Ready, Set, Grow!

How Do Increasing Temperatures and Changing Precipitation Patterns Affect Primary Producers?

Description

Students play the roles of water-intensive and drought-tolerant plants to understand the effect of the phenomenon they observed in Climate Data Jam.

Phenomenon

In New Mexico, temperatures are expected to rise, and precipitation patterns are expected to increase in variability.

Objectives

Students will:

- Identify ways increased temperatures and variable precipitation patterns affect plant systems
- Model the uptake of resources by plant structures
- Analyze the effects of limited resources on plant populations

Grade Level

5 – 8

Time

1 Hour

Materials

- *Ready, Set, Grow* handout [1 per student]
- Drought-Tolerant Plant nametags [1 per every 1-2 students]
- Water-Intensive Plant nametags [1 per every 1-2 students]
- Mystery resource cards [135 cards]
- Water resource cards [108 cards]
- Computer and projector*

* Not included in kit

Background

Plants are an essential component of the water cycle and affect water movement through Earth's systems. Plants release water to the atmosphere through the process of transpiration. Transpiration occurs when water is absorbed by the roots and carried up through the stem to the leaves. Some of this water is used in photosynthesis, and some is released as water vapor through the stomata, which are pores on plant surfaces that regulate gas exchange.

Most areas in the United States are predicted to experience warmer temperatures in the future. As temperatures continue to increase, more water from lakes, streams, oceans, soil, and plants will likely evaporate or transpire, especially in arid areas. Evaporation and transpiration are often combined and termed evapotranspiration, which is the total of evaporation and transpiration from Earth's surfaces, bodies of water, and plants. Higher temperatures cause water to evaporate more quickly because water molecules move faster when they are warm. Since the molecules are moving faster, more of them can leave the surface at one time. For evapotranspiration to occur, however, the humidity of the atmosphere must be less than the surface, and therefore evapotranspiration rate increases will be most pronounced in

dry regions. In dry regions, evapotranspiration rates may offset any gains experienced through increased precipitation.

Because transpiration rates vary with climatic conditions, plant responses to climate change can significantly affect plant populations and soil moisture. Some plant species are drought tolerant and adapted to warm and dry conditions. Under the conditions presented in Climate Data Jam, drought-tolerant plants may be more likely to survive than plants without the same adaptations. Drought-tolerant plants include cacti and creosotebush throughout the continental desert Southwest. Plant responses to these conditions may affect the entire ecosystem. If plant populations decline, there will be less food available to primary consumers, and their populations may also decrease. These effects may be felt throughout the food web and could be especially detrimental in species with limited ability for resource switching.

Tips for Entire Class Participation

- Every student can play either a drought-tolerant or water-intensive plant during one of the rounds.
- In a large class, students may be left standing in the "sprout" line for too long. Here are some options to reduce the line size and give students tasks to complete while waiting.
    - Reduce the line size by giving some students roles as game helpers. Ask students whether they would rather have a job as a helper or play the game. Possible game helper roles:
        - A student could graph the numbers from each round on the Game Graph.
        - A student could add and remove resource cards between each round.
        - A student could hand out plant nametags to surviving plants each round.
    - Students waiting in line could keep the handout with them and add to the Game Graph after every round.

Preparation

1. Locate a suitable space in a classroom or outside area and scatter resource cards throughout the area. The space can be a room with surfaces like benches or tables, where students can quickly move through the area without hazards, or a suitable outdoor spot. Refer to Table 1 for the recommended starting resource card numbers for round one based on class size.
2. Place drought-tolerant and water-intensive nametags and water and mystery resource cards in an accessible location for the educator.
3. Draw the Game Graph, including the water and drought plant population data table, from page 1 of the *Ready, Set, Grow* handout on the board/large piece of paper or prepare to show it with a document camera or computer and projector.

	20 students		**25 students**		**30 students**		**35 students**		**40 students**	
	Water	Mystery	Water	Mystery	Water	Mystery	Water	Mystery	Water	Mystery
Round 1	45	40	55	50	65	60	75	70	80	80
Subsequent Rounds	Decrease by 5	Increase by 5	Decrease by 5	Increase by 5	Decrease by 5	Increase by 5	Decrease by 5	Increase by 5	Decrease by 5	Increase by 5

Table 1. Recommended resource card numbers based on class size

Teaching Guide

Introduction (~5 minutes)

1. Pass out a *Ready, Set, Grow* handout to each student.
2. Slide 2: Explain the following:

a. Plants are part of the water cycle. Plants absorb water from the soil and move it through their structures, which allows them to have water available for photosynthesis.
b. When a plant photosynthesizes, it loses water to the air through microscopic openings on its surfaces called stomata (singular = stoma). This is known as transpiration, and it is the process by which plants release water vapor into the atmosphere. In this way, plants affect the movement of water through the water cycle.
c. The availability of water has a significant effect on plants as well; it is an important factor for plant survival, distribution, and population growth.

3. Slide 3: As we saw in Climate Data Jam, precipitation patterns are changing in New Mexico. Some areas are expected to receive more precipitation, while others are expected to receive less precipitation. However, all four New Mexico counties that we examined had predicted drier conditions in spring, an essential season for plant growth. Click forward - Today, we will be modeling the conditions present in Bernalillo County (the most populous county in New Mexico), with a predicted 4.7 mm drier and 3.6°C warmer spring.
4. Slide 4: Ask students how they think the processes in this diagram (precipitation, transpiration, and evaporation) will be affected by the changes we saw in Climate Data Jam? Have students annotate the diagram on their worksheet to record some ways they think these changing conditions will affect these processes. Click forward - After students have annotated their diagrams and shared their thoughts, reveal the annotations on the slide.
5. Tell students that today, we will explore the effects of reduced water availability and increased temperature on plant populations. Scientists predict that New Mexico and other areas of the world may experience increased and prolonged periods of drought. **As temperatures rise, more water evaporates from Earth's surface**. Because of this, some areas, including Alaska and other high latitudes of the Northern Hemisphere, will receive more precipitation. Many other areas, such as the US Southwest, Mediterranean, and southern Africa, will receive less predictable precipitation and more drought.

Playing the Game (~40 minutes)

1. Explain that students will use a game to model how the changing conditions observed in Climate Data Jam affect plant systems in New Mexico. Again, we will be modeling the conditions present in Bernalillo County (the most populous county in New Mexico), with a predicted 4.7 mm drier and 3.6°C warmer spring.
2. Slide 5: Review the rules of the game.
    a. Assign one-third of the class as plants to begin the game. The rest of the students will wait in line for the next round. Half of the beginning students will be assigned as drought-tolerant plants, and half will be water-intensive plants. Hand out the appropriate nametags to students.
    b. Begin the game by explaining the baseline conditions for each round. Each round is like a growing season, with a certain amount of water available for plants. Students act as plants to quickly and carefully gather water resource cards to ensure survival until the next round. Additionally, plants need other resources to survive. These resources are represented by mystery resource cards. Students need to gather these as well to survive until the next round. In reality, of course, plants do not move around to uptake resources. However, in the game, students move around to act as plants taking in the resources needed to survive.
    c. At the end of every round, students will have to transpire an increasing number of water points back to the environment (Table 2). The transpiration cost for round one is one water point, and it increases by one water point every round. Ask students why they think the transpiration cost increases each round? Students can reference their annotated diagram to respond. Be sure that students understand that increasing transpiration is the

result of increasing temperatures and decreasing humidity. It may be helpful to draw Table 2 on the board.

Round	Transpiration Cost
1	1
2	2
Subsequent Rounds	Increase by 1

Table 2. Transpiration costs for each round increase as a result of increased air temperatures and decreased humidity.

   d. At the end of each round and after transpiration, **drought-tolerant plants must have two water cards and two mystery cards to survive to the next round. Water-intensive plants must have four water cards and two mystery cards after transpiration**. It may be helpful to write this on the board. Emphasize that different types of plants require different amounts of resources to survive, affecting the composition of plant systems if temperature and precipitation change. Advise students to pick up as many resource cards as possible, even if they get more than they need.
   e. If students have difficulty retrieving the resource cards, try using the eraser of their pencil to slide cards across the floor.
3. Graph the number of drought-tolerant and water-intensive plants that will begin round one on the Game Graph.
4. Graph the number of mystery and water cards in the environment that will begin round one on the Game Graph.
5. After ensuring that students understand the transpiration cost for the round and how many water and mystery cards are needed, say "Ready, Set, Grow" and release students to gather as many cards as possible.
6. There is no set time for each round. In a medium-sized class, a round takes 15-20 seconds. Watch students gathering cards, and when almost all the cards are gathered, begin a five-second countdown. Call students back to a central location to end the round.
7. Instruct students to transpire the appropriate number of water cards for the current round back to the environment (Table 2).
8. After transpiration, ask how many drought-tolerant plant students have two water cards and two mystery cards remaining, and instruct students to show you their cards. Then ask drought-tolerant plants to return all of their resource cards to the environment, making sure they are scattered well enough for the next round of play. The ones who had enough cards are the surviving drought-tolerant plants and will stay in the game. The drought-tolerant plant students who did not survive this round must move to the end of the line of students waiting to play.
9. Ask how many water-intensive plant students have four water cards and two mystery cards remaining after transpiration, and instruct students to show you their cards. Then ask water-intensive plants to return all of their resource cards to the environment, making sure they are scattered well enough for the next round of play. The ones who had enough cards are the surviving water-intensive plants and will stay in the game. The water-intensive plant students who did not survive this round must move to the end of the line of students waiting to play.
10. Give each of the surviving drought-tolerant and water-intensive plant students a nametag that matches their own. Instruct these students to give the nametag to the next student in line to create a new "sprout."
11. Discuss the number of plants that survived and reproduced as you graph the number of drought-tolerant and water-intensive plants that will begin the next round on the Game Graph.

12. Remind students of the conditions predicted for Bernalillo County in Spring (warmer temperatures and less precipitation). Ask students how we could model this change for the next season in our game.
    a. Explain that the number of water resource cards will decrease by five in the next round, and graph the water cards available for the next round on the Game Graph.
13. Explain that there are other resources that plants need to survive and that one of these is modeled by the mystery resource cards. In our game scenario in Bernalillo County, this mystery resource is increasing steadily.
    a. Explain that the number of mystery resource cards will increase by five in the next round, and graph the mystery cards available for the next round in the Game Graph.
14. Before beginning the next round, add five mystery resource cards to the environment and remove five water cards (Table 2).
15. **Explain that as conditions become drier and warmer, plants lose more water during transpiration, and the transpiration cost has gone up by one point.**
16. Repeat procedures 5 – 15.
17. Depending on the time available, end the game after any round or wait until one or both plant populations die out.
18. If one or both of the plant populations dies out and there is time to conduct more rounds, restart the game.
19. After the game, finish the graph. Draw lines to connect the points for each of the graphed items. Discuss the trend(s) of each plant population and how they relate to the changing temperature and the water available in the environment.
20. During or after the game, instruct students to complete the Game Graph on their handout.

Results (~5 minutes)

1. Instruct students to answer the results questions on page 2 of their handout. Use the questions to elicit a discussion about how increasing temperatures and drought affected the plant populations in Bernalillo County throughout the game.

Discussion (~10 minutes)

1. Slide 6: Instruct students to respond to questions 3 and 4 of their handout. Encourage whole class discussion as students consider how plant populations will be affected by changing conditions in New Mexico. Encourage students to consider impacts not only to plant populations but also other parts of the ecosystem.
2. Slide 7: Ask students to consider what plants need to survive from both the game and their background knowledge. Have them list the answers in discussion question 5 of their handout [answer: nutrients, water, sun, suitable temperature range, space, CO_2]. Explain that limiting resources limit the growth, abundance, or distribution of an organism.
3. Ask students to circle which of these resources were modeled in our game [temperature, water].
4. Have students respond to question 6, identifying which of the resources modeled in the game scenario are limiting resources.
    a. Water: As we saw in Climate Data Jam, water availability may decrease in New Mexico in the future. This limited plant growth in our game.
    b. Suitable temperature range: We also saw that temperatures in New Mexico are anticipated to increase in the future. This limited plant growth in our game since it affects water availability.
5. Slide 8: Have students respond to question 7 after conversations in small groups or as a whole class. Ask students to share what resource they believe is being modeled by the mystery resource in the game. Encourage students to use their background knowledge and the game context as evidence to support their claim. Once it has been revealed that the mystery resource is carbon

dioxide (CO_2), have students record this in question 7 if they hadn't already predicted it. Highlight the characteristics of the mystery resource in the game that indicate CO_2: plants need it for survival; atmospheric levels are increasing.

6. Explain that we will be exploring this mystery resource (CO_2) in upcoming activities. We will examine why we see an increase in this resource and how it is affecting Earth systems.

Game Variations

1. If one of the plant populations looks like it will crash and you would like to keep playing the game without starting over, institute a wet season. A wet season is an adjustment round and a method for returning plant population numbers to higher levels. This is also an opportunity to reinforce the variability of precipitation patterns predicted.
    a. At the beginning of a round, increase the number of water resource cards available (instead of decreasing them).
    b. Try increasing the available water by two to seven cards. Be cautious. Changing the water by a few points can dramatically change the outcome and the length of play.
    c. If there is time, increase water conservatively and conduct more than one wet season.
    d. Go on to play the round as usual after adding more water cards.

Extensions

1. Explore the concept of carrying capacity (K) by keeping resource availability constant instead of instituting warmer and drier conditions.
    a. If students are not familiar with carrying capacity, introduce the topic. Carrying capacity is the number of individuals of a species that an area's resources can sustain. Populations that grow exponentially tend to start slowly, grow rapidly, and then level off when the carrying capacity has been reached (Figure 3).

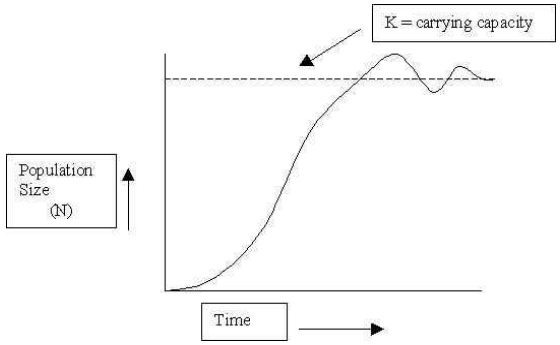

Figure 3. Graph of population size over time showing carrying capacity (K). Source: faculty.plattsburgh.edu/thomas.wolosz/popbionote.htm Accessed 9 Apr. 2015

    b. Start with a relatively abundant amount of water and mystery resource cards, perhaps five or ten more cards than suggested in Table 1 for your class size.
    c. Plan to play the game with only the drought-tolerant plant population, and then try it with both plant populations.
    d. Before playing, ask students to hypothesize about how the curves of population size over time will look for each version of the game (one plant population and two plant populations) when assuming a stable environment. Ask students whether they think drought-tolerant plants will have a larger or smaller carrying capacity once water-

intensive plants are introduced and ask them to draw their graphs to reflect their hypotheses.

e. Do not remove water resource cards or add mystery resource cards. Keep the environment constant.
f. After both games, compare student hypotheses with the Game Graphs created while playing each game version (one plant population vs. two plant populations).

Additional Resources

1. A website with student-friendly information about transpiration:
   United States Geological Survey. Transpiration–The Water Cycle. Published 15 Apr. 2014. Web. Accessed 24 Mar. 2015. <http://water.usgs.gov/edu/watercycletranspiration.html>.

This lesson has been adapted for New Mexico Climate Champions from "Ready, Set, Grow" by the Asombro Institute for Science Education and the Southwest Climate Hub. <https://swclimatehub.info/education/climate-change-and-water-cycle/day5>