The Pueblo Farming Project

Lesson Two: Farming Through Drought
The Resilient Life Cycles of the Pueblo People and their Plants

Format: One approximately 90 minute session
Grades: 6, 7, 8
This lesson can be taught to each middle school grade with increasing complexity and detail.
Season: Spring/early Summer, Fall

Objectives

- Understand how drought can disrupt the lifecycle of a plant and diminish yields.
- Understand the relationship between corn, the environment and Pueblo culture and diet.
- Learn how past Pueblo farmers might have mitigated the effect of drought on their crops.
- Create an experimental dryland garden.
- Explore the mathematics of agricultural labor: time needed for planting annual corn crops using the Hopi's "so'ya" (digging stick) method

Key Terms

- Annual plant
- Perennial plant
- Domesticated plant
- Wild edible plant
- Digging stick/*so'ya*
- Plant spacing and depth
- Hectare
- Check dams

Materials and Tools

- ❏ Jars of seeds to be used teaching props:
    - ❏ heirloom varieties, purchased from Native Seeds/SEARCH: https://www.nativeseeds.org/ or through their Community Seed Grants program
        - ❏ corn
        - ❏ beans or squash
    - ❏ a variety of wild edible plants that have been an important part of the Hopi culture, such as portulaca (purslane), amaranth, chenopodium (goosefoot), cleome (bee plant/wild spinach)
- ❏ Seeds for planting, chosen from above crop varieties but not taken from prop jars
- ❏ A cooked or raw tasting sample of one or more of the crop varieties chosen for planting
- ❏ Several deep and stable bowls for dividing up and holding seed

- ❏ Digging sticks (called "*so'ya*" by the Hopi people): wooden (Greasewood and/or oak), or metal (welded metal bar) ; 1 per pair of students
- ❏ A few modern hand trowels, if needed to supplement a lack of digging sticks for each student pair
- ❏ Planting measurement tools: rulers, tape measure (to be used alongside traditional Pueblo methods: walking paces and handspans)
- ❏ 1 printed copy for each working group adult supervisor of the "Handout: Traditional Hopi Planting Techniques" (attached)
- ❏ 1 printed copy for each working group of Diagram 1: A planting hole in a Hopi maize field (attached)
- ❏ Optional: seed garlic for planting into digging sticks holes (Fall only)
- ❏ Hole measuring tool (narrow-bottomed travel mug or Solo cup; 3–4 inches wide)
- ❏ Wrist watch or stopwatch for timing hole digging
- ❏ Flagging tape and tall stakes/poles, tall enough to be seen at a distance
- ❏ Journal/notebook and pencil for each student
- ❏ White board and markers
- ❏ Calculators (one for every two students)

Before You Begin

- ❏ Educators/instructors/volunteers should prepare themselves by viewing the following short videos:
  - ❏ "Hopi Dry Farming: Ahkima's Field Hopi Reservation": https://www.youtube.com/watch?v=LWm2AExHLik.
    Measuring plant spacing with pacing steps: minute 2:10 – 6:00
    Use of digging stick, or "so'ya": minute 12:37 – 15:20
  - ❏ "4000 Year-Old Corn": https://www.youtube.com/watch?v=1MaSSSwWwKQ
    Overview of whole planting process: minute 2:50 – end.
  - ❏ "Planting With A Digging Stick": an overview of the So'ya planting technique that will be used in the lesson plan: https://drive.google.com/open?id=0BxtsRLfk1nrWcXNkUHkwNnhVWEU
- ❏ Print copies of "Handout: Traditional Hopi Planting Technique": ensure that at least one educator/instructor/volunteer will be available to supervise each planting group and to deliver demonstrations of planting techniques, using this handout.
- ❏ Print copies of Diagram 1: A Planting Hole in a Hopi Maize Field.
- ❏ Secure and prepare the cooked or raw tasting sample to be used during closing circle.
- ❏ Ensure the areas to be used in this class have clearly marked/defined areas or rows for planting and areas for walking. Ideally, plants/rows are labelled with a weather-tolerant label indicating the name of the crop to be planted.
- ❏ Borrow or make digging sticks

Opening Circle: Questions and Discussion

IIntroduce students to the plant varieties relied upon by the Hopi: pass bowls of seed around the circle. Encourage students to handle them and share observations based on their sense of sight and touch.

Introduce the plants' traditional uses by the Hopi people:

1. Corn: food and ritual
2. Squash: food
3. Beans: food
4. Portulaca (pronounced "por-chew-laca"; common name: purslane): food
5. Amaranth: food and dye
6. Chenopodium (pronounced "key-no-podium"; common name: goosefoot): food
7. Cleome (pronounced "klee-OH-mee"; common name: bee plant or wild spinach): food and an ingredient in pottery paint

Survey students' understanding and/or opinions by verbally sharing the questions or text in italics. Briefly gather input from the students, while steering the discussion toward the answers listed below the question.

What is the difference between an annual and a perennial plant? Can you give an example?

- An annual plant is a plant that completes its life cycle, from germination to the production of seed, within one year, and then dies. The seeds that annual plants produce builds a bridge between one generation of annual plants and the next. For example, all of the plant varieties depended upon by the Hopi are annuals.
- A perennial plant has a life cycle that lasts more than one year; some even live for many centuries. They *appear* to die off in the winter (this is called "dormancy") but come back to life every spring. There are perennial plants, used by Hopi people, that produce food. Examples: yucca (fruit), Piñon pine (seeds), Gambel oak (acorns), juniper (berries).

What is the difference between a domesticated plant and a wild plant?

- Domesticated plants are planted and cared for by people. All domesticated plants originated as wild plants and over time were adapted for human use.
- Wild plants succeed without human help. They have the ability to reproduce on their own and/or self-seed.

After examining the seeds in the jars, discuss: How do each of these plants continue growing from year to year? Are they annuals or perennials? Are they domestic or wild?

- Corn, beans, squash: domesticated, annual plants
- Portulaca, amaranth, chenopodium, cleome: wild, annual plants

All of these plants were an important part of ancestral Puebloan culture. The Pueblo people needed to be knowledgeable about the growth and life cycle of plants used in their culture for food, medicine, tools and ceremony.

Optional: if time allows, students can view one or more of the videos listed under “Before You Begin: Preparation for Educators/Instructors/Volunteers”

Discuss the following questions:

Why was it important for the ancestral Puebloan people to be knowledgeable about the life cycles of plants used in their culture?

Review with students the plant varieties relied upon by ancestral Puebloan culture; these plants sustain them physically, spiritually and culturally.

What are the stages of a plant’s life cycle?

A plant has Four Essential Needs: the right amount of (1) light, (2) heat/temperature, (3) water and (4) nutrients. If a plant has these four things, it will move through these stages in growth:

1. Germination of the seed
2. Developing roots, stems and leaves
3. Producing flowers
4. Pollination and Fertilization
5. Producing a fruit
6. Seeds mature
7. Plant death (or dormancy for winter if the plant is a perennial)

How could drought interrupt the stages of a plant’s life cycle? How could drought challenge a plant’s ability to get its Four Essential Needs met?

- Drought is “a long period of abnormally low rainfall, especially one that adversely affects growing or living conditions.” (American Heritage® Dictionary of the English Language, Fifth Edition.)
- Changes in weather and climate can affect the soil’s **temperature,** causing it to be too cool or too hot for seed germination or seedling growth.
- Less rainfall and changes in weather can also disrupt the life cycle of the soil microorganisms that create **nutrients** needed for plant growth.
- Drought disrupts the normal annual rainfall; this can disrupt any and all of the stages of a plant’s life cycle. A lack of **water** can:
    a. prevent germination
    b. kill a seedling that emerged after germination
    c. cause a seedling to prematurely flower and bolt (“to bolt” means to produce seeds early in the life cycle)
    d. cause the plant’s stems, leaves, flowers, fruit and seeds to be small and perhaps deformed
    e. cause the plant to produce far fewer fruits, leading to the production of much less food for eating and far fewer seeds to plant for next year’s crops.

When drought challenges a plant's ability to get its Four Essential Needs met, what domino-effect could play out, leading to a cycle of food scarcity?

Most plants will respond to stress by producing fewer flowers, which leads to fewer fruits, which leads to a lower harvest, which leads to fewer fruits available for eating and fewer seeds for saving and planting for next year's harvest. By having fewer seeds to plant, the harvest can become smaller yet again, leading to less food to eat and fewer seeds to plant.

Pueblo people successfully adapted to an environment that often experienced drought. Which of their agricultural practices reflect their knowledge of their crops and their land's drought conditions?

- Building check dams (rows of low rock walls to slow down the movement of runoff water) in drainages, washes and canyons
- Planting their gardens on or near north facing slopes where there is more shade and less water is lost to evaporation.
- Planting seeds deeply where natural reservoirs of water are held by the soil
- Planting seeds in clumps that are widely spaced. This creates little soil-moisture reservoirs and provides long-term moisture for each clump of plants.
- Long-term storage of seeds for future food needs
- Saving seeds for future planting

Today's planting activity will combine ancient and modern seeds, practices and knowledge. The goal is to complete two experiments:

1. ***Create an experimental dryland garden, planted using traditional Hopi planting techniques.***
2. ***Conduct an time-challenge experiment to find out how long it takes to create a planting hole using a traditional Hopi hand tool: the "so'ya" or digging stick.***

Show the students the digging sticks and circulate copies of "Diagram 1: A Planting Hole in a Hopi Maize Fields". This is the technique, used by the Hopi people for centuries, that will be used in both experiments.

Procedure

Divide the students into at least two working groups. Instructors can choose whether or not working groups will rotate and experience both activities.

Group 1— Digging Stick Time-Challenge: instructions listed below, in *"Digging With a So'ya."* At least one working group must be assigned to prepare an area for planting by conducting the "digging stick time-challenge".

Group 2, & up — Hopi Planting Methods: planting instructions for corn, beans, squash and melons are listed in the attached handout, *"Traditional Hopi Planting Techniques"*. Wild edible plants should be planted by following the planting instructions on the seed packet.

The objective for each group is to either prepare a bed/row or plant the type of seed their group is named after. Depending on available digging sticks and trowels, students may be paired up within their planting group to share digging tools.

- **Fall Planting:** Use Opening Circle concepts to guide fall garlic planting, and tasks associated with planting, like preparing beds for seeds that will overwinter (cover crops).
- **Spring:** Divide students into small planting groups, assigning each one of the following:
    - Corn
    - Bean
    - Squash
    - Melon
    - Portulaca, amaranth, chenopodium, cleome

Digging With A So'ya:

While creating planting holes, we will also use math to answer this question:

Using the Hopi method of planting clumps of corn seed using a So'ya (digging stick), how long would it take to plant a Hopi cornfield that was big enough to supply one Hopi family for one year?

Students should carry the so'yas, the hole measuring tool (narrow-bottomed travel mug), their notebooks and calculators out to the 10x10 meter space flagged area.

1. In the flagged area , students can practice using the so'ya to dig holes for the first row. With 2 meter spacing customary in Hopi fields, the first row will have 4 holes. The 2 meter spacing should be approximated by using paces: one adult pace ~ one meter. This is traditionally how the Hopi measured their spaces.

2. The holes should be dug in the following way:
    a. Hole #1: dug 2 meters from the edge of the flagged space by student #1
    b. Hole #2: dug 2 meters from hole #1 by student #2, and so on.
    c. The result is that four holes are dug, by four students, creating the first row.
    d. If the working groups rotate, the second group to dig should use the established digging space, but dig their holes in the undisturbed soil 2 meters away from the holes dug by the first working group.

3. Students must make a properly dug hole—one that would be successful at moistening and germinating Hopi corn seeds. The hole has several criteria:
    a. The circumference of the bottom of the hole should be no larger than approximately 3–4 inches. Use a travel mug or Solo cup for judging this after a hole has been dug.
    b. The correct depth of the hole is traditionally judged by the appearance of moist soil. This is often at least 8–12 inches.
    c. The soil that comes out of the hole must not be tossed far away from the opening. It must be pulled back only as far as necessary; the moist soil that is the last to come out of the whole must be stored right next to the hole's opening, as it would be the first soil to be returned to the hole to cover seeds.
    d. **Record the amount of time it takes each group to dig a row of four holes** and find the average amount of time it takes to dig one proper hole by dividing by 4. The calculations presented in the Closing Circle assume an average of 3 minutes per hole.
    e. In the **Fall**, garlic may be planted in the holes created by the digging sticks. In the **Spring**, the holes can be used for planting beans, melons or squash, by adjusting the depth of the hole (see the handout *"Traditional Hopi Planting Techniques"*.)

Closing Circle

Anthropologists have studied the diet and farming practices of the ancestral Pueblo people to learn how much corn a Pueblo family would have traditionally planted to feed their family and provide for their ceremonies.

For a one year supply, a family of four would need:

11,284 ears of corn.

To grow that amount of corn, a family would need to make digging sticks planting holes for:

1,128 clumps of corn plants

Report Back:

Connect the above research to the digging stick time-challenge activity:

What was the average amount of time it took to dig a hole for each group?

Survey each group for their result.

Approximately _____ minutes (approximation used in formula below: 3 minutes)

What was the average hole-digging time among all the groups?

Calculate by adding all the results and dividing by the number of working groups.

Approximately _____ minutes (approximation used in formula below: 3 minutes)

Bring it all together! How long would it take to dig holes for all of the clumps a family would have to plant in one year?

Calculate: Multiply the number of clumps per year by the average hole-digging time:

$$\frac{1128 \text{ clumps}}{1 \text{ year}} \times \frac{3 \text{ minutes}}{1 \text{ clump}} = \frac{3384 \text{ minutes}}{1 \text{ year}}$$

*Result: It would take a family approximately **3,384 minutes** to plant all their corn each year, or ~**56 hours** of work. At 8 hours of work per day, that is **7 full days** of work!*

A representative from each working group gives an update on the progress of their garden job. Instructors explains that the next group who works in these planting areas will take up the unfinished portions of their jobs; this helps them to understand that their contribution to the garden is both important and only a small part of a greater whole. Record on a planting map or calendar:

i. names of seed/plant varieties that were planted
ii. date they were planted and date when seeds are expected to germinate
iii. the locations of the plantings

Tasting: Taste a cooked or raw version of one of the vegetable varieties planted today.

Discussion Questions:

Ancestral Pueblo diets were built upon three important crops: corn, beans and squash. What are some of the benefits to the body of eating a diet that is rich in whole foods such as these?

Corn provides minerals that help the body resist diseases such as heart disease, diabetes; it provides fiber which helps prevent digestive ailments and cancers.

Beans are high in antioxidants (slows aging, prevents disease), fiber (digestive health), protein (energy, muscle health), B vitamins (energy, immune system booster). Eating beans regularly can decrease the risk of diabetes and heart disease.

Squash: vitamin A deficiency, caused by a carcinogen in cigarette smoke, can lead to a disease called emphysema. Winter squash contains high levels of vitamin A. While quitting smoking is ideal, a diet rich in vitamin A may protect lung health if a person unable to quit or is still exposed to cigarette smoke.

We think of medicine as something we use to balance our minds and our bodies to create health. In what ways might have corn, beans, squash, and wild edibles acted as medicines for the ancestral Pueblo people?

PFP/MSTFP and Colorado State Education Standards

	PFP/MSTFP Garden Education Standards	Colorado Academic Standards
6th	Recognizing nitrogen, carbon and nutrient cycles at work. Hand and power tools. Watersheds: connect communities through cause and effect. Applied systems thinking: waste, renewable and nonrenewable natural resources.	Science 1.3, 2.1, 2.2, 3.2, 3.3 Math 1.1, 4.1 Health 2.1 Phys Ed 1.2, 3.2, 4.1 Social Studies 1.1, 1.2, 2.2
7th	Biodiversity benefits nitrogen, carbon and nutrient cycles. Hand and power tools.	Science 2.1, 2.4, 2.5 Math 1.1, 4.2 Health 2.1, 2.2, 3.1, 4.2 Phys Ed 4.1 Social Studies 1.2, 2.2
8th	Hand and power tools. Changing systems: climate and weather in the Southwest.	Science 2.1, 2.2, 3.2 Math 4.2 Health 4.5 Phys Ed 2.1, 2.3 Social Studies 1.1

For further information in regards to the Colorado State Standards, please follow this link:
https://www.cde.state.co.us/apps/standards/

The Pueblo Farming Project[1] is a collaboration between the Crow Canyon Archaeological Center,[2] the Hopi Tribe Cultural Preservation Office,[3] and the Montezuma School to Farm Project[4] to understand ancient maize (corn) agriculture in the Mesa Verde region through documenting traditional ecological knowledge, experimental farming, and genetic analysis. The development of this lesson plan was funded by a History Colorado State Historical Fund[5] grant to Crow Canyon.

[1] https://www.crowcanyon.org/pueblo-farming-project
[2] https://www.crowcanyon.org/
[3] https://www8.nau.edu/~hcpo-p/
[4] https://www.montezumaschooltofarm.org
[5] https://www.historycolorado.org/state-historical-fund
[6] https://creativecommons.org/licenses/by-nc-sa/4.0/

HANDOUT: Traditional Hopi planting techniques

Traditional Hopi planting techniques for Dryland Farming of Corn

1. Spacing is an important consideration for plant health, root development and good pollination. Unlike the conventional practice of planting seeds in a row and measuring the space between seeds, the Hopi plant several seeds together in a clump and pace off, with measured steps, the space between clumps. Spacing in a Hopi garden is 2–3 adult paces/steps, or 4–6 feet, between clumps. Widely spaced plant clumps create groups of reservoirs of moisture for each clump.
2. To plant, the ground is first scraped with the hands or the side of the foot to remove dust/loose top soil on the surface to the depth of hardpan or compacted soil. The soil that comes out of the hole must not be tossed far away from the opening. It must be pulled back only as far as necessary. This creates a 2 X 2 foot basin.
3. In the center of the basin, the digging stick, or "so'ya" is used to create a hole. The correct depth of the hole is reached when the soil's moisture can be seen and felt. The hole should be the shape of a cone, no wider than 4 inches, and 6–10 inches deep.
4. About 12 seeds are planted into each hole. Later, when the plants are approximately 1 foot tall, the clump is thinned to about 6 plants.
5. The soil must be placed back in the hole in the same order that it was removed: the moist soil that was the last to be removed is the first to be returned.
6. To finish, some of the loose topsoil from the edge of the basin is brushed and scattered over the filled-in hole. This creates a "dust mulch" that seals in moisture.
7. Two to three adult paces/steps are taken to the next planting clump location.

Traditional Hopi planting techniques for Dryland Farming of Bean, Squash and Melon

1. Repeat step # 2 from Corn Planting Techniques, with the exception that the basin created is only 1 X 1 foot.
2. These varieties are planted deep enough that each seed is surrounded by moist soil, approximately 5 - 7 inches deep. View Diagram 6.17 and Diagram 6.18 from the link listed in Materials.
3. Four to five seeds are planted in each hole. Later, when the plants are approximately 6 inches tall, the clump is thinned to 2 plants.
4. To finish, some of the loose topsoil from the edge of the basin is used as a "dust mulch" to cover the hole.
5. One adult pace/step is taken to the next planting location.
6. Traditionally these varieties are planted in separate areas but could be interplanted between corn clumps.

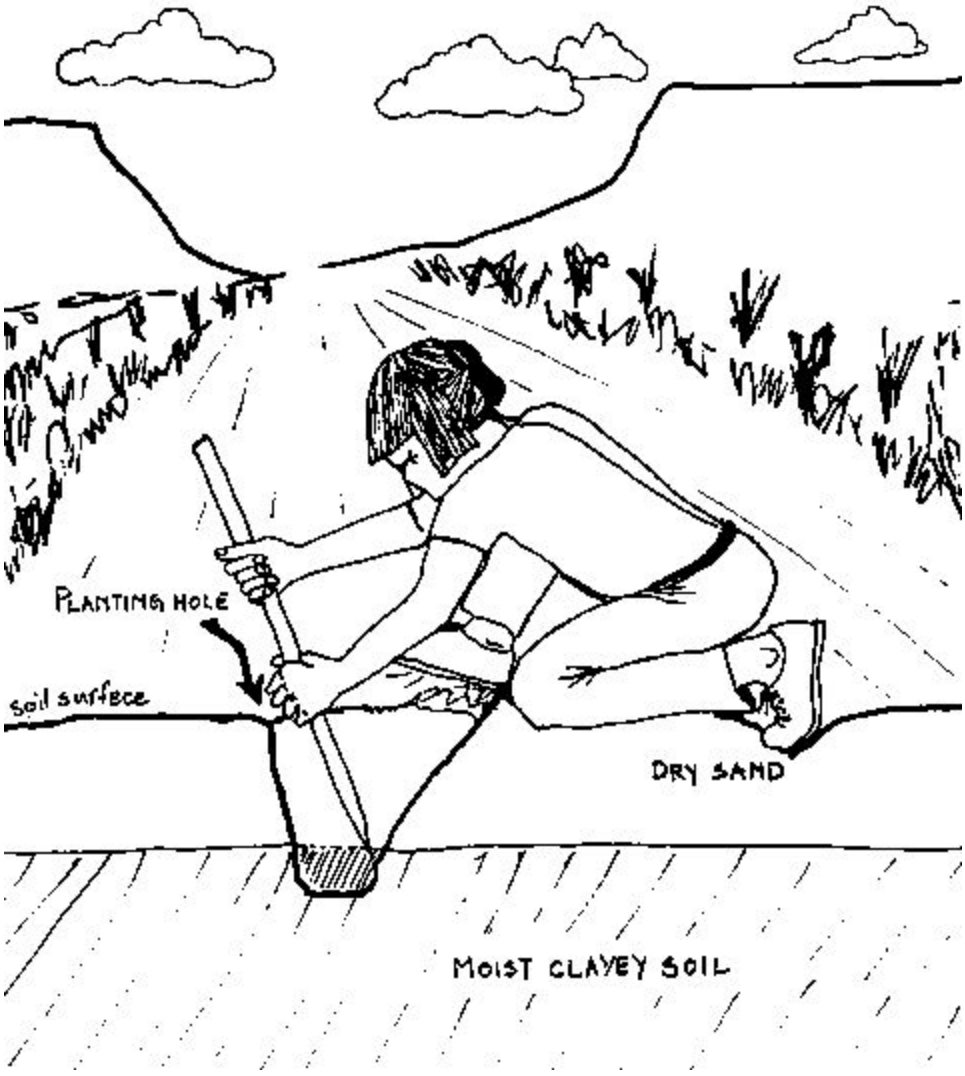

Diagram 1. A Planting Hole in a Hopi Maize Field. From Cleveland and Soleri 1991: Figure 6.19.[7]

[7] Cleveland, David Arthur and Daniela Soleri. 1991. *Food from Dryland Gardens: An Ecological, Nutritional and Social Approach to Small Scale Household Food Production*. The Center for People, Food and Environment, Tucson, Arizona.