Streaming Live:
How Do Streams Affect How Well Trees Use Water?

Meet the Scientists!

Dr. Darin Law,
plant ecologist:

My favorite science experience was completing a **native** and **exotic** grass study within the University of Arizona Biosphere 2 **(figures 1a and 1b)**. Biosphere 2 is a research facility where scientists perform experiments. Biosphere 2 also enables public participation in the scientific process. Biosphere 2 is a large enclosed building that **simulates** different ecosystems.

It was especially fun to talk with students from nearby schools who came to tour Biosphere 2. I told students about the work I do as a scientist. From the time I was young, I watched PBS *Nature* every Sunday evening. This TV show had a tremendous influence on my life. Now, I measure how plants respond to environmental conditions outside and inside Biosphere 2. When I make my measurements, I like to imagine that my work is being filmed for the PBS program *Nature*.

Figure 1a. Biosphere 2 is a large building that is completely closed to the outside environment. Within Biosphere 2, different land and **marine** environments are simulated**.** Scientific research is done within these environments. Photo courtesy of John Adams, University of Arizona, Biosphere 2.

Figure 1b. Inside Biosphere 2, different environments have been created. This water body simulates an ocean. Photo courtesy of John Adams, University of Arizona, Biosphere 2.

Dr. Deborah Finch,
biologist:

One of my most favorite science experiences was climbing with pack burros to the top of El Triunfo (trī **ün** fō), a **Biosphere** Reserve in southern Mexico. I was searching for the resplendent (rə **splən** dənt) quetzal (**ket** säl). The resplendent quetzal is a tropical bird with bright green feathers and a long tail. We were setting up a sister forest program with Mexican protected areas. This reserve was famous for protecting this spectacular bird!

What Kind of Scientist Did This Research?

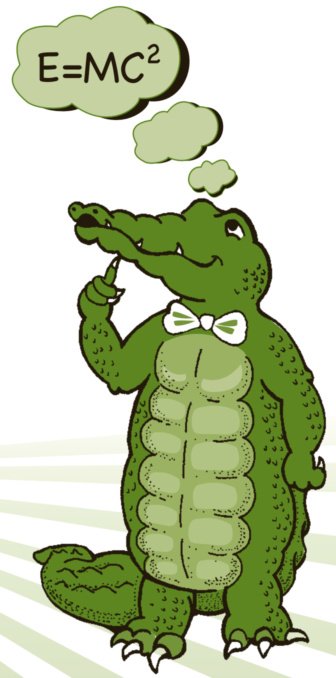
biologist: This scientist studies living organisms and systems.

plant ecologist: This scientist studies the relationships between plants and their environment.

Thinking About Science

Scientists use a lot of interesting and useful instruments. Technology improves the accuracy of scientific measurement. Technology has also enabled scientists to measure some things they could not measure in the past.

In this research, the scientists used a densiometer (**den** sē **ä** mə tər) to measure the amount of leaf cover (shade) in forested areas. The scientists used a porometer (pȯ **rä** mē tər) to measure the amount of carbon dioxide (CO_2) entering and the amount of water exiting leaf pores.



The scientists took measurements from thermometers, barometers, and anemometers (**an** ə **mä** mə tərs). Thermometers measure temperature. Barometers measure atmospheric pressure. Anemometers measure wind speed. The scientists used quantum meters **(figure 1)** to measure the amount of light reaching tree leaves. They used water level meters to measure the distance between the ground's surface and the top level of the water underground (**groundwater**). What do most of these instrument names have in common? What does "meter" tell you when it is the last five letters of a word?

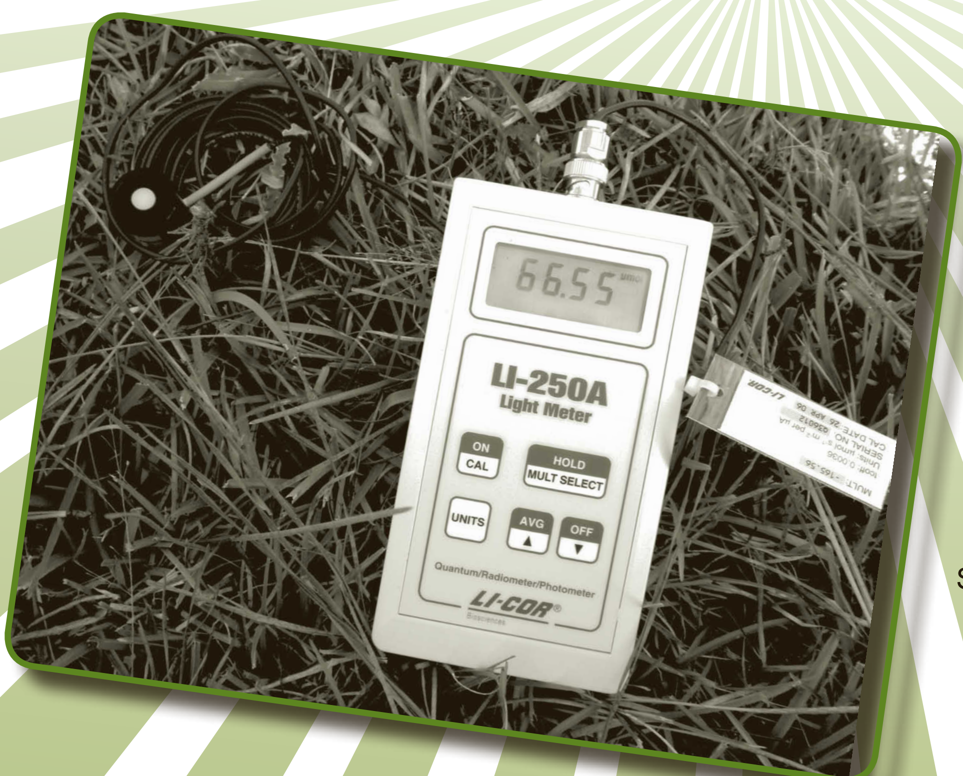


Figure 1. Quantum meters measure the amount of light. Photo courtesy of University of Georgia Warnell School of Forestry and Natural Resources. Photo by Jean Szymanski.

Thinking About the Environment

The Southwestern United States contains much **arid** land **(figure 2)**. Arid land has little water. In an area with little water, streams are important. Of all the streams in the Southwestern United States, 19 percent have water all year. The remaining 81 percent are either intermittent (in tər **mit** ənt) or ephemeral (əf **əm** ər äl) **(figures 3a and 3b)**. An intermittent stream has water for only part of the year. An ephemeral stream has water only following rain storms.

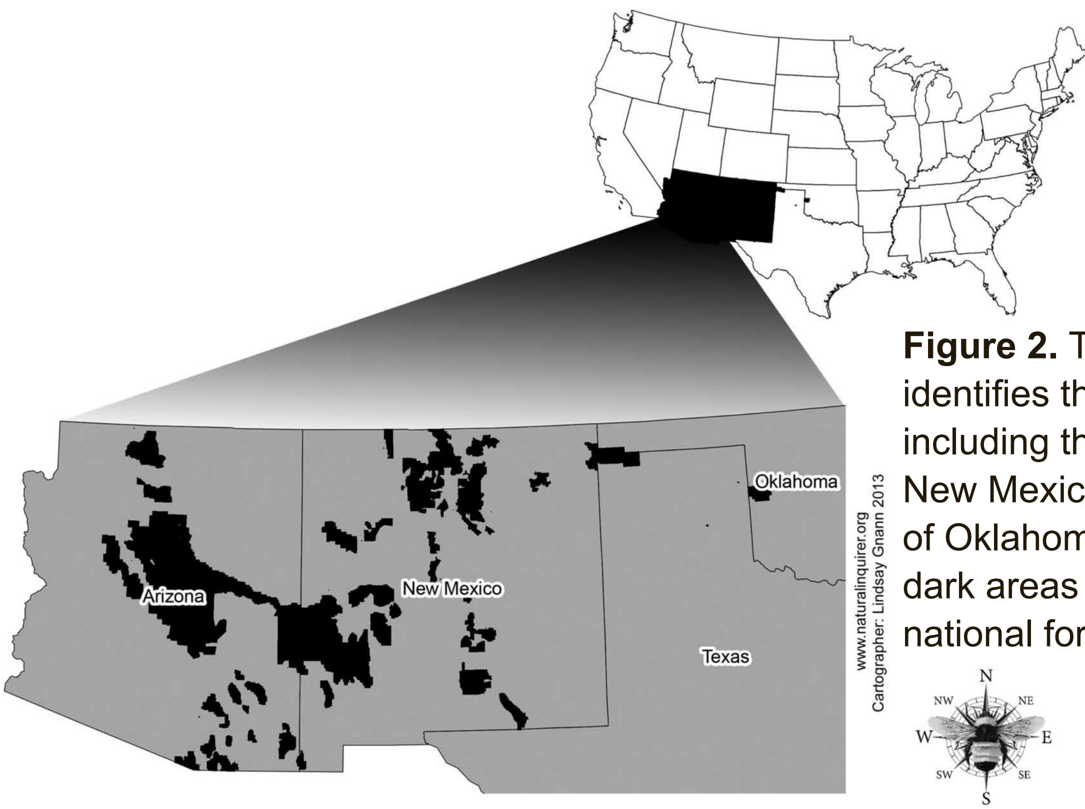


Figure 2. The Forest Service identifies the Southwest as including the states of Arizona, New Mexico, and western parts of Oklahoma and Texas. The dark areas show the location of national forests.

Although intermittent and ephemeral streams may not always have water you can see, these streams contribute to the area's groundwater. Groundwater is water found under the soil's surface. Groundwater from these streams supports plants that otherwise could not live in arid environments. These streams also provide benefits when they have water you can see. These streams provide **breeding habitat** for **amphibians**. Streams also cool the nearby air.

In this research, the scientists were interested in groundwater near intermittent and ephemeral streams. The scientists wondered how trees growing near and away from these streams used available groundwater. Since water is necessary for plants to survive, groundwater is important to plants. This is especially true during times of low or no rainfall, when most available water is groundwater.

Figure 3a. Intermittent streams have water during the rainy season. Ephemeral streams have water only after a rain. This illustration shows either an intermittent or an ephemeral stream during its wet season. Illustration by Stephanie Pfeiffer.

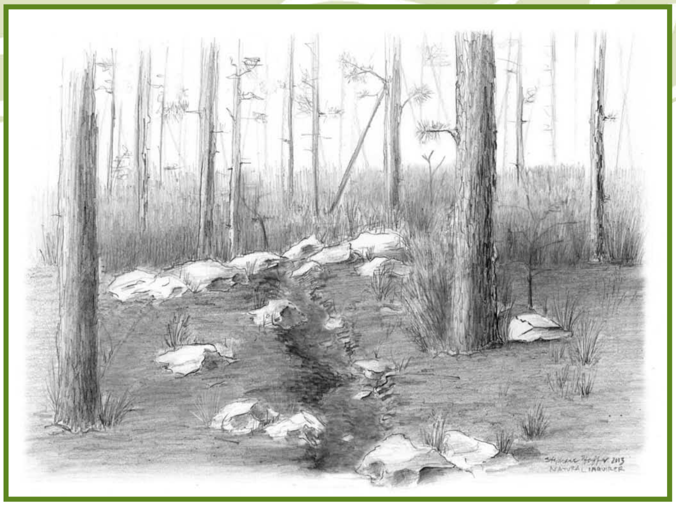


Figure 3b. Intermittent streams are dry during dry seasons. Ephemeral streams are dry between periods of rain. This illustration shows either an intermittent or an ephemeral stream during its dry season. Illustration by Stephanie Pfeiffer.

Introduction

Imagine a tree during times of low or no rainfall. To survive, this tree must use groundwater. Water in arid environments, including groundwater, is **scarce**. Trees, therefore, need to use groundwater **efficiently**.

Groundwater is absorbed by a tree's roots. The groundwater moves upward toward the leaves. The water carries **nutrients** with it **(figure 4)**. The leaves use some of the water for **photosynthesis.** Leaves have small openings called stomata. When a leaf's stomata are open, some of the water escapes into the air.

The process of water movement from inside the leaf into the air is called **transpiration**. Water is pulled upward through a tree similar to the way liquid is pulled upward through a straw. Transpiration helps move water from the ground into the roots, through the stem, and out of the leaves into the air. When stomata close a little or completely, transpiration is reduced or stopped. Think about what happens when the end of a straw is pinched.

Stomata have another job to do. When open, stomata allow carbon dioxide (CO_2) from the air to enter the leaf. In addition to water, trees need CO_2 for photosynthesis **(figure 5).** Photosynthesis is the process whereby trees use sunlight to change CO_2 to high-energy sugar. The trees use the sugar as food. The energy stored in the sugar enables trees to grow.

Open stomata are necessary for photosynthesis. Open stomata, however, can lower a tree's water use **efficiency**. When water is scarce, a tree has to balance transpiration (water loss) with the CO_2 it takes in. When a tree uses scarce water efficiently, two things happen. First, the tree maximizes photosynthesis. Second, the tree minimizes water loss.

The scientists in this study were interested in comparing the water use efficiency of trees. They wondered if the water use efficiency of trees growing away from intermittent and ephemeral streams was greater than the water use efficiency of trees growing near such streams. Compare this to a person using something more carefully because they only have a limited amount of it. The scientists also wondered if other nearby trees and wind speed affected the water use efficiency of trees.

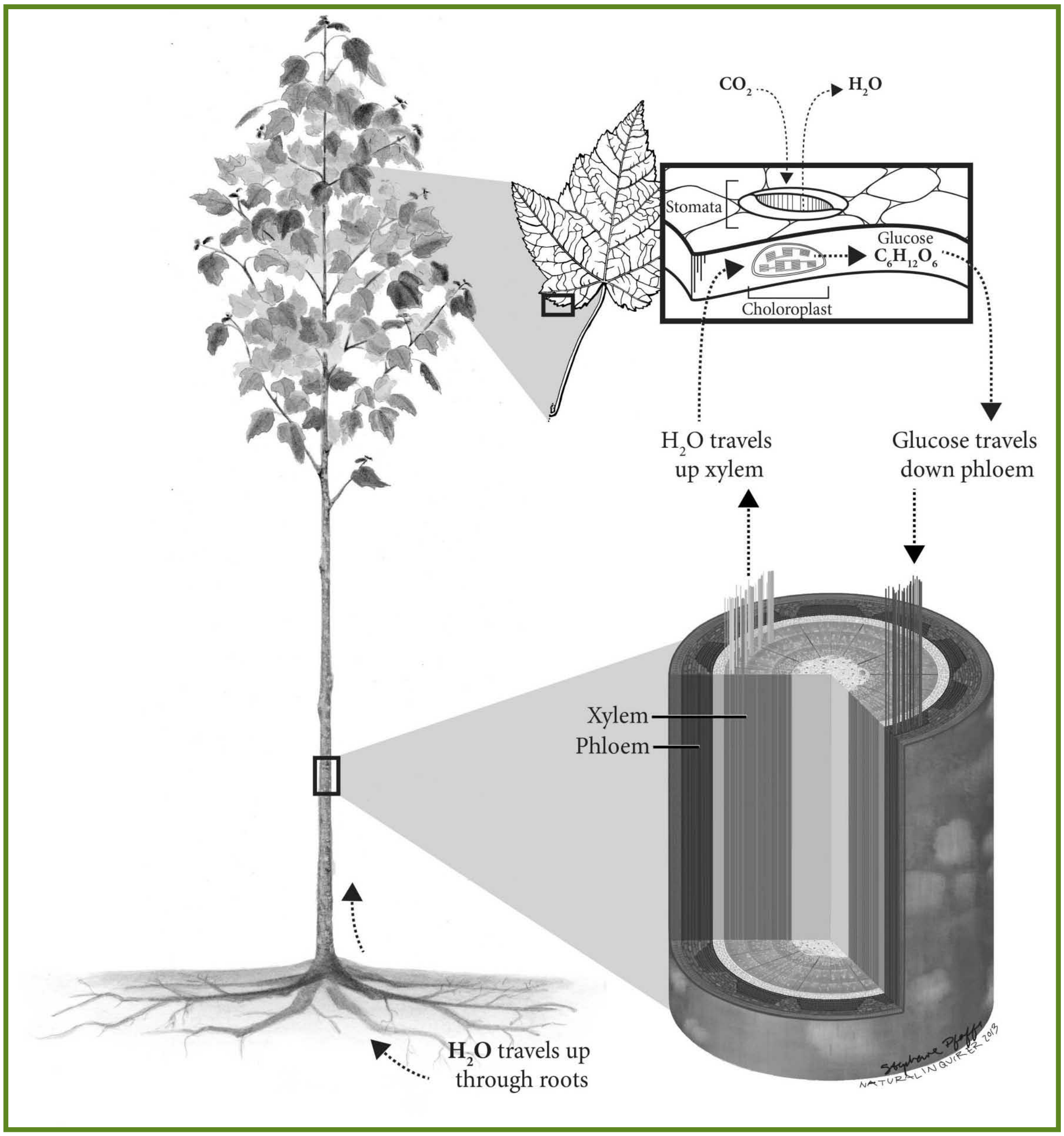


Figure 4. Water is carried upward from a tree's roots through the tree's xylem (**zī** ləm). Water exits the tree through stomata in the leaves. Illustration by Stephanie Pfeiffer.

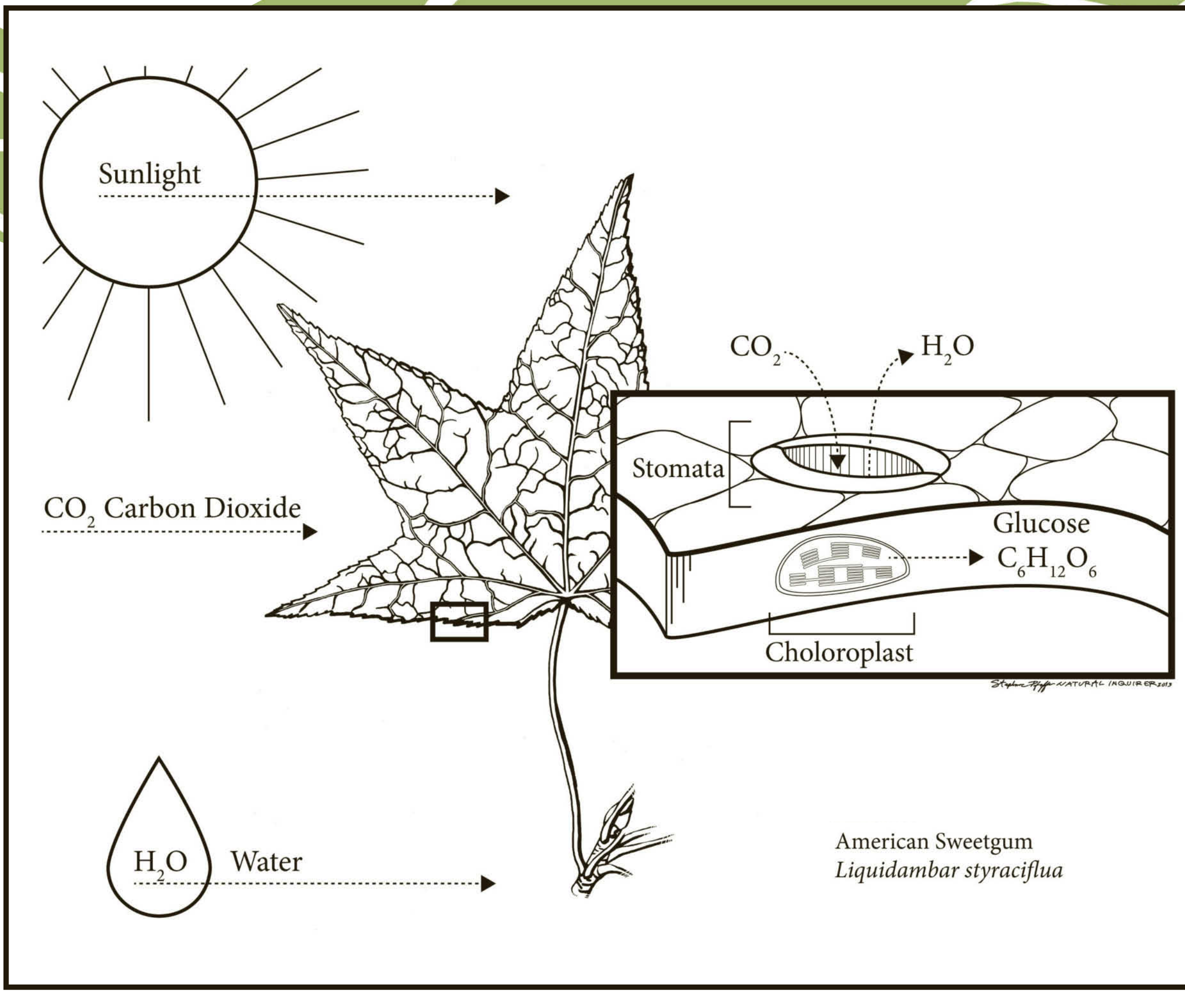


Figure 5.
Photosynthesis is the process plants use to convert sunlight into energy in the form of glucose. Illustration by Stephanie Pfeiffer.

- What problem do trees face when growing where water is scarce?
- How might nearby trees affect a tree's water use efficiency?
- How might wind speed affect a tree's water use efficiency?

Methods

First, the scientists needed to know if areas next to and away from intermittent and ephemeral streams had groundwater. They also needed to know how far the groundwater was from the soil surface. The scientists dug shallow water wells next to and away from intermittent and ephemeral streams and measured the groundwater depth **(figure 6)**.

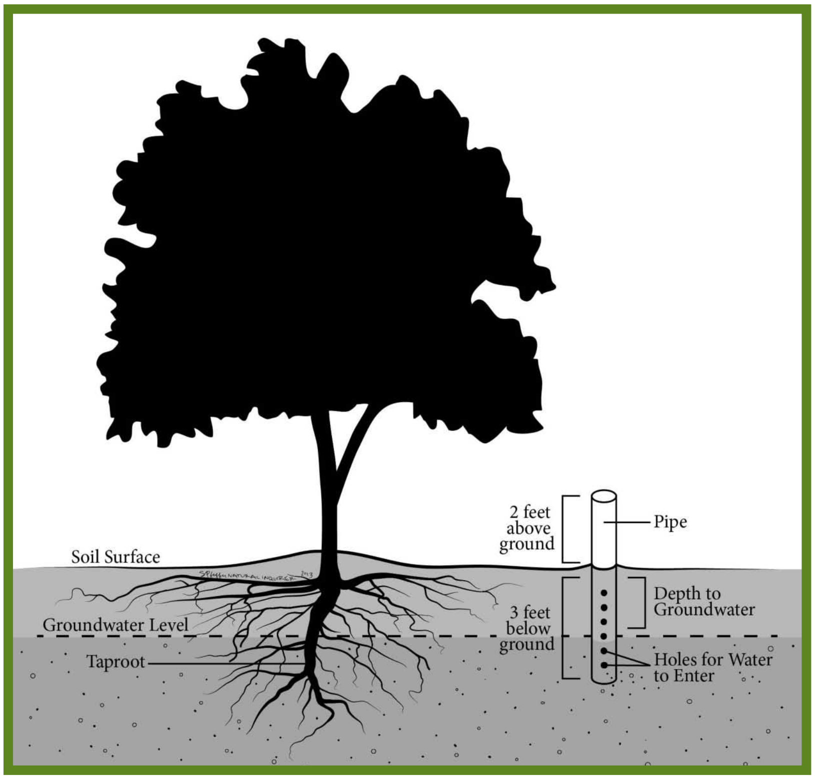


Figure 6. The scientists dug shallow water wells to check for groundwater. The wells were thin pipes with small holes. The pipes were placed deep into the soil. The holes allowed groundwater into the pipe. The scientists then measured the distance between the soil surface and the groundwater in the pipe below the soil surface. Illustration by Stephanie Pfeiffer.

The scientists needed a way to measure the abundance of trees growing in an area. They did this by measuring the amount of shade cover in an area. Shade cover can be measured by the percentage of an area covered by leaves. The scientists also measured air temperature, **relative humidity**, wind speed, and rainfall **(figure 7)**. They measured the amount of light reaching the trees **(figure 8)**. The scientists measured the amount of CO_2 entering and the amount of water exiting the leaf pores **(figure 9)**. The scientists also selected leaves from some of the trees and traced the leaves on paper. They then calculated the area of each leaf to compare leaf sizes from different trees.

Figure 7. Weather stations were set up to measure air temperature, relative humidity, wind speed, and rainfall. This is a weather station at the University of Georgia. Photo courtesy of University of Georgia Department of Geography. Photo by Jean Szymanski.

Figure 8. A densiometer measured the amount of **canopy** cover. Canopy cover is the percentage of leaves shading the ground. Photo courtesy of University of Georgia Warnell School of Forestry and Natural Resources. Photo by Jean Szymanski.

Figure 9. A porometer measured the amount of CO_2 entering and the amount of water exiting a leaf pore. Photo courtesy of University of Georgia Warnell School of Forestry and Natural Resources. Photo by Jean Szymanski.

The scientists used a computer program to compare all of these things. The scientists compared the amount of photosynthesis with the amount of water transpired. This comparison was used as a measure of water use efficiency. The scientists then compared the water use efficiency of trees growing near and away from intermittent and ephemeral streams. They also compared the water use efficiency of trees growing with many trees nearby and with few trees nearby.

Reflection Section

- Why did the scientists need to know how much rain had fallen?
- As Earth's climate changes, some areas may receive less rainfall. Could this research be useful to people living in areas that already have enough rainfall? Why?

Findings

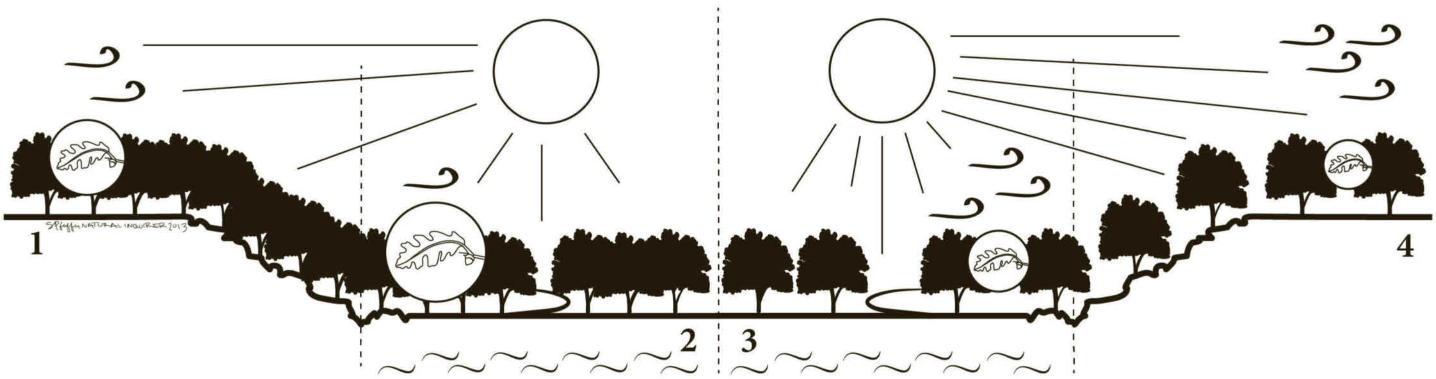
The scientists compared trees in four areas (see figure 10):

1. Areas with many trees growing away from intermittent and ephemeral streams.
2. Areas with many trees growing close to intermittent and ephemeral streams.
3. Areas with few trees growing close to intermittent and ephemeral streams.
4. Areas with few trees growing away from intermittent and ephemeral streams.

The scientists discovered relationships among water use efficiency, photosynthesis, transpiration, and leaf size **(figure 10)**.

The areas with highest water use efficiency were the areas with few trees growing away from streams. The areas with lowest water use efficiency were the areas with many trees growing close to streams. High amounts of sunlight and low transpiration seem to favor a more efficient use of water. When water use efficiency is high, leaf size is smaller. When water use efficiency is low, leaf size is larger.

When trees are not growing near each other, wind speed is higher and transpiration increases. When many trees are growing close to each other, wind speed is lower and transpiration decreases.



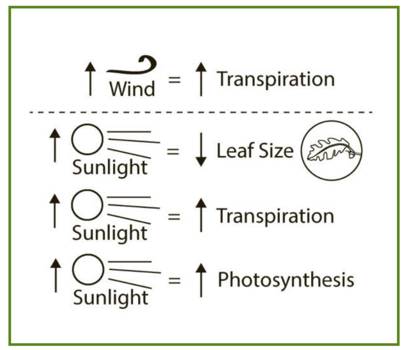
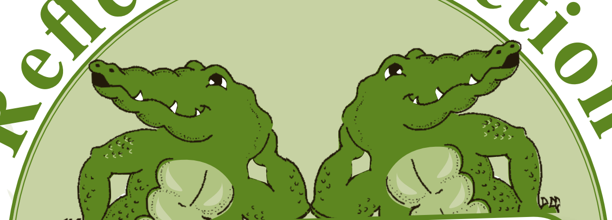


Figure 10. What are the relationships between water use efficiency, leaf size, photosynthesis, and transpiration? Illustration by Stephanie Pfeiffer.

Reflection Section



- Look at figure 10. What can you conclude from this figure?
- Why do trees growing closer to intermittent and ephemeral streams not need to be as efficient with water use as trees growing away from streams?

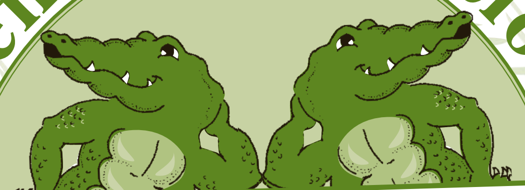
Photo courtesy of Gila National Forest.

Discussion

Based on their results, the scientists suspect something important about CO_2 gain and water loss in trees. They believe that trees work to balance CO_2 gain with water loss to remain healthy. In areas with scarce water, trees try to absorb more CO_2 and transpire less water. To achieve this balance, trees open or close their stomata to increase water use efficiency. If trees are growing close to other trees, the trees increase their leaf size to help absorb more CO_2.

The scientists noted that trees responded to many things in their environment. Trees responded to the amount of light and water available. The trees responded to the number of other trees growing nearby. The trees also responded to wind speed. Trees must respond to all of these conditions. When water is scarce, trees must increase their water use efficiency. They increase water use efficiency by decreasing the amount of water they lose and increasing the amount of light and CO_2 they absorb.

Reflection Section



- Are you surprised that trees respond to environmental conditions? Why? What is another example of plants responding to their environment?
- In the human body, what mechanism is similar to transpiration?

Adapted from Law, D.J.; Finch, D.M. 2010. Hydrologic, abiotic and biotic interactions: plant density, windspeed, leaf size and groundwater all affect oak water use efficiency. Ecohydrology. 4:823-831. http://www.fs.fed.us/rm/pubs_other/rmrs_2011_law_d001.pdf

Glossary

absorption (əb **sȯrp** shən): The process of taking in.

amphibian (am **fib** bē ən): An organism that lives both on land and in water; a class of cold-blooded vertebrate animals.

arid (**a** rəd): Excessively dry.

biosphere (**bī** ə sfir): The part of the world in which life exists. In this article, Biosphere 2 is the name of a man-made enclosed area that supports life and a biosphere reserve is a protected natural area that supports a diversity of life.

breeding habitat (**brēd** iŋ **ha** bə tat): An environment where a plant or animal naturally reproduces.

canopy (**ka** nə pē): Anything that covers like a roof. On a tree, the area of leaves that covers the ground.

decay (di **kā**): To break down, rot, or undergo decomposition.

efficient (i **fi** shənt): Capable of getting desired results without waste.

exotic (ig **zä** tik): Strange, different, or foreign.

groundwater (**grau̇nd wä** tər): Water that is underground.

habitat (**ha** bə tat): The environment where a plant or animal naturally lives and grows.

intensity (in **ten** sə tē): The quality or state of being extreme in strength or force.

marine (mə **rēn**): Of or relating to the sea.

native (**nā** tiv): Living or growing naturally in a particular region.

nutrient (**nü** trē ənt): A substance that plants, animals, and people need to live and grow.

photosynthesis (**fō** tō **sin** thə səs): The process by which plants turn water and carbon dioxide into food when exposed to light.

relative humidity (**re** lə tiv hyü **mi** də tē): The amount of water vapor actually present in the air compared to the greatest amount possible at the same temperature.

scarce (**skers**): Not plentiful.

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

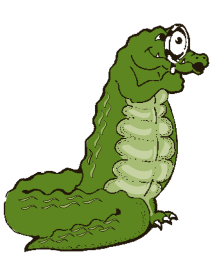
transpiration (**tran(t)s** pə **rā** shən): The process by which plants give off water vapor through the stomata in their leaves.

unit of measurement (**yü** nət äv **me** zhər mənt): A quantity used as a standard of measurement.

urban forest (**ər** bən **fȯr** əst): Trees and other vegetation growing within a city or town.

variable (**ver** ē ə bəl): Something that, when its quantity is measured, can have a range of different values.

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



If you are a trained Project Learning Tree educator, you may use Activity 41: How Plants Grow or Activity 42: Sunlight and Shades of Green.

FACTivity

Time needed:
One class period and, optionally, an additional 30 minutes in a second class period

In this FACTivity, you will explore a range of instruments used by scientists. You will then use your imagination to create instruments that measure a range of classroom **variables**.

Materials
- Access to the Media Center or the Internet
- Graphic organizers on pages 68-69
- "Streaming Live" article

In this article, the scientists used the following instruments to collect, measure, and record data:

Instrument	Measures
Thermometer	Air temperature
Barometer	Relative humidity
Anemometer	Wind speed
Porometer	Pore opening size (stomata opening size)
Densiometer	Tree canopy cover
Water well meter	Depth from soil surface to ground water
Quantum meter	Light intensity

If you read "Thinking About Science," you will have a good idea of what the word "meter" at the end of each of these instrument names means. It gives you a clue that the first part of the instrument name tells what variable the instrument measures.

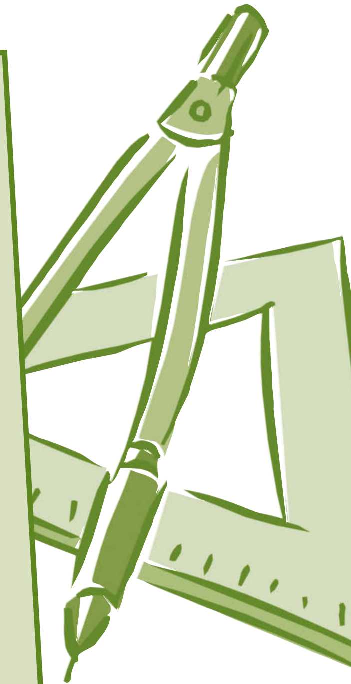
The questions you will answer in this FACTivity are:

1. What are at least five more instruments with the word "meter" in their name, and what variables do they measure?
2. What instrument names can be created for imaginary use in the classroom and what **unit of measurement** would these instruments use?
3. What are the characteristics of a useful unit of measurement?
4. How does having a measurement range help someone to understand the measurement?

The method you will use to answer this question is:

1. Your class should first brainstorm any additional instruments you know ending with the letters "m-e-t-e-r." These instruments should be written in the graphic organizer given in the next section. You should then do research on the Internet or in your Media Center about scientific instruments. Record any instrument ending with the five letters "meter" and what variable it measures in the graphic organizer. To complete the graphic organizer, you should also fill in the column named "unit of measurement." The unit of measurement is the numeric unit used to measure the variable. A thermometer, for example, measures the air temperature in degrees Fahrenheit or Celsius. Your class should identify as many instruments as possible.

2. After you have identified instruments, it is time to get creative! Using the second graphic organizer, imagine instruments that measure variables that could be found in the classroom. Below are examples. Remember that these are not real instruments!



Instrument Name	Measures	Unit of Measurement	Measurement Range
Footometer (fö **tə** mə tər)	Foot length	Inches or centimeters	6 inches-15 inches (15.24- 38.1 centimeters)
Silencometer (sī lən **sö** mə tər)	The amount of time students have been silent	Seconds or minutes	0-600 seconds or 0-10 minutes
Jumpometer (jum **pö** mə tər)	How far or high a student can jump	Feet or meters	6 inches-4 feet (0.15-1.22 meters)

3. After the created instruments have been identified and the graphic organizer is completed, your teacher will lead a class discussion about scientific instruments. In particular, you will discuss the need for a clear unit of measurement and a measurement range. Discuss and answer the following questions:

    a. What are the characteristics of a useful unit of measurement?

    b. How does having a measurement range help you understand the measurement?

While doing Internet or Media Center research, other instrument names may have been found. An example is "rain gauge." You should realize that scientific instruments do not all end with the five letters that spell "meter."

FACTivity
continued

Your teacher will lead a class discussion in which you explore how the use of scientific instruments helped the scientists in this study do their research.

Scientific Instruments

Instrument Name	Measures	Unit of Measurement

Instruments That Might Be Used in the Classroom

Instrument Name	Measures	Unit of Measurement	Measurement Range

Optional (using an additional 30 minutes at the end of a week): Student teams identify additional real scientific instruments and/or create new imagined instruments over a week's period. The team with the longest (and best documented) list of instruments wins. All listed instruments, whether real or imagined, must include the four columns shown in the second graphic organizer. Students will present their instruments and the class will pick the team winner.

For a FACTivity about leaf transpiration, see the FACTivity for the "Woolly Bully" monograph at http://www.naturalinquirer.org.

Web Resources

Weather instruments
http://www.weatherwizkids.com/weather-instruments.htm

Biosphere 2
http://www.b2science.org/

What is a densiometer?
http://www.youtube.com/watch?v=nTc_sqUPVZo

We need trees!
http://kids.discovery.com/tell-me/earth/why-do-we-need-trees

Do trees grow on farms?
http://www.realtrees4kids.org/index.htm