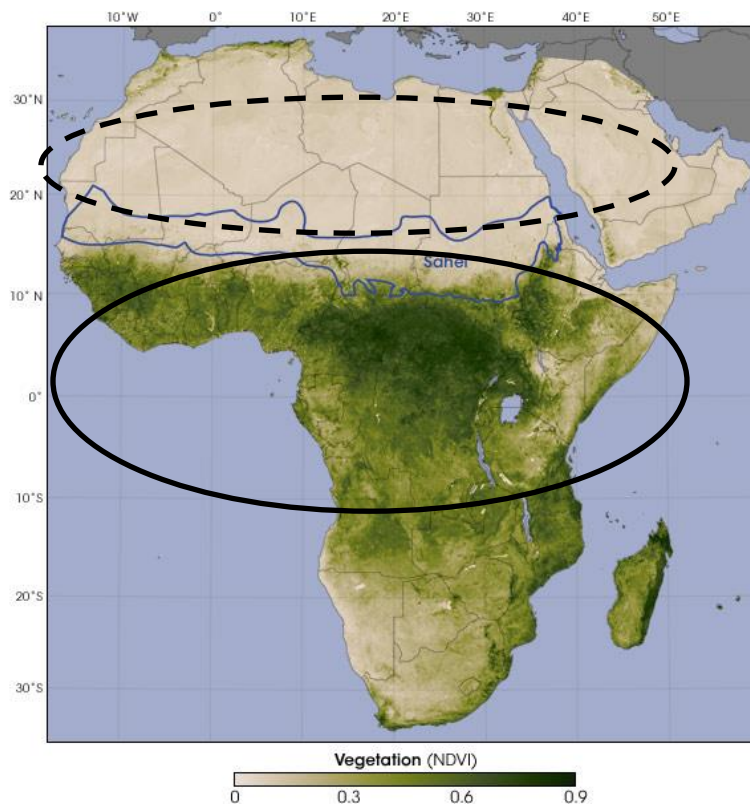
6. If you have access to student computers, have students work through the activity on the student worksheet in pairs or solo at a computer. If not, then project the graphs, images, and animations and work through the worksheet with students or photocopy the reading and give to students.
- Page 1 can be found here:
<http://earthobservatory.nasa.gov/Features/Desertification/desertification.php>
 - Page 2 is located here:
<http://earthobservatory.nasa.gov/Features/Desertification/desertification2.php>

Student Worksheet Part 1, Section B Answer Key:

1. What is a vegetation index?

Answer: A vegetation index is based on satellite data collected from National Oceanic and Atmospheric Administration (NOAA) satellites. The index shows how much photosynthesis happens in every 8 x 8 km patch of ground. In map form, the index can show the productivity of an entire continent.

2. In the map below, circle the area that has the high vegetation index at the time the image was created. Put a dotted line around the area with the lowest vegetation index.



3. Define desertification

Answer: Desertification is land degradation in dry areas resulting from various factors, including human activities and climactic variation. Desertification is when land cannot return to its productive state.

4. List the causes of desertification

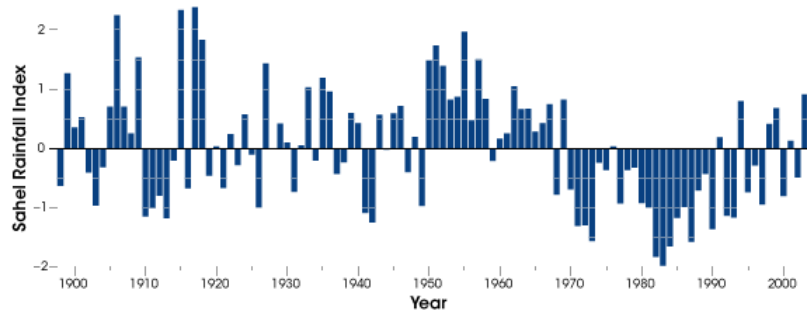
Answer: Drought, overgrazing, poor farm management, fire, and deforestation can lead to desertification. These things can thin out vegetation and leave soil exposed to the elements. When soil blows or washes away, plants may not be able to grow. Drought and over-farming can change the soil so that rain cannot seep into the soil, creating a situation of continued dryness for plants.

5. If a piece of land appeared to be desertified, but then its productivity and plant life returned, can it still be called desertified?

Answer: No, desertified land cannot return to a productive state. Desertified land cannot support the same growth it had in the past. It is permanently changed.

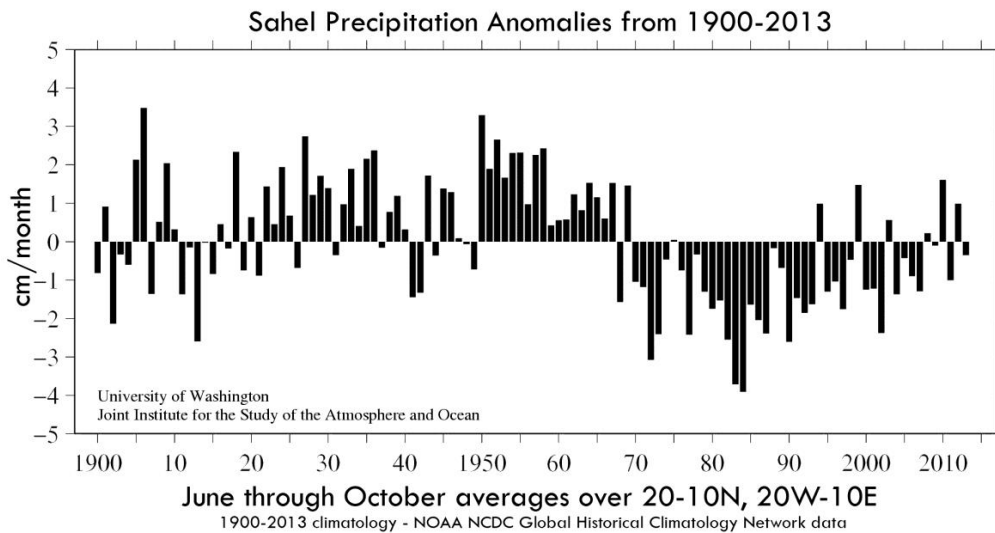
6. In the graph below, identify the range of years in which the Sahel region experienced a long drought. A positive rainfall index value means that there is heavy precipitation compared to normal (for that area) over time. A negative rainfall index value means that there is low precipitation compared to normal.

Answer: Beginning in 1970 and lasting until 1990 (with the exception of one year)



Graph source: NASA Earth Observatory

7. The graph below is similar to the rainfall index graph from the reading. This graph shows the actual rainfall deviation in centimeters from the June-October (rainy season) average. An anomaly is something that deviates from the standard or expected. Looking at the graph below, describe the precipitation anomalies beginning in 1970 to 2013. Compare this time period to the time from 1900 to 1970. Use data from the graph in your answer.



Answer: Answers may vary, but one possible answer is – During the period from 1970 to 2013, the Sahel experienced several years of negative rainfall anomalies. Around 1985 was the driest year with a -4 cm rainfall anomaly. Since 1970, there have only been 7 years with positive rainfall anomalies. However, the highest positive rainfall anomaly around 2010 was less than 2 cm. This time period is much drier than the time from 1900-1970 where there was a lot more yearly fluctuation and a greater number of years with positive rainfall anomalies compared to negative anomalies. In fact, from 1950 to 1970, there were positive rainfall anomalies every year

with the exception of 1968. The highest positive rainfall anomaly between 1950 and 1970 was slightly less than 3.5 inches in 1950.

8. What determines if an area is experiencing a drought? Is drought the same as desertification?

Answer: A drought can occur when there is less rainfall than normal. An area going through a drought does not necessarily become desertified. Extended periods of drought can lead to desertification.

9. Based on the NASA reading, how can scientists use rainfall and the vegetation index to determine if an area is desertified?

Answer: Scientists can compare rainfall maps to vegetation maps. In normal cases, the vegetation maps should match the rainfall maps. When there is an increase in rainfall, it should be followed by an increase in vegetation. Possibly desertified areas can be identified where vegetation and rainfall no longer match up.

Global Desertification Vulnerability

Examine the Global Desertification Vulnerability and the Historical Population Density Maps below and answer the corresponding questions (**larger versions are attached at the end of the lesson plan, or you can click on the links and project the digital version of the graphs**).

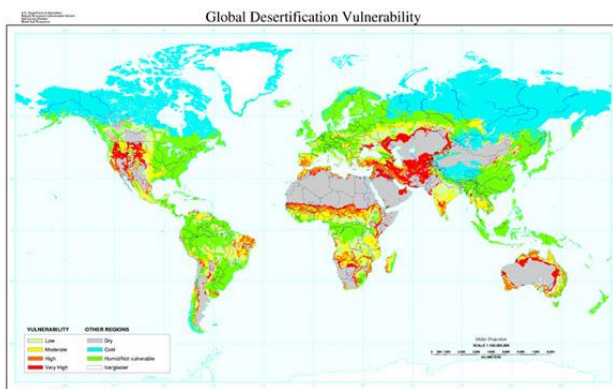


Image Source: [USDA Natural Resources Conservation Science](http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/necdc/training/soil/?cid=nrcs142p2_054003)
http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/necdc/training/soil/?cid=nrcs142p2_054003

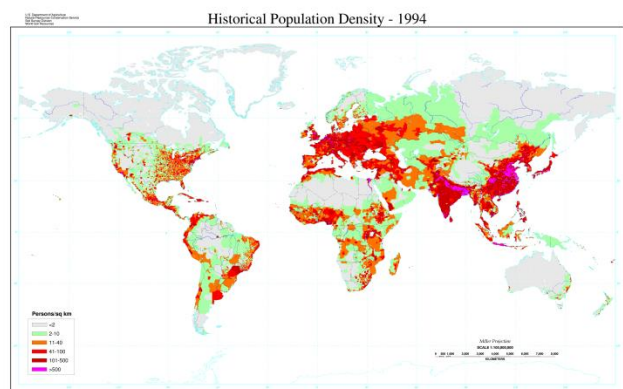


Image Source: [USDA Natural Resources Conservation Science](http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/edu/?cid=nrcs142p2_054015)
http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/edu/?cid=nrcs142p2_054015

10. Desertification is not just a problem that affects the Sahel in Africa. What other parts of the world are at risk for desertification?

Answer: The United States, South America, parts of Asia and the Middle East, other parts of Africa, Australia.

11. Are there overlaps between high population areas and areas of land that have high vulnerability to desertification? What implications does desertification have for the populations that live in vulnerable areas?

Answer: There are overlaps between high population and desertification vulnerability. These overlaps occur in the parts of the Western US like in California, South Africa, South America, the Middle East, and parts of Asia. Desertified lands would have trouble supporting large numbers of people. The larger a population is the more pressure it puts on already degraded lands. There might be higher poverty levels and/or rates of malnutrition in these areas because the land cannot support the population.

12. Which states in the United States are at very high risk for desertification?

Answers will vary. The states most vulnerable to desertification are Western states including parts of Washington, Oregon, California, Arizona, New Mexico, Utah, Nevada, Idaho, Montana, Wyoming, Colorado, and Texas.

13. How could you find out why these states are at risk for desertification?

Answer: Choose one state and conduct an internet search on desertification causes in that state.

14. Pick one of the states in the U.S. that are at risk for desertification and do an internet search to find out what kinds of human activities might be contributing to desertification in that state.

Answers will vary. Overgrazing and poor agricultural practices are the main human activities that contribute to desertification in the U.S.

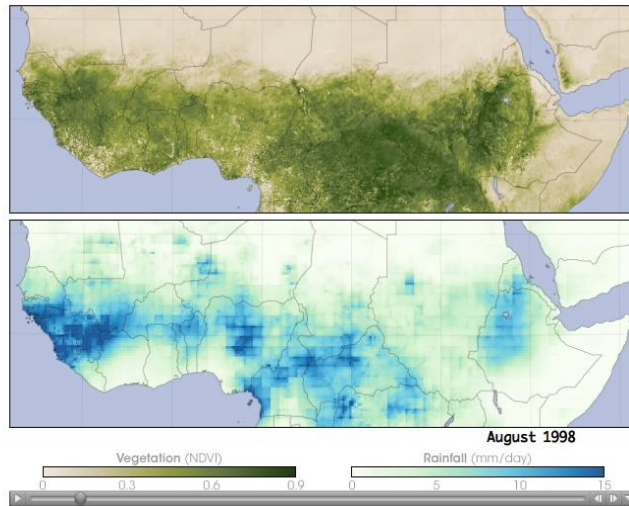
Extension #1: Examining Visualizations

Show the NASA animation (a QuickTime movie), pictured below, to your students. A high-resolution version can be obtained at:

http://earthobservatory.nasa.gov/Features/Desertification/Images/ndvi_trmm_combined_lrg.mov. This animation shows satellite data on vegetation and rainfall over time from January 1998 to June 2005. It might be helpful to play the video once through on full speed and then use the right arrow on the screen to step through one month at a time to be able to answer the questions below.

In the vegetation (NDVI, or Normalized Difference in Vegetation Index) animation, dark green indicates dense vegetation and brown indicates barren land. Light green or shades in between green and brown indicate sparse vegetation. NDVI is calculated from the visible and near-infrared light that is reflected from vegetation.

For an in depth explanation of how NDVI is calculated, see the “Measuring Vegetation” article on NASA’s Earth Observatory at:



http://earthobservatory.nasa.gov/Features/MeasuringVegetation/measuring_vegetation_2.php

Possible questions to pose to students:

- In the rainfall animation, what do the areas of dark blue indicate? Light blue?
- In the vegetation animation, if an area is really dark green, what can you say about the plant life in that area?
- Look at the rainfall animation on the bottom of the screen and determine which months tend to be the rainiest in the Sahel region. How did you pick these months?
- Are there any months that indicate a dry season? If so, which ones?
- Pick any year and click through the months from January to December. Describe what happens to the vegetation over time. In your statement, describe the relationship of the vegetation to the rainfall.
- Are dry seasons the same as a drought?
- If an area experiences a drought, will it become desertified? Why or why not?
- Choose one year to watch and find an area on the rainfall animation that has the darkest blue (15 mm/day of rain). Now find the same location on the vegetation map and see if the high rainfall during any month corresponds to a high level of vegetation. If it does not, what might be the reason why?

Extension #2: Primary Sources

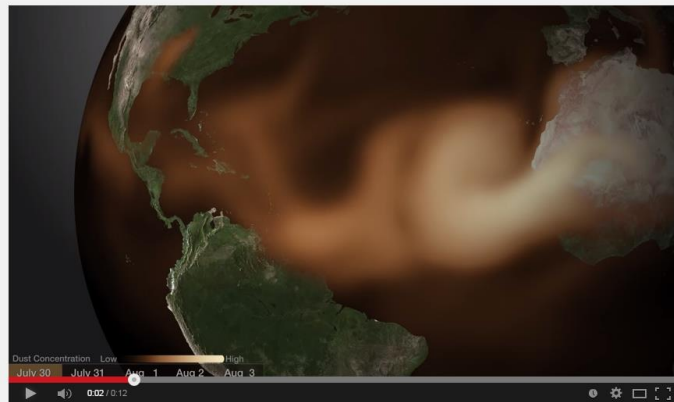
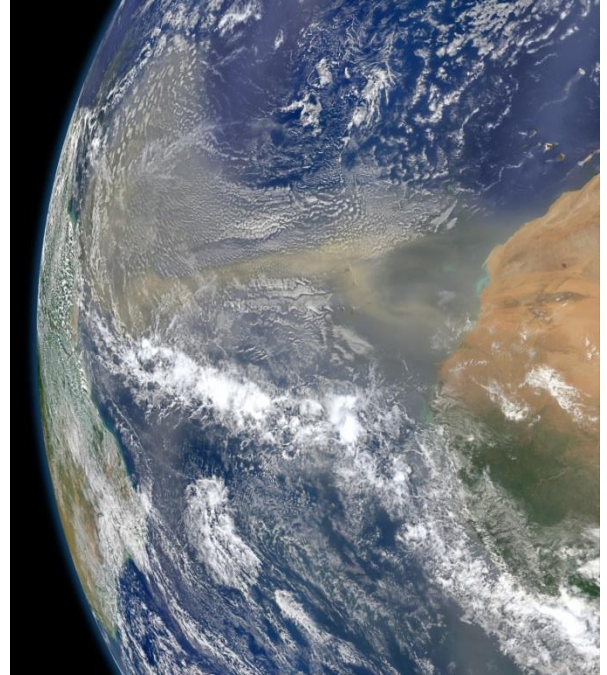
In 2010, scientist Theodore Evans and his colleagues published a paper in Nature entitled “Ants and termites increase crop yield in a dry climate.” To give students an opportunity to read a scientific paper that documents the positive effects of termites on agriculture, the article can be found here:

<http://www.nature.com/ncomms/journal/v2/n3/full/ncomms1257.html>.

Have students read the journal article and determine the central ideas of the text and provide a summary. Be sure to have students refer to data from the article to support their summary.

Extension #3: Impacts Around the World

Dry conditions in Africa can affect ecosystems far beyond the African continent. In the picture to the right from [NASA](#), you can see a dust plume blowing from the Saharan desert across the Atlantic Ocean. Go to this URL: <https://www.youtube.com/watch?v=F3Q8Sh2AjPo> or click on the picture below to see an animated version of this phenomenon in a video created by NOAA.

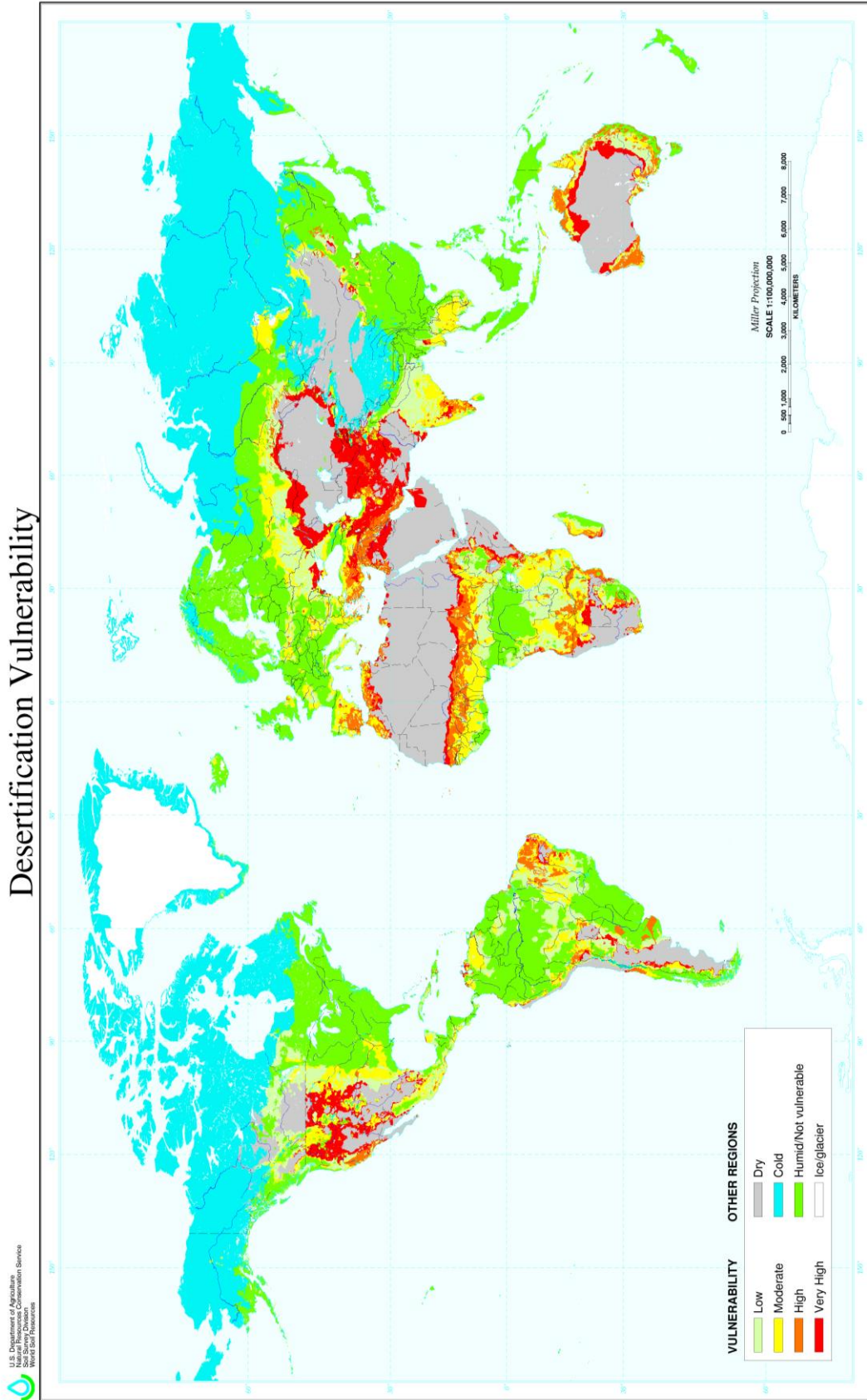


Possible questions to pose to students:

1. How might the dust blowing from the Sahara affect ecosystems across the globe?
2. Read the short passage by NASA (<http://earthobservatory.nasa.gov/IOTD/view.php?id=83966>) about the June 2014 Saharan Dust Plume and see if you can add to your original ideas. Fill out the chart below to indicate whether the dust plume effects are positive or negative.

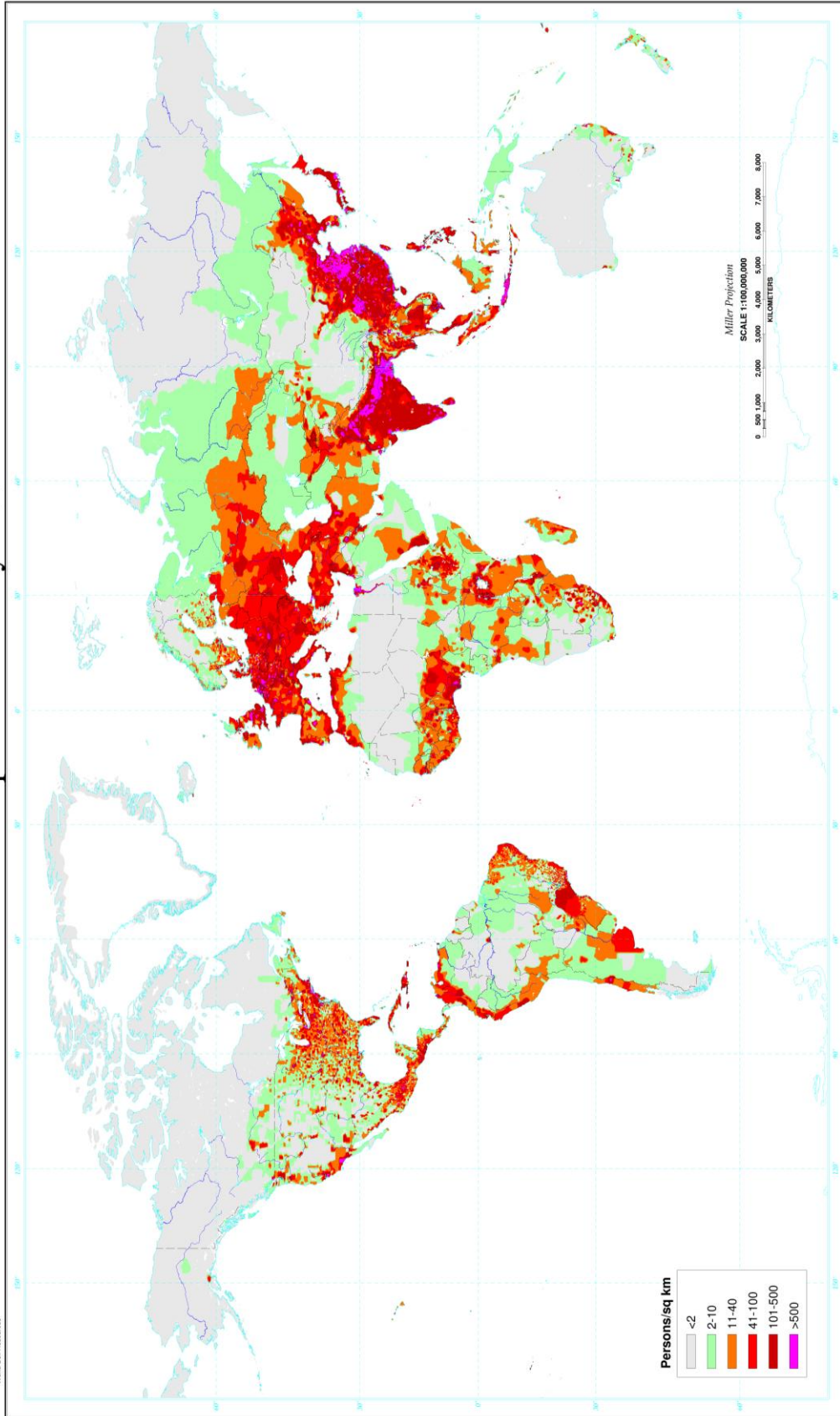
Positive Ecosystem Effects	Negative Ecosystem Effects

Desertification Vulnerability



Historical Population Density - 1994

U.S. Department of Agriculture
Soil Conservation Service
World Soil Resources



Part 2: Microclimate Survey Design Challenge

Time: One 45-minute period for the survey and one 45-minute period for the analysis and discussion

Overview:

It was mentioned in the [“Farming the Desert” video](#) that the tree-planting Yacouba Sawadogo had done actually changed the microclimate in his area. A microclimate is the climate of a very small area. It can be influenced by the type of land surface, the presence or absence of plants, the type of plants, and the amount of shade.

In this activity, you will have your students complete an experimental design challenge in which they will discover the differences between the microclimates of various locations at their schools while they search for the most extreme microclimates.

This experiment can be structured from basic to more complex and the level of student involvement in the experimental design can be increased as you see fit for your class. This lesson will provide an entry point activity and will reference ways to increase the depth of the activity if desired.

Materials:

Basic:

- Thermometer, compass, camera, several flags (per each group)
- Copies of the student worksheet for Part 2: Microclimate Survey Design Challenge
URL: <http://www.pbslearningmedia.org/resource/b07e7fe0-7703-4542-b094-9a9b85c43cfd/farming-the-desert-science-part-2-student-worksheet/>

Advanced (everything in the basic list plus these resources):

- If you already have [Vernier Probewear](#), the following sensors could be used in this activity: soil moisture, relative humidity, anemometer, and thermometer.
- Alternatively, there are a wide variety of handheld weather stations available for purchase online that you could use if you want to measure more than temperature.
- Instead of using flags to mark locations, you could also have students use a handheld GPS if you already have them.

Objectives:

The student will...

- Design a microclimate survey to determine the most extreme microclimates on their school grounds.
- Determine the necessary equipment needed to carry out the survey.
- Conduct multiple trials during the data collection phase of the survey.
- Analyze their data and use this information to support claims about the most extreme microclimates.
- Evaluate the effect of extreme (in this case – hot) microclimates in urban areas and relate this to the concept of urban heat islands.
- Describe a solution to reduce the urban heat island effect.

Next Generation Science Standards:

Disciplinary Core Ideas

- LS2.A: Interdependent Relationships in Ecosystems
- LS4.D: Biodiversity and Humans
- ETS1.B: Developing Possible Solutions

Cross-cutting Concepts

- Patterns
- Cause and Effect
- Scale, Proportion, and Quantity

Science and Engineering Practices

- Planning and Carrying Out Investigations
- Analyzing and Interpreting Data
- Constructing Explanations and Designing Solutions
- Engaging in Argument from Evidence

Performance Expectations

Middle School

- MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

High School

- HS-LS2-6. Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.
- HS-LS2-7. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

Common Core English Language Arts – Science and Technical Subjects

Grades 6-8

- CCSS.ELA-LITERACY.RST.6-8.3 Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

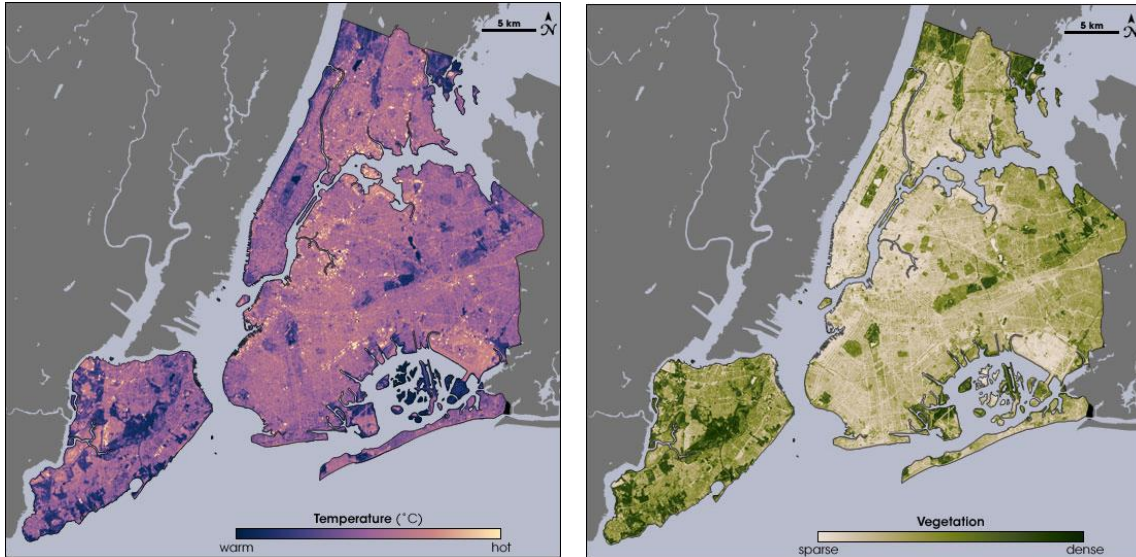
Grades 9-10

- CCSS.ELA-LITERACY.RST.9-10.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.

Suggested Flow:

1. Suggested concepts to discuss with your students before they begin this activity:
 - What is the difference between climate and weather?
http://oceanservice.noaa.gov/facts/weather_climate.html
 - What is the difference between climate and microclimate?
http://www.metlink.org/secondary/key-stage-4/microclimates/#urb_micro

- If you feel that it might be difficult for students to determine where to start looking for differences in microclimate, you could display the images below from NASA Earth Observatory, which depict New York City Temperature and Vegetation Maps (download here: <http://earthobservatory.nasa.gov/IOTD/view.php?id=6800>).



- Have students discuss the possible correlation between temperature and vegetation. Note that the scale in the temperature visualization is from warm to hot (not cold to hot), which may be misleading for some students.
- Create student groups of 3-4 students. Distribute the [Part 2 student worksheet](#) and explain the design challenge below:

Survey Design Challenge:

Find the two most extreme (coldest and hottest) microclimates on the school campus, create an inventory of what lives there, and characterize what factors make the microclimates so different.

- Have students complete the Design Challenge on the [Part 2 student worksheet](#) and construct a data table. When they have completed these items you can suggest that they get approval from you before moving forward.
- The suggestion on the worksheet is that students conduct measurements in a minimum of five locations, but this can be varied according to the time allotted. If time is limited, you could also have one student group responsible for only one location and then compile the data from the class.
- Make sure that students take a minimum of three measurements at each location. Depending on the time available, students could add a component to sample their microclimates on different days/times. Even if there is not enough time to do this, it's worth having a discussion about how these changes might affect the microclimate of an area.

8. Student designed data tables may look different to reflect their design ideas, but here's an example if needed:

Sample Data Collection Chart for One Location Sampled

Location 1 Measurements Date: _____ Time: _____

	Trial 1	Trial 2	Trial 3	Average
Air Temperature				
Soil Temperature				
Relative Humidity				
Soil Moisture				
Wind Speed				
Wind Direction				
Description of Area				

9. Make sure to have a discussion with students about the size requirements for the sites they are sampling. For example, is there a minimum or maximum area that should be used? Also help them to decide how to photograph their sites.
10. Have the students go outside and conduct their investigations.
11. Once all of the data is collected, students should complete the “data analysis” and “conclusion” sections of their worksheets.

There is also an “extend your knowledge” section at the bottom of the worksheet. If you choose to have students complete this section, you may wish to share the resources below with them either before or after they complete this section. This activity lends itself to a discussion on Urban Heat Islands. The resources below can be used for supplemental reading as desired.

- NASA Earth Observatory - Beating the Heat: In the World's Big Cities
<http://earthobservatory.nasa.gov/Features/GreenRoof/>
- NASA - Bright is the New Black: New York Roofs Go Cool
<http://www.nasa.gov/topics/earth/features/ny-roofs.html>
- NASA Earth Observatory - Roof Temperature Graph
http://earthobservatory.nasa.gov/IOTD/view.php?id=77717&eocn=image&eoci=related_image

Other Resources:

- For a related lesson on the geography of the Sahel and the lifestyles of its inhabitants visit: <http://www.pbslearningmedia.org/resource/6fff48ab-1254-4f06-b0fa-af78e180dbdd/farming-the-desert-geography-lesson-plan>
- For more information about the regreening of the Sahel: <http://www.ifpri.org/sites/default/files/publications/oc64ch07.pdf>
- For more background on the Sahel including who lives there, climate change impacts, and humanitarian implications: <http://www.irinnews.org/report/78514/sahel-backgrounder-on-the-sahel-west-africa-s-poorest-region>
- Read more about desertification in other locations and innovative methods being used to halt desertification: <http://www.newyorker.com/magazine/2011/12/19/the-great-oasis>
- For information on how climate change and drought in the Sahel are contributing to the displacement of residents now termed “climate change refugees”: <http://www.theguardian.com/global-development/poverty-matters/2013/aug/02/sahel-climate-change-displacement-migration>
- To see the data that shows current rainfall amounts in the Sahel region of West Africa: http://www.cpc.ncep.noaa.gov/products/global_monitoring/precipitation/wafrica_1yrprec.shtml

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Standards:

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