Circles in the Landscape:
Irrigating Oklahoma Crops

Objective
Students will read about irrigation and become familiar with vocabulary words. Students will conduct various scientific experiments and mathematical calculations related to irrigation and rainfall.

Background
Irrigation is the number one use of water in Oklahoma. Many of the crops that grow in our state could not survive without an alternative to rainfall and other precipitation. The average annual precipitation for Oklahoma is about 37 inches, but that amount varies a great deal from southeast to northwest and from spring to fall. Annual average precipitation for the eastern part of the state averages between 35 and 57 inches, while the average in the west averages between 15 and 35 inches. Irrigation fills in the gap by providing water stability, which allows Oklahoma farmers to grow a wider diversity of crops.

Crops require a consistent water supply, since 85 percent of a plant may consist of water. Water moves through and cools the plant as it evaporates while carrying the nutrients needed for its growth. Early water stress limits growth and delays development. Later water stress can result in reduced yields and poor crop quality. Inadequate soil moisture also limits the availability of nutrients needed for root growth.

Water is lost from the soil through evaporation and transpiration. Evaporation is the loss of water by conversion into vapor. Transpiration is the process by which plants give off water vapor through the stomata in their leaves. Evapotranspiration is the loss of water from the soil both by evaporation and transpiration.

Plants can best use water if the soil moisture is maintained near field capacity at all times. Field capacity is the point at which gravity has drained all the free water down through the root zone, and the remaining water is held by the soil particles. It is a good balance of soil moisture and aeration.

A crop's water requirement changes during its life cycle. For most crops, water requirements are modest during early growth. Soil water content during germination and early growth is critical. Once the seed coat ruptures and the radicle (root) and plumule (shoot) emerge, the plant cannot return to seed dormancy. If the germinating seed does not receive ample water, it will die. Too much water will displace air containing needed oxygen in the soil, and most plants will suffocate. Water needs increase with increased growth and leaf area. For the many crops harvested as fruits or seeds, meeting water needs during reproduction and grain fill is critical.

Irrigated crops in Oklahoma include corn, hay, wheat, grain sorghum, cotton, peanuts and soybeans. The amount of water needed for irrigating crops

Oklahoma Academic Standards

GRADE 6
Social Studies: 1.1,2,4; 3.1; 5.2B,3
Number & Operations: 4.1,4. Algebraic Reasoning: 3.1

Life Science: 2-1; 4,5. Earth Science: 2-4, 3-3

GRADE 7
Social Studies: 1.1,2,3
Number & Operations: 2.3. Algebraic Reasoning: 2.2; 3.3. Geometry & Measurement: 3.1,2
Life Science: 1-5

GRADE 8
Algebraic Reasoning: 4.3
Earth Science: 3-1

HIGH SCHOOL
World Human Geography: 1.1,2,4; 5.2,4
Life Science: 1-3; 2-1,2,6
Earth & Space Science: 2-5; 3-1,2

depends on many factors, including weather conditions, soil type and the specific needs of the crop. Many Oklahoma farmers plant drought-resistant crops because of the unpredictable nature of our weather. Wheat, hay, cotton and grain sorghum are examples of drought-resistant crops.

Most Plains farmers apply water to their fields using either surface or sprinkler methods. One method makes use of furrows plowed between crop rows. Water flows into the furrows from a pipe with holes called "gates" or out of a ditch using tubes called "siphons." Furrow irrigation is used when the land is flat and the soils absorb water slowly.

The leading form of sprinkler irrigation is the center pivot method. The center pivot sprinkler is a lateral pipe, with spray nozzles, often suspended on drop tubes and mounted on wheeled structures called "towers." The tower is anchored at the center of the field and automatically rotates in a circle. A typical center pivot has a 1/4-mile radius and waters about 130 acres. Adding or subtracting pipeline and towers can irrigate more or less ground. Center pivot systems can water uneven terrain and fast absorbing soils.

Drip irrigation is a method used by some Oklahoma farmers to conserve water, especially for crops that are not drought-tolerant. Drip or trickle irrigation refers to the frequent application of small quantities of water at low flow rates and pressures. Rather than irrigating the entire field, drip irrigation delivers water precisely at the plant where nearly all the water can be used for plant growth. This method is especially useful in the production of fruit and vegetable crops.

Background Sources: Broner, I, and J. Schneekloth, "Seasonal Water Needs and Opportunities for Limited Irigation for Colorado Crops," Colorado State University Extension, fact sheet no 4.718; Kizer, Michael, "Drip (Trickle) Irrigation Systems," OCES Fact Sheet BAE 1511

Social Studies

1. Read and discuss the background and vocabulary.
2. Students will conduct an online map search for "Guymon, Oklahoma."
   —Students will choose the satellite view and discuss what they see. Explain that the large circles are fields of corn irrigated with center pivot sprinkler irrigation systems. The corn is used for feeding the swine and beef produced in that area. In some areas students should see housing and lagoons used in swine production. Effluent from the swine operations is pumped from lagoons and plumbed into irrigation systems for irrigating the corn crop used to feed the swine.
   —Provide graph paper.
   —Students will work individually or in groups to develop blueprints for farming operations similar to those seen on the satellite image.
   —Students will provide space for hogs and for cornfields.
   —Students will place a marker in the center of each cornfield and draw a circle from that point as large as possible while staying inside the field boundary. Students should keep in mind that a typical center pivot has a 1/4-mile radius and waters about 130 acres.
   —Students will find the area of the irrigated and non-irrigated parts of

Resources Needed

cuttings from houseplants

measuring cups

small clear plastic cups

markers

aluminum pans or bowls to catch overflow

water

tablespoon measuring spoons

circular lawn sprinkler

rain gauges (or clear jars marked at 1/2 inch intervals

computer access

Oklahoma Mesonet

Oklahoma farmers are able to take much of the guesswork out of irrigation through use of the Oklahoma Mesonet network. A multidisciplinary project of scientists at OSU and OU, Oklahoma Mesonet provides up-to-date information about soil temperature and water content, evapotranspiration levels and other critical information. Producers can even get specific information about how much to irrigate specific crops in specific parts of the state, based on accumulated precipitation, evapotranspiration levels and crop needs.

agweather.mesonet.org

the farm.

Math

1. Hand out the "Center-Pivot Irrigation" worksheet.
   —Read and discuss the information on the worksheet. Ask the following questions.
   - What type of terrain works best for center-pivot irrigation?
   - Would our area be suitable for this type of irrigation? Why or why not?
   - Where in Oklahoma do you think this type of irrigation would work best? Why?

   —Review how to find the area of a rectangle.
   —Students will follow the instructions on the worksheet.
2. Hand out copies of the Rainfall Chart for Stillwater.
   —For each of the years listed, students will determine how much more water would be needed for growing winter wheat during the winter wheat growing season (September-June), assuming wheat needs 16 inches for a season.
   —For each of the years listed, students will determine how much more water would be needed for growing corn during the corn growing season (April-October), assuming corn needs 30 inches of precipitation for a season.

Science

1. Lawn experts recommend at least one inch of water per week to keep a lawn healthy. Students will use the Scientific Method Format included with this lesson to conduct the following experiment:
   - Place rain gauges (can be simple glass jars with marks at half inch intervals) to collect water from a circular lawn sprinkler.
   - Run the sprinkler for 30 minutes.
   - Read the gauges to determine how much water was collected.
   - How long would the sprinkler need to run to accumulate one inch of water?

   —Students will develop methods for determining how far the sprinkler reaches and how much area it covers.
2. Discuss the definitions for evaporation, transpiration and evapotranspiration.
   —Provide cuttings of houseplants that can survive in water for a long period of time (philodendron, English ivy, airplane plant, etc.) Students will conduct an experiment, as follows, for measuring evaporation, transpiration and evapotranspiration using the Scientific Study Format included with this lesson.
   —Measure one cup of water in a clear plastic cup and place the plants in the water.
   —Measure one cup of water into an identical clear plastic cup and place the cup next to the first container.
   —Place marks on the outside of the cup to indicate the water level.
   —Observe the two cups over a one-week time period and place marks at the water level daily to indicate water loss. Water loss from the second container will indicate evaporation, while water loss from the first container will indicate transpiration and evaporation (evapotranspiration).
   —Record measurements and determine loss from evaporation (second container), evapotranspiration (first container) and transpiration
3. Hand out copies of the "Water Balance" diagram included with this lesson.
   —Discuss the concept of water balance, as explained on the diagram.
   —Students will work in groups to conduct the experiment described on the "Water Balance" worksheet.

Additional Reading

Groundwater Foundation, *Rainmakers: A Photographic Story of Center Pivots*, Groundwater Foundation, 2005.

Vocabulary

aeration—the act of exposing to, supplying or filling to the limit with air
alternative—a chance to choose between two or more things
aquifer—a water-bearing layer of rock, sand, or gravel capable of absorbing water
canal—an artificial waterway for boats or for draining or irrigating land
capacity—the largest amount that can be contained
consistent—unchanging
distribution—the act of spreading out so as to cover something
diversity—the quality or state of having different forms or types
divert—to turn from one course or use to another
drought—a period of dryness that causes extensive damage to crops or prevents their successful growth
effluent—waste material discharged into the environment
emitter—something that throws or gives off or out
evaporation—loss or water by conversion into vapor
evapotranspiration—loss of water from the soil both by evaporation and by transpiration from the plants growing thereon
furrow—a trench in the earth made by a plow
gradient—a part sloping upward or downward
groundwater—water within the earth that supplies wells and springs
irrigation—the watering of land by artificial means to foster plant growth
lateral—extending from side to side
pivot—a shaft or pin on which something turns
plumule—the shoot or bud of a plant embryo or seedling that is located between the cotyledons and grows into the stem and leaves
precipitation—water or the amount of water that falls to the earth as hail, mist, rain, sleet, or snow
precision—designed for very accurate measurement or operation
radicle—the embryonic root of a seedling
radius—a line extending from the center of a circle or sphere to the circumference or surface
reservoir—a place where something is kept in store; especially an artificial or natural lake where water is collected as a water supply
sluice—an artificial passage for water with a gate for controlling its flow or changing its direction
stability—not readily changing
terrain—the surface features of an area of land
tilled—worked by plowing, sowing, and raising crops on or in
transpiration—the process by which plants give off water vapor through the stomata in their leaves
truss—a rigid framework of beams, bars, or rods
turbine—an engine whose central driving shaft is fitted with a series of blades spun around by the pressure of a fluid (as water, steam, or air)
undulating—having a wavy appearance
vapor—a substance in the gaseous state yield—the

Name____

Center Pivot Irrigation

Write the definitions for these words:

circumference—

diameter—

radius—

Center-pivot irrigation is a method of crop irrigation in which equipment rotates around a pivot. A circular area centered on the pivot is irrigated, often creating a circular pattern in crops when viewed from above. Central pivot irrigation is a form of overhead (sprinkler) irrigation consisting of several segments of pipe (usually galvanized steel or aluminum) joined together and supported by trusses, mounted on wheeled towers with sprinklers positioned along its length. The system moves in a circular pattern and is fed with water from the pivot point at the center of the circle. A full rotation typically occurs every three days. Terrain needs to be reasonably flat, but the system can also function in undulating country. The system is used in parts of the US, Australia, new Zealand, and also in desert areas such as the Sahara and the Middle East. A quarter-mile (1,300-foot) system that irrigates about 120 acres typically costs $325 to $375 per acre, excluding the cost of groundwater well construction, turbine pumps and power units. Longer systems usually cost less on a per-acre basis. For example, half-mile systems (2,600 feet) that irrigate approximately 500 acres cost about $200 to $250 per acre.
(Source: New, Leon, and Guy Fipps, "Center Pivot Irrigation," Texas Agricultural Extension Service, http://itc.tamu.edu/documents/extensionpubs/B6096.pdf)

Mr. Brown owns a section of land that is ½ mi X ½ mi. He uses this section of land to produce cotton to sell. His land is relatively flat, and so he is interested in using center-pivot irrigation. He wants to use as much of his land as possible to grow cotton. He has hired you to answer the following questions:

1. What total length of trusses does he need to purchase?
2. What is the circumference of the irrigated area?
3. What is the diameter of the irrigated area?
4. Draw a sketch of the land showing the irrigation circle. Label all known mathematical facts.
5. Write a three- to five-sentence paragraph providing your answers to Mr. Brown. Include the cost for the trusses. In addition, answer the following questions in your paragraph:
   —What is the area of irrigation?
   —how much of Mr. Brown's land is NOT being irrigated?
   —What percent of Mr. Brown's land is being irrigated by center-pivot irrigation?

Name____

Stillwater Rainfall in Inches per Month

1. Winter wheat needs 16 inches of rainfall per season for best growth. A season is September-June. For each of the years listed, figure out how much more water would be needed for growing winter wheat during the winter wheat growing season.________________Which year's rainfall came closest to the 16 inches needed?____Which year was farthest from the 16 inches needed?_____
2. Corn needs 30 inches of precipitation per season for best growth. A season is April-October. For each of the years listed, figure out how much more water would be needed for growing corn during the corn-growing season.__________________Which year's rainfall came closest to the 16 inches needed?____Which year was farthest from the 16 inches needed?____

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1981-2010 Normal	1.33	1.67	3.16	3.51	5.30	4.82	3.02	2.99	3.98	3.23	2.45	1.80
2004	2.24	1.67	3.98	2.81	0.23	9.08	4.37	1.70	0.76	4.57	--	0.96
2005	2.77	1.31	0.69	0.39	3.85	--	3.21	8.77	3.53	1.88	0.00	0.08
2006	0.70	0.07	1.85	5.14	3.33	2.40	3.15	2.39	1.32	1.58	1.24	2.81
2007	1.34	0.42	5.46	4.15	10.43	16.74	7.01	1.31	4.60	3.30	0.87	1.05
2008	0.56	2.58	4.15	5.74	6.37	4.92	5.00	1.32	1.65	2.07	2.65	0.78
2009	0.17	2.08	3.63	5.07	3.26	1.73	4.96	7.50	3.07	7.24	1.55	0.55
2010	1.01	2.69	1.66	3.61	7.13	5.49	4.39	2.51	2.78	1.73	1.94	0.53
2011	0.32	1.87	0.83	1.98	3.91	1.71	0.73	--	--	--	2.62	2.15
2012	0.96	2.93	3.92	6.16	1.12	2.16	0.07	2.64	1.10	0.61	0.45	0.43
2013	1.00	3.11	1.12	5.33	6.22	3.95	5.57	2.54	1.69	1.88	1.61	0.64
2014	0.09	0.40	1.21	0.84	0.65	6.29	3.98	2.01	4.19	2.18	2.09	0.57

Source: Oklahoma Mesonet, http://www.mesonet.org/index.php/weather/monthly_rainfall_table

3. Look at the 1981-2010 normal. Based on those numbers for winter wheat season, is it more or less likely that producers in the Stillwater area would need to irrigate?
4. Based on the numbers for corn season, is it more or less likely that corn producers in the Stillwater area would need to irrigate?

Extra: Go to the Oklahoma Mesonet site, http://www.mesonet.org/index.php/weather/monthly_rainfall_table , and find the rainfall table for your area.

Name____

Scientific Method Format

Title of Experiment or Study:

I. Stating the Problem:

What do you want to learn or find out?

II. Forming the hypothesis:

What is known about the subject or problem, and what is a prediction for what will happen?

III. Experimenting: (Set up procedures)

This should include: materials used; dates of the experimental study; variables, both dependent and independent (constant and experimental); how and what was done to set up the experiment; fair testing procedures.

IV. Observations:

Includes the records, graphs, data collected during the study.

V. Interpreting the Data:

Does the data support/defend the hypothesis?

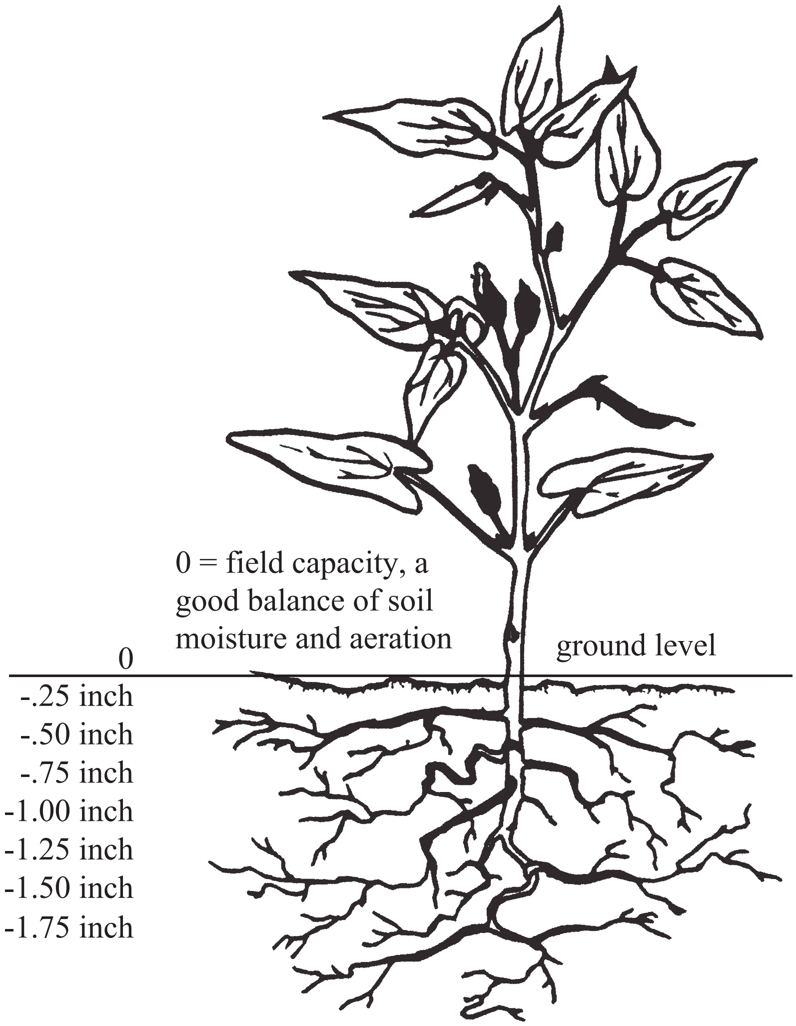
VI. Drawing Conclusions:

Justify the data collected with concluding statements about what has been learned. Discuss any problems or concerns. Use other studies to support the conclusion. Give alternative ideas for testing the hypothesis.

Oklahoma Ag in the Classroom is a program of the Oklahoma Cooperative Extension Service, the Oklahoma Department of Agriculture, Food and Forestry and the Oklahoma State Department of Education.

Water Balance Diagram

Plants can best use water if the soil moisture is maintained near field capacity at all times. Field capacity is the point at which gravity has drained all the free water down through the root zone and the remaining water is held by the soil particles. It is a good balance of soil moisture and aeration. This shows in the water balance column of the diagram at right as 0. Zero is field capacity. Picture this by imagining a container of water below ground. When the water level is below ground, it is less than zero. When it goes above zero, it overflows into the aquifer below the root zone, much as a container of water overflows when it is overfilled.



aquifer—below root zone and not accessible to plants. This is where the overflow (amounts greater than zero) goes. To make use of the water here, farmers must use pumps.

<u>Materials Needed</u>
small clear plastic cup
aluminum pan or bowl for overflow (aquifer)
tablespoon measure
marker
water

1. Mark the sides of your cup, top to bottom, at 1/4 inch intervals, beginning with zero at the very top.
2. Fill the cups to the brim with water. This represents field capacity, a perfect balance.
3. Use the measuring spoon to add and subtract water as follows:
   —Remove 2 tablespoons of water to represent evapotranspiration for Day 1. Determine the evapotranspiration level by looking at the level mark on the side of the cup. This is also the Water Balance level.
   —Remove 4 tablespoons of water (evapotranspiration for Day 2). Look at the level mark on the side of the cup. Record the level. This represents the accumulated evapotranspiration level for Day 2 and the Water Balance level.
   —Add two tablespoons of water. This represents rainfall for Day 3. Record the level. This is the Water Balance level for Day 3.
   —Add four tablespoons of water (more rainfall). The cup should overflow. The overflow goes into the aquifer and is not available to the plant. The Water Balance level is 0.

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