



Flow Down!

Can Managing Forests Help Maintain Water Supplies in the Face of Climate Change?

What Kinds of Scientists Did This Research?

ecologist: This scientist studies the relationship of living things with their living and nonliving environment.

hydrologist: This scientist studies water and water systems.

Meet the Scientist



Stephanie Laseter, HYDROLOGIST:

A favorite recent experience of mine was installing a series of flumes in several stream channels. We can use these flumes to measure the amount of water flowing in the streams. Installing these instruments means that we get to hike through the forest in search of the perfect location in the stream. In this photo, I am standing by a flume.

Once a site is chosen, we fit a large fiberglass flume into the stream channel, making sure that we have it perfectly level. We can use an instrument called a pressure transducer to measure the height of the water in the flume. By putting these flumes in sites that have different forest types and various forest ages, we can learn a lot about how these forests use and store water.

Thinking About Science

Sometimes when scientists conduct their research, they collect data over a short period of time and then they analyze the data and draw conclusions. The scientists use data from shorter time periods because those data are usually the most accessible. Obtaining data that span decades is often difficult because of the money and other resources needed to obtain data over a long time period. However, when data are available over long time periods, scientists are thrilled to use it. Scientists like to use these data because these data offer the opportunity to discover long-term trends as opposed to only having short snapshots of how a system is responding.



Think about if someone has a bad year in school and they are evaluated on just this one year for getting into college. Do you think it is better to look at one year or several years the student was in school to make a decision about getting into college? Looking at several years a student has been in school is a better way of determining whether to accept a person into college. It is a better way because it provides more details and history about the person. Similarly, this longer-term understanding provides scientists with more detail for them to draw their conclusions. In this study, the scientists analyzed **streamflow** data over a 75-year time period.

Thinking About the Environment

Have you ever heard the term “ecosystem services?” Ecosystem services are provided by healthy natural areas just because they are healthy natural areas. Examples include clean air, clean water, beautiful landscapes, healthy soil, places for wildlife to live, minerals, and even places to do outdoor activities. Ecosystem services are important because they provide goods and services that are vital to human health and quality of life. For example, many people rely on water from streams for drinking water and everyday use in their homes.



Ecosystem services can be influenced by many things. For example, climate change can influence ecosystem services because landscapes and ecosystems may change how they function or look due to the change in climate. In this study, the scientists were interested in ecosystem services, including streamflow, provided by forested **watersheds**. The scientists were interested in how climate change may impact the streamflow provided by these forests (FIG. 1).

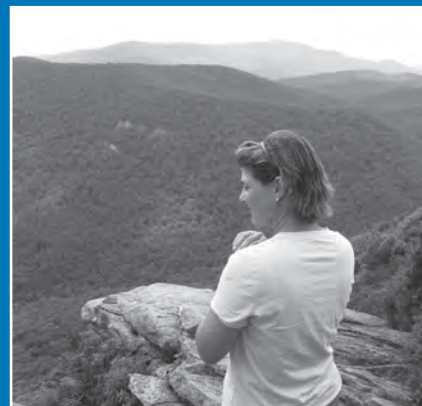
FIGURE 1. A WATERSHED IS AN AREA OF LAND WHERE ALL OF THE WATER THAT IS UNDERGROUND WITHIN THE AREA, AND ALL OF THE WATER IN STREAMS AND RIVERS IN THE AREA, FLOWS TO THE SAME PLACE. ILLUSTRATION BY STEPHANIE PFEIFFER.



Introduction

Climate change can have direct and indirect impacts on water resources. Direct impacts of climate change can be seen by the presence of more extreme weather events. Extreme weather events include things like heat waves and droughts (FIG. 2). Droughts have a direct impact on water and water supply. The indirect impacts of climate change on water resources relate to temperature and the amount of carbon dioxide in the atmosphere. For example, an increase in temperature could increase the amount of water plants use because of **transpiration** and **evaporation** (FIG. 3). If plants increase their use of water, then there will be less water available for streamflow or **groundwater**.

Meet the Scientist



Chelcy Ford Miniatt, ECOLOGIST:

One of my favorite recent experiences was conducting an experiment. A group of scientists and I wanted to figure out if trees could take up carbon that is dissolved in the soil water and use it for growth and reproduction. When we conducted this experiment, we found that the trees could take up carbon through their roots and use it to grow new roots, leaves, and wood. Trees still get most of their carbon for growth and reproduction through taking up carbon dioxide through their leaves, but they can also take up a very small percentage of carbon as **bicarbonate** through their roots.

Forests and how forests are managed also have impacts on water resources. For example, some types of forest management change the number of trees in an area. The number of trees that are in an area influence how much water is **intercepted** by these trees. The number of trees also influences how much water evaporates in this area. Forest management can change the way water flows. Some types of forest management can also create disturbances in the soil. The scientists **hypothesized** that climate impacts may either be made better or worse

by forest management that changes the **land cover**.

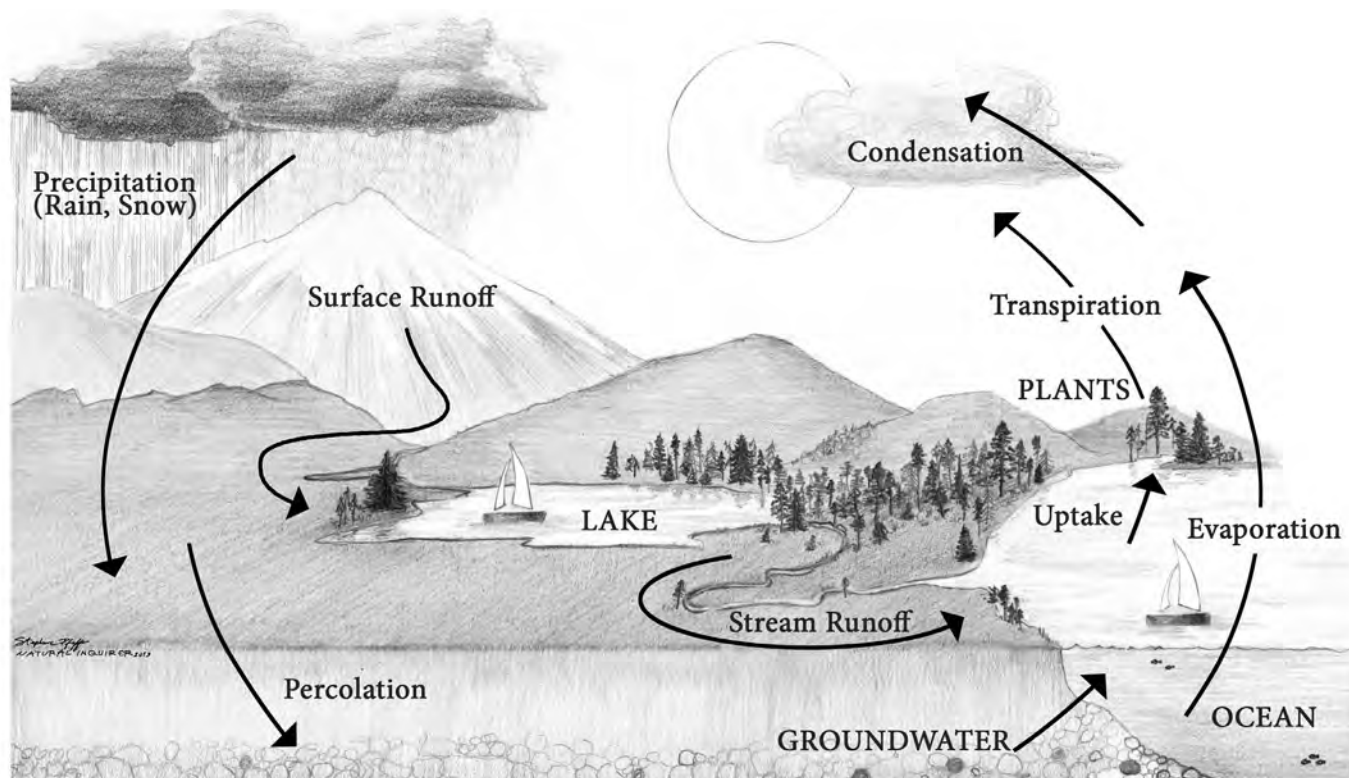
The scientists in this study wanted to figure out how forest management, climate change, and streamflow interact. First, the scientists wanted to

identify if forest management could affect streamflow. Second, the scientists wanted to identify types of forest management that would help protect against extreme precipitation changes that may occur as the climate changes.



FIGURE 2. DROUGHTS CAN HAVE A HUGE IMPACT ON GROWING PLANTS.
PHOTO BY R.L. CROISSANT AND COURTESY OF
[HTTP://WWW.BUGWOOD.ORG](http://www.bugwood.org).

FIGURE 3. EVAPORATION AND TRANSPIRATION ARE PART OF THE WATER CYCLE. ILLUSTRATION BY STEPHANIE PFEIFFER.



Reflection Section



- ➡ In your own words and in the form of a question, state what questions the scientists were trying to answer.
- ➡ Do you think it is important to figure out how forest management, climate change, and streamflow interact? Why or why not?
- ➡ Look at figure 3. In this illustration, identify one more way trees and other plants contribute to the water cycle.

Methods

The scientists obtained their data from an area called the Coweeta basin in the Southern Appalachian mountains (FIGS. 4A, 4B, AND 5). Air temperature and precipitation have been recorded at the main climate station there since 1934. Nine recording rain gauges and twelve standard rain gauges are located throughout the basin (FIG. 6). Six of these gauges have been recording since 1936.

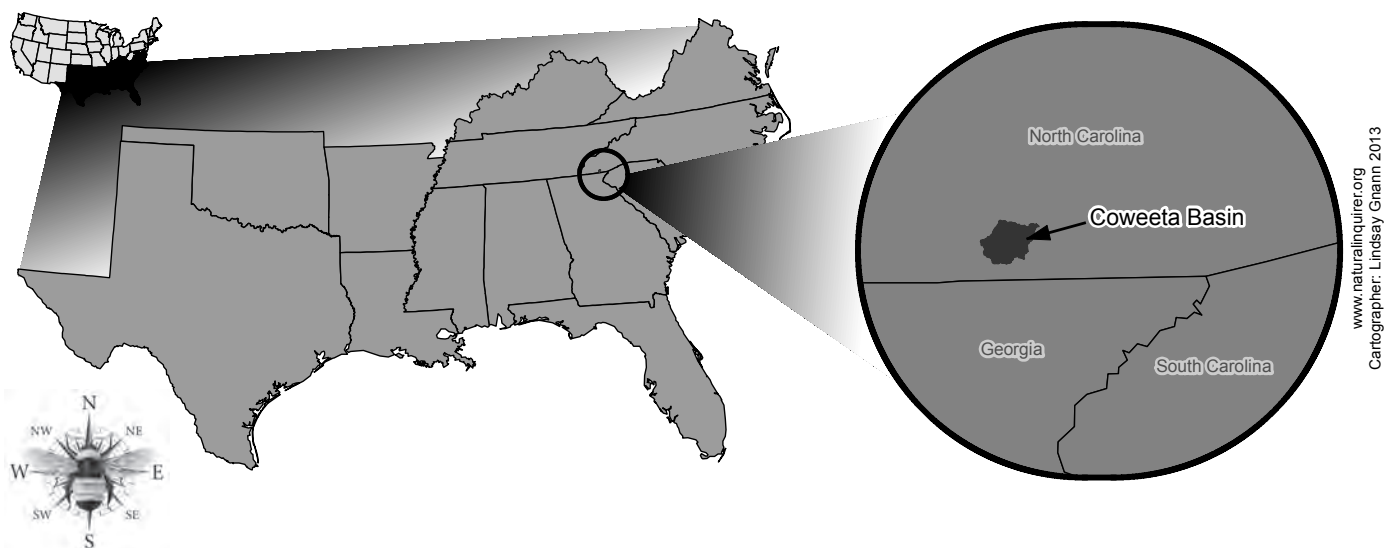
Meet the Scientist



James Vose,
RESEARCH ECOLOGIST:

Growing up in a big city, I never realized the important connection between forests and the water that I enjoyed for swimming and fishing. The river where I spent most of my summers began as a small creek in a forest more than two States away! Dr. Stephanie Laseter is with me in this photo.

FIGURE 4A. THE COWEETA BASIN IS LOCATED IN THE SOUTHERN UNITED STATES. MAP BY LINDSAY GNANN.



Number Crunch



► What percent of the rain gauges have been in use since 1936?

FIGURE 4B. THE COWEETA BASIN IS A FORESTED WATERSHED.
PHOTO COURTESY OF USDA FOREST SERVICE.



FIGURE 5. THE AREA OF STUDY IN THE COWEETA BASIN IS OUTLINED IN THE MIDDLE OF THE PHOTO. PHOTO COURTESY OF USDA FOREST SERVICE.

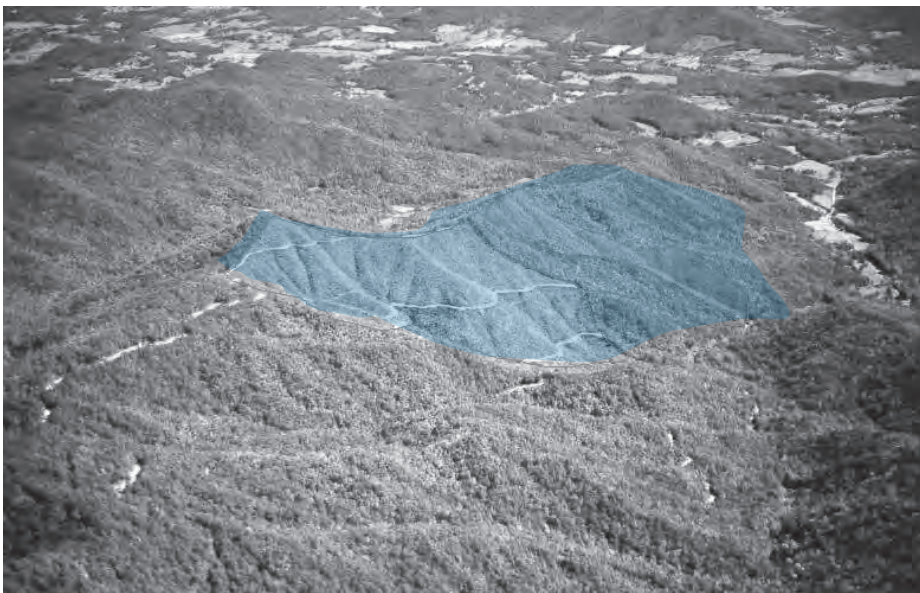


FIGURE 6. RAIN GAUGES ARE USEFUL IN DETERMINING HOW MUCH AND HOW FAST WATER FALLS ACROSS DIFFERENT AREAS. THE SCIENTISTS IN THIS STUDY FOUND THAT THE AMOUNT OF PRECIPITATION INCREASED BY 30 PERCENT AT HIGHER ELEVATIONS. WHY DO YOU THINK THIS MIGHT HAPPEN?



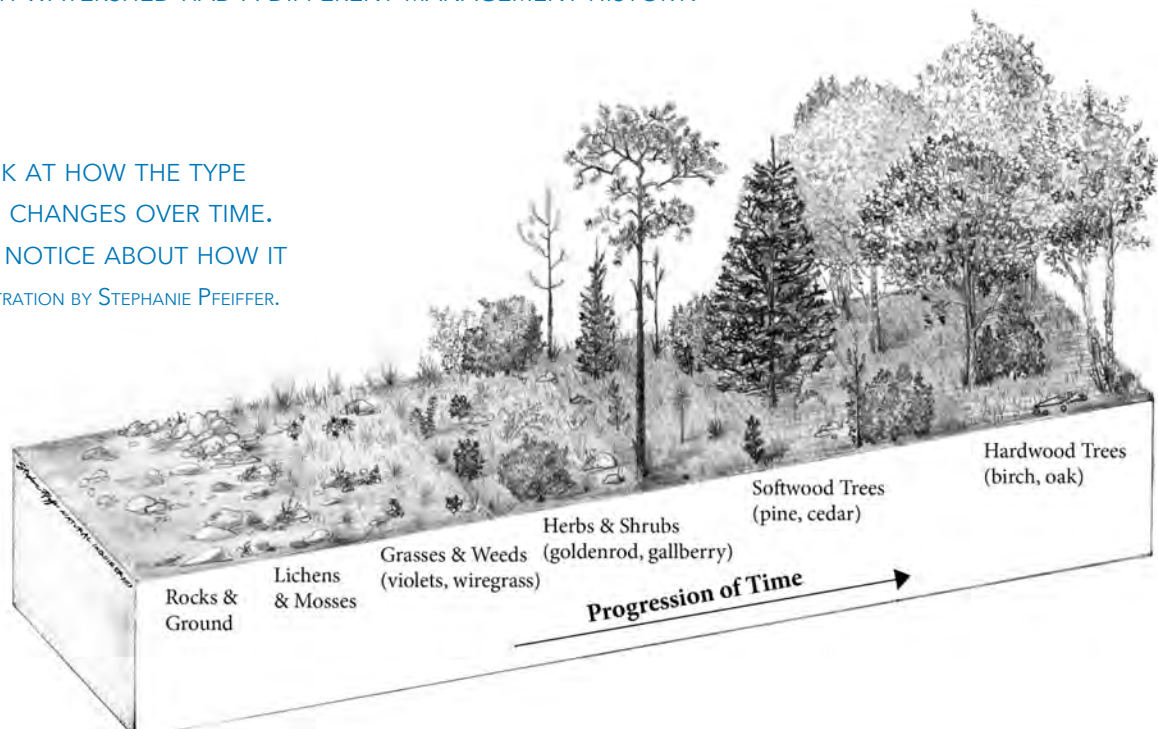
PHOTOS BY BABS McDONALD.

The scientists also used long-term streamflow records from six watersheds. The six watersheds had different management and land use histories (FIG. 7).

Watershed (WS=watershed)	Management History
WS1	Changing Tree Types- First, the entire watershed had a prescribed burn in 1942. The watershed was changed from Southern Appalachians deciduous forest to evergreen, eastern white pine plantation through planting and managing white pine trees.
WS17	Changing Tree Types- First, all woody vegetation was cut in 1941. The watershed was changed from Southern Appalachians deciduous forest to evergreen, eastern white pine plantation through planting and managing white pine trees.
WS37	High-Elevation Clear-cut - All woody vegetation cut in 1963.
WS7	Low-Elevation Clear-cut in 1977 and 1978.
WS13	Change to Coppice Stand- Clear-cut in 1939-40 and1962. Vegetation recovered through stump sprouting and existing roots creating a coppice stand.
WS6	Change from Trees to Successional Vegetation - Mixed-hardwood forest clear-cut in 1958. Changed to successional vegetation (FIG. 8).

FIGURE 7. EACH WATERSHED HAD A DIFFERENT MANAGEMENT HISTORY.

FIGURE 8. LOOK AT HOW THE TYPE OF VEGETATION CHANGES OVER TIME. WHAT DO YOU NOTICE ABOUT HOW IT CHANGES? ILLUSTRATION BY STEPHANIE PFEIFFER.



What Is a Reference Watershed?

A reference watershed is similar in size, character, and shape to another watershed being studied. The difference between the two watersheds in this study is that people did not take management action on the reference watershed. In some studies, a reference watershed is similar to the watersheds being studied, except that the effects of human activities are not visible or as visible.

If you are familiar with the concept of a **control** in scientific research, you will better understand reference watersheds. A control is one of the experimental conditions in which nothing is changed by the scientist. A control, like a reference watershed, enables a scientist to compare the results of their experiment (or management action) to a condition in which no action was taken.

The scientists were interested in the effect of the different management practices on these watersheds. The scientists compared closely located watersheds that were similar in size and pre-management land conditions. One watershed served as a reference watershed, and the other watersheds had a management treatment applied (SEE FIG. 7).

The scientists created mathematical models to help them explain the interaction between forest management and changes in climate on streamflow. The scientists used future precipitation and temperature forecasts from general circulation models (GCMs) and management histories to estimate the streamflow up to the year 2050. The scientists determined management forecasts by assuming that in 2009, each watershed was managed as it had been in earlier years.

The scientists then predicted how streamflow from the different watersheds might respond to future extreme precipitation events. Extreme precipitation events include extremely dry, or drought, conditions and extremely wet conditions. The scientists' predictions were based on what happened to these watersheds in the past. Instead of past weather and climate **variables**, however, the scientists used weather forecasted for the area from GCMs.

What Is a General Circulation Model?

A general circulation model is a computer model that allows people to forecast weather and predict future changes in climate. A general circulation model (GCM) can **simulate** the interactions of water, atmosphere, land surfaces, and ice. A GCM is run on computers and the output is interpreted by scientists.

Reflection Section



- ➡ The scientists examined six different watersheds with different types of forest management. Why do you think it was important for the scientists to look at a variety of different types of management?
- ➡ The scientists compared two watersheds at a time. In your own words, explain this comparison and why it would be useful for the scientists to use.

What Do the Abbreviations F and C Stand For?

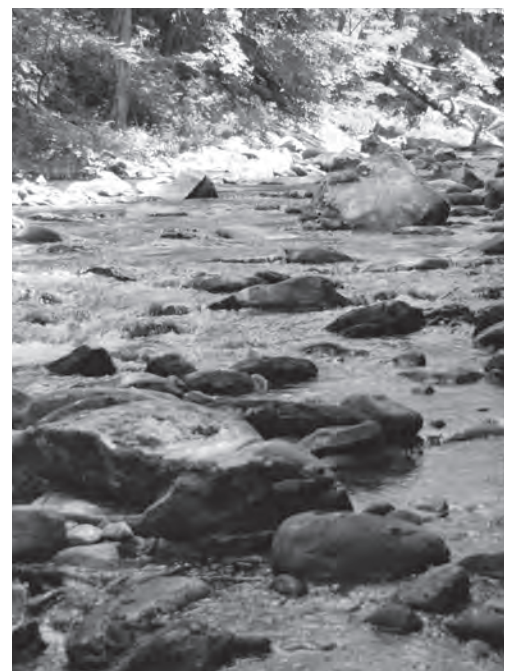
F is the abbreviation that stands for Fahrenheit, a nonmetric temperature scale, and C is the abbreviation for Celsius, the metric temperature scale. The ° symbol stands for "degrees." So, "18 °C" is read as "eighteen degrees Celsius." You will see temperatures written this way in *Natural IQ* articles as well as in articles that scientists publish in other journals. Most scientific publications use the metric scale.

Findings

The **mean** annual air temperature has been increasing at Coweeta. Since 1982, the temperature has been increasing at 0.5 °C per decade.

The scientists identified 10 extreme drought years since 1936. Eight of these extreme drought years have occurred since 1980. The most extreme dry year was 2000. The frequency of extreme wet years did not increase with time. The scientists identified 6 extreme wet years. Three of these extreme wet years occurred in the 1970s. The most extreme wet year was 1989. The summer months are becoming drier over time. The fall months are becoming wetter.

The scientists found that predicted streamflow in different future weather conditions was affected by almost all of the management actions examined. This finding supported the scientists' **hypothesis** that climate impacts may either be made better or worse by forest management that changes land cover. The streamflow in different possible climate conditions depended on what type of management action was taken. Converting areas of deciduous trees to pine trees reduced annual streamflow during both extreme wet and extreme



PHOTOS BY BAHS McDONALD.

dry years. Different tree species absorb different amounts of water through their roots. Different species emit different amounts of water from their leaves during transpiration. Because of these differences between tree species, more or less groundwater may be available to fill streams. The type of tree species being managed, therefore, affects the rate of streamflow during both extreme wet and extreme dry years.

Reflection Section



- ➡ Name two things the scientists found out about precipitation in the Coweeta basin. Why do you think this information is important?
- ➡ The scientists found that converting areas of deciduous trees to pine trees is likely to reduce the rate of streamflow, even in extremely wet years. What might happen in these converted areas as the climate warms and if yearly precipitation declines?

Discussion

The scientists found that both temperature and precipitation changed over the time period they studied the Coweeta basin. The scientists determined that management affected the relationship between precipitation and streamflow.

The scientists also determined that how an area is managed has an impact on streamflow. The change from deciduous trees to pine trees reduced annual streamflow during both extreme wet and extreme dry years. The scientists said that the reduced flow may worsen a drought during extreme dry years. However, the reduced flow may also help reduce flooding during extreme wet years.

Number Crunches

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What is 0.5 °C in °F? Use this equation to calculate the temperature in °F:
 $^{\circ}\text{C} \times 9/5 + 32 = ^{\circ}\text{F}$

How many decades have passed between now and 1982? How many degrees Celsius has the temperature increased during that time? How many degrees Fahrenheit?



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Number Crunch work area

In areas where pine trees were managed, the scientists found that there is a higher rate of **evapotranspiration** (ē **vap** ō tran spīr ā shən) (ET). Greater ET means that soils have more room to store water during wet years. Using this management treatment would be useful, therefore, in a future climate where precipitation is increasing. If the climate becomes drier in the future, however, then this management treatment would not be a good option.

The scientists are not sure if the forest management actions they studied can reduce the effects of climate change. They found, however, that converting areas from deciduous trees to pine trees helps to reduce the impact of **excessive** precipitation. In a future climate with too much precipitation, therefore, this management action would be helpful.

Reflection Section



- ➡ Why do you think it is useful for scientists to figure out how climate change may impact an area before the climate changes?
- ➡ Why would converting areas from deciduous trees to pine trees not be a good option if the climate becomes drier in the future?

Adapted from Ford, C.R., Laseter, S. H., Swank, W.T, and Vose, J. M. (2011). Can forest management be used to sustain water-based ecosystem services in the face of climate change? *Ecological Applications*. 21(6), 2049-2067. http://www.srs.fs.usda.gov/pubs/ja/2011/ja_2011_ford_001.pdf



ILLUSTRATION BY STEPHANIE PFEIFFER.



Glossary

bicarbonate (bī kār bə nāt): A type of acid that is developed from carbon.

clear-cut (klēr kət): A forestry procedure that removes all of the trees in a stand of timber.

control (kən trōl): A control is something used for comparison when checking the results of an experiment.

coppice (kā pəs): Forest originating mainly from shoots or root suckers rather than seed.

deciduous (di si jə wəs): Plants or trees that shed their leaves every year; not evergreen.

evaporation (i va p(ə-) rā shən): The process of converting water into vapor or fumes.

evapotranspiration: (i va pō tran spə rā shən): Loss of water from Earth by evaporation from Earth's surface and by transpiration from the leaves of plants.

excessive (ik se siv): Going beyond what is usual, proper, necessary, or normal.

groundwater (graünd wä tər): Water that sinks into the soil and is stored underground.

hypothesis (hī pä thə səs): An unproven idea that is accepted for the time being and is often tested during a scientific study.

hypothesize (hī pä thə sīz): To make an assumption to test its logical consequences.

intercept (in tər sept): To stop or interrupt the progress or intended course of something.

land cover (land kə vər): The observed cover of Earth's surface, such as vegetation and manmade features.

mean (mēn): The average in a set of numbers.

prescribed burn (pri skribed bərn): Controlled fires used to improve forest habitat.

simulate (sim yə lāt): To create the appearance or effect of something for purposes of evaluation.

streamflow (strēm flō): The movement of water in streams, rivers, and other channels.

successional vegetation (sək se shən əl ve jə tā shən): Plants, trees, and shrubs that naturally replace other plant life over time.

transpiration (trans pə rā shən): The process by which plants give off water vapor through the stomata in their leaves. Stomata are a part of a leaf and include a pore and special cells which regulate the size of the pore's opening.

variable (ver ē ə bəl): Something that is able or apt to vary.

watershed (wä tər shed): Land area that delivers water and sediment to a major river via small streams.

Accented syllables are in **bold**. Marks and definitions are from <http://www.merriam-webster.com>.

FACTivity

Time Needed

This FACTivity is meant to take a month to complete. The initial setup should take 1-2 class periods, and then it just takes a few minutes each day to monitor and record information.

Materials

- Five rain gauges or the materials to make rain gauges
- Paper for logbook or your science notebook

Rain gauge materials

- Five 2-liter bottles
- Tool to be able to cut top off plastic 2-liter bottles
- Duct tape
- Ruler
- Permanent marker
- Stones/ pebbles
- Water



The question you will answer in this FACTivity is: How much precipitation falls over a month's time at my school (or where I live)?

The method you will use to answer the question is:

1. Find five rain gauges. If you don't have rain gauges, you can easily make them. To make a rain gauge, follow these instructions. See the illustration on page 40.
2. Get a 2-liter plastic bottle and have an adult cut the top of the bottle off. Keep the top. Place duct tape around the areas that were cut so that sharp edges are covered.
3. Place pebbles or stones in the bottom of the bottle. These stones will help keep the bottle upright if it is windy outside.
4. On the bottom part of the bottle use a ruler to make a scale of horizontal lines. Start marking the lines from two inches above the bottom to two inches from the top. The lines should be separated by $\frac{1}{2}$ inch.
5. Fill the bottom with water to the first line on your scale.
6. Next, place the cut off top upside down into the bottle. The upside down top creates a funnel. Now your rain gauge is ready.
7. Number your rain gauges from 1 to 5. Take two rain gauges and place them in flat areas away from buildings or trees. Take the other three rain

gauges and place them in flat areas underneath trees and near buildings.

8. Create a logbook so that you can keep track of the precipitation over an entire month. Make a separate page for each rain gauge and write the number of the gauge as well as a brief description of the area in which the rain gauge is located. Be sure to date each entry.
9. Each day, check the rain gauges to see whether water has evaporated from the rain gauge. If water has evaporated, then fill the gauge with water again to the first line. After it rains and you have taken your measurement, empty the rain gauge and fill to the first line. Doing this will help you make better measurements when it rains. Make a note in your logbook every time you have to fill up the water to the first line.
10. After a month, examine the data you collected. Create a graph for each rain gauge and the amount of precipitation.

As a class, discuss what you learned when you examined the data. Here are some questions to get you started.

- Were there really wet times and really dry times? Did you see the same thing with each of the rain gauges?
- How did different rain gauges compare?
- Did all the gauges get the same amount of precipitation? If not, why do you think they may be different?
- Did you have to fill certain rain gauges with water more often than others? If so, why do you think this is?

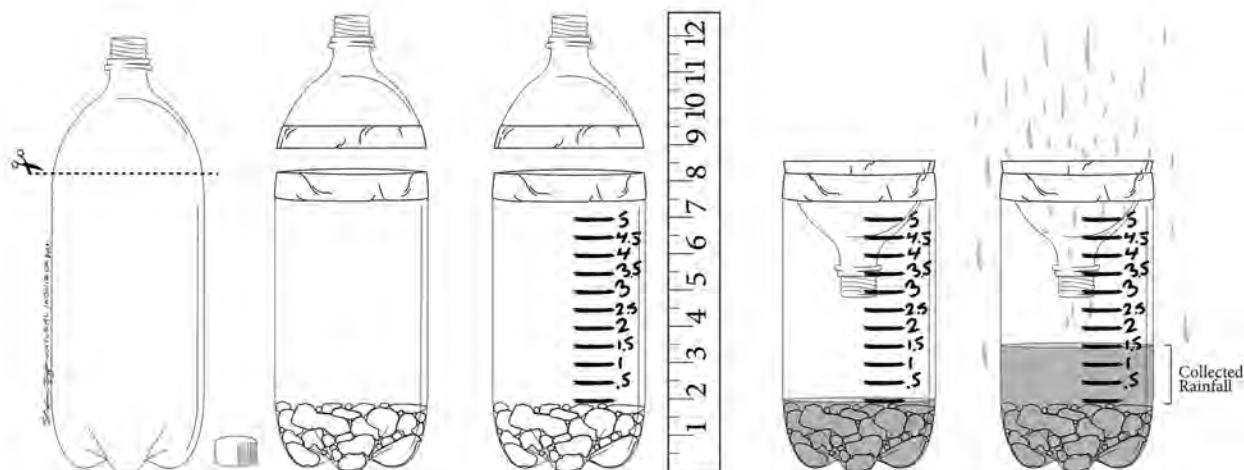


ILLUSTRATION BY STEPHANIE PREIFFER.

FACTivity Extension

You may want to continue this rain gauge project for a longer period of time. Additionally, you could compare your data to weather data that has been collected by the National Oceanic and Atmospheric Organization (NOAA). See the NOAA Web site for more information. <http://water.weather.gov/precip/>

Web Resources

Coweeta Long Term Ecological Research Web Site
<http://coweeta.uga.edu/>

Coweeta LTER Schoolyard Program
<http://coweeta.uga.edu/lterschoolyard>

U.S. Geological Survey (USGS) Water Cycle for Kids
<http://ga.water.usgs.gov/edu/watercycle-kids.html>

USGS Science in Your Watershed
<http://water.usgs.gov/wsc/watersheds.html>

Natural Inquirer Ecosystem Services Edition
<http://www.naturalinquirer.org/Eco-i-26.html>



If you are a Project Learning Tree-trained educator, you may also use the following activity as an additional resource: "Field, Forest and Stream."