Climate Change

and Wildfire

DESCRIPTION

Students investigate the impacts of climate change on wildfire. They will interpret graphs to see the connections between temperature and wildfire, then conduct an experiment to understand why increasing temperature plays a role in wildfire risk and severity.

PHENOMENON

Wildfire risk, severity, and size are affected by temperature.

GRADE LEVEL

9-12

OBJECTIVES

Students will:

- Understand that fires are a natural part of ecosystems, and fire regimes vary across ecosystems.
- Understand the effects of climate change on forest ecosystems.

TIME

50 MINUTES

COMMON CORE STATE STANDARDS

English Language Arts

CCSS.ELA-LITERACY.W.9-10.1/ W.11-12.1 Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.

CCSS.ELA-LITERACY.RST.9-10.7. Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

NEXT GENERATION SCIENCE STANDARDS

Science & Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Planning and Carrying Out Investigations Developing and Using Models Constructing Explanations and Designing Solutions	LS2.C Ecosystem Dynamics, Functioning, and Resilience	Patterns Cause and Effect

AGRICULTURE, FOOD, AND NATURAL RESOURCES (AFNR) STANDARDS

CCTC Standard: NRS.01 Plan and conduct natural resource management activities that apply logical, reasoned, and scientifically based solutions to natural resource issues and goals.

Performance Indicator: NRS.01.03 Apply ecological concepts and principles to atmospheric natural resource systems.

Sample Measurements:

NRS.01.03.02a Research and summarize how climate factors influence natural resource systems.

BACKGROUND

Wildfires are a natural part of many ecosystems. Each ecosystem has a unique fire regime, or pattern of how frequent, large, and severe fires are when naturally caused by lightning strikes. These fires can be catastrophic and destructive. However, when fires happen regularly, they can support healthy ecosystems by clearing away the dead plant material that may build up or preventing a forest from becoming too crowded with small trees. Humans have altered fire regimes in many ways by introducing new ignition sources (e.g., cars, cigarettes, campfires, fireworks, and power lines), by altering fuel loads and plant communities (e.g., introducing new plant species or removing others and introducing grazing livestock that eats small plants), and by suppressing fires through constant firefighting. These changes have led to a build-up of flammable materials in some ecosystems.

Climate change adds another layer of complexity to changing fire regimes. Climate change is predicted to increase wildfire danger in two ways: 1) increased evapotranspiration and 2) increased fuel load. Evapotranspiration is the combination of evaporation from the earth's surface and transpiration by plants, which pull water in through their roots and release it out through pores in their leaves. As temperatures increase, so does evapotranspiration. When evapotranspiration increases, soil moisture decreases, resulting in drier systems. Higher temperatures also result in a longer growing season for most plants. With a longer growing season, there is an increase in plant growth and biomass. This is especially true for small plants; when they die, they leave behind fuel that will burn easily.

MATERIALS

- Wildfire: Past and Future instructional video, optional introduction to the experiment for the instructor
- PowerPoint presentation
- Student handout [1 per student]
- Model description [1/3 page per group]
- Experiment materials [1 set per group plus 2 sets for class demonstrations]:
    - 1 small aluminum pie plate
    - Approximately 1/2 cup of sand or soil
    - 15 toothpicks to represent trees
    - 1 cotton ball pulled apart into about 12 pieces to represent shrubs
    - A spoonful (about ½ tsp) of small paper shreds to represent grass (We suggest emptying a hole punch or chopping up shredded paper. We used a small spoonful of hole punch chads.)
    - Note: if you would like to tailor your ecosystem model to represent a local ecosystem, leave out the unnecessary plants (e.g., use paper shreds only to represent a grassland, or paper and cotton balls to represent a grassy shrubland).
    - 1 spray bottle with water (groups can share if necessary)
    - 1 scale (groups can share if necessary)
    - 1 lighter (groups can share if necessary)
    - 1 thermometer (or 1 per 2-3 groups if placed under lamps next to models)
- Extra toothpicks, cotton balls, and paper shreds for students to choose from
- Desk or clamp lamps with incandescent or heat bulbs (LED bulbs do not produce enough heat - 1 per 2-3 groups)
- Optional: aluminum baking pans or aluminum foil for students to place models in/on before lighting them on fire.

PREPARATION

1. If possible, watch the Wildfire: Past and Future instructional video for an introduction to the experiment.
2. Create two ecosystem models (Figure 1). These will be the experiment controls ("Current Temperature" and "Increased Temperature").
3. The model is made up of:
    a. 1 small aluminum pie plate
    b. 1 cup of sand
    c. 15 toothpicks to represent trees
    d. 1 cotton ball pulled apart into about 12 pieces to represent shrubs
    e. A spoonful of small paper shreds to represent grass
4. Print student handouts (1 per student).
5. Print and cut the model description pages (1 description per group, 8 groups per class).
6. Find a place to plug in lamps so students can place models under the lamps. The bottom of the lamp needs to be 6-10 inches off of the table surface. If using clamp lamps, we suggest clamping multiple lamps to a box so students can set their models around the box.
7. Options for model extensions or alterations:
    a. If you would like to tailor your ecosystem model to represent a local ecosystem, remove the unnecessary plants from your model (e.g., use paper shreds only to represent a grassland, or paper and cotton balls to represent a grassy shrubland).
    b. You can compare live versus dead fuel by soaking some of the toothpicks in water before placing them in the model; it will be very unlikely that wet toothpicks light on fire.

Figure 1. Control model set-up.

PROCEDURES

INTRODUCTION

1. **Slide 2**: Think about a time you've heard about wildfires. Were you affected by the wildfire? How can wildfires affect you? In recent years, we've heard more about large fires, and they are linked to climate change.
   a. Wildfires are a natural part of many ecosystems, often originating from dry lightning strikes. They can support ecosystem health, promote certain plant species, and help nutrient cycling in the soil. However, depending on the fire's frequency, severity, and size, they can also be catastrophic and destroy habitats, decrease water and air quality, and decrease the availability of natural resources like lumber or grazing land. Most ecosystems naturally experience large catastrophic fires at some point. Forests in the Southwest have catastrophic fires every 200-500 years.
2. **Slide 3**: Climate change is caused by increased atmospheric carbon dioxide, which leads to higher atmospheric temperatures. This increase in temperatures has many cascading effects.
3. **Slide 4**: Based on the graphs, what trends do you see in the relationship between wildfire and temperature? The red y-axis on the left side of the graph shows wildfire frequency, represented by the red bars. The black y-axis on the right side of the graph shows temperature, represented by the black line [Answer: Years with higher temperatures have higher fire frequency]. You might expect the amount of rain to be linked to fire severity, but why temperature? Two major factors affect wildfire risk and severity, (1) moisture levels, or how much water is in the plants and soil, and (2) fuel levels, or how much burnable material, usually dead plants, is present.
4. **Slide 5**: What do you need to make a fire? [Click to show answer: fuel, oxygen, and ignition.]
   a. Which of these is most likely to be influenced by climate change? [Answer: Fuel. Oxygen and ignition sources will not change due to climate change, but the amount of plants and dead, dry plant material is likely to change as the temperature and precipitation patterns change.]
5. **Slide 6**: Which of these ecosystems is more likely to burn? [Answer: #1. This is a ponderosa pine forest with little bare ground. The grass on the ground can carry fire between larger plants. Generally, fire is more likely to spread in a forest with more grass and shrubs in the understory. Picture #2 is creosote shrubland, with little vegetation between shrubs, making it hard for fire to spread.]
6. **Slide 7**: Which of these ecosystems is more likely to burn [Answer #1, Again, picture #1 is a ponderosa pine forest, which is much drier than the rainforest shown in picture #2. So despite having more fuel, picture #2 is less likely to catch fire. These three pictures highlight that fuel and moisture levels are important aspects of fire risk.]

EXPERIMENT SET-UP

1. **Slide 8**: We will experiment with how higher temperatures affect wildfire risk, size, and severity. Imagine you're a part of a research team trying to determine how climate change and future changes in moisture and fuel levels impact wildfire. Each group will build an ecosystem.
2. **Slide 9**: Show the students the control models you have already made; students will use EXACTLY the same amount of materials as the control models, EXCEPT that they will change one variable by adding more or less of that material to understand the impact of that variable on fire risk. You will assign a change for each group to make. Wet both of your control models by spraying the entire model with five sprays of water from a spray bottle and weigh each model. Students should record these weights on their worksheets.
3. Place one of your control models under a lamp with a thermometer next to the model; this is the climate change control. The other is the no climate change control. Set it aside, far enough away from the light that it will not be warmed by it, and place a thermometer next to the model.
4. **Slide 10**: Assign students to small groups (8 groups per class). Give them the materials to make their ecosystem models, and assign each group one of the eight changes on the Model Description Page (adding more or fewer trees, shrubs, grass, or water). If you prefer, you can give students the goal of increasing or decreasing the fire risk. Encourage students to build their models quickly and get them under the lights in the next 5-7 minutes (Figure 2). Students should follow the instructions on their worksheet and then answer questions 1-3.

Figure 2. Experiment set-up.

5. The models should sit under the lights for 15-20 minutes. Models will need time to dry out; you may choose to leave them longer if you have time, but do your best to use the same time for both control and experimental models.

DISCUSSION

1. While the models warm, students should answer questions 1-3. Then have a class discussion using Slides 11-15.
2. **Slide 11**: Ask students to share their observations of the models so far and their predictions for which will have the greatest fire risk.
3. **Slide 12**: One of the changes we see when temperatures increase is an increase in *evapotranspiration*. Plants act like straws that pull water out of the soil and release it into the air as water vapor through pores in their leaves (stomata). This process is called transpiration and is also how plants regulate their leaf temperature. Evapotranspiration is the combination of evaporation from the earth's surface and transpiration.
4. **Slide 13**: Increasing air temperatures mean more water is lost through evapotranspiration. Warmer temperatures also result in a longer growing season, allowing more small plants to grow. This increased plant biomass can later become fuel in a fire.
5. **Slide 14**: Warmer temperatures and increased evapotranspiration weaken plants and lead to more disease and plant death. An increase in dead plant material in an ecosystem means more fuel for fires.
6. **Slide 15**: Remember that fire is a natural part of ecosystems. Many ecosystems go through cycles of large and small fires. These graphs show the area burned in wildfires since 1915. What do you notice about the size and frequency of fires across western North America? [Answer: The area burned in wildfires has been increasing in recent years, especially compared to the mid-1900s. This also has to do with a history of fire suppression, which is explored more in the lesson Playing with Fire.]

EXPERIMENT WRAP-UP

1. **Slide 16**: As a class, record the temperature and mass of each control model in the table at the top of the worksheet. Calculate the mass of water lost.
2. Give students time to record the temperature and mass of their models.
3. You will then attempt to light each model on fire (Figure 3). Do this by lighting an extra toothpick on fire and laying it down in the middle of the model.
   a. Note: we suggest that students light their models outside on a sidewalk for safety.

Figure 3. Model burning.

4. Some models may be hard to light, especially if they are still wet. Give students a limit of two tries to set their model on fire. The room temperature control should be too wet to light, but the climate change control should light. Fires will burn out after a minute or two. Leave slide 16 up so students can refer to the instructions.
5. **Slide 17**: Ask some groups to share their results and observations with the class.
   a. What was the effect of the warming on moisture in the ecosystem, and why? [Answer: It decreased due to increased evaporation. Even though we started with the same amount of water in both controls, we lose more to evapotranspiration when it is warmer.]
   b. What happens when we increase the fuel load and why? [Answer: We see larger fires. Fuel loads are likely to increase for two reasons; the longer growing season means more small plants can grow, but if/when they dry out, they become fuel. Increased drought will kill trees, and dry/dead trees are great fuel for big fires.] Have students answer questions 4-6 on their worksheets.
6. **Slide 18**: The combination of drier ecosystems and more fuel is predicted to impact fire risk, severity, and size. Fire risk is the likelihood that a fire will start; click to show animation. How did climate change affect the fire risk in our experiment? [Answer: It increased because the ecosystem was drier.]
7. **Slide 19**: Fire severity is how much vegetation burns in a fire; click to show animation. How did climate change impact the fire severity in our experiment? [Answer: It increased because the ecosystem was drier, and more fuel allowed the fire to reach the tops of the trees more easily.]
8. **Slide 20**: Fire size is how large an area burns; click to show animation. How did climate change impact the fire size in our experiment? [Answer: It increased because more dry fuels in the ecosystem allowed the fire to spread.]
9. **Slide 21**: Students should look back at their answers to questions 4-6 and expand on them using the words fire risk, severity, and size.

EXTENSIONS

1. Discussion Question: After a fire, ecosystems recover, plants regrow, and they provide shelter and food to animals. Small fires are easier to recover from than large fires. Do you think climate change will affect how well ecosystems can recover from fires?

ADDITIONAL RESOURCES

Grissino, Mayer, and Swetnam. Century scale forcing of fire regimes in the American Southwest, *Holocene*. 2000.

Scatsa, J.D., Weir, J.R., and Stambaugh, M.C. Droughts and wildfires in western U.S. rangelands. *Rangelands*: 38.4. August 2018: 197-203.

Westerling, A.L., Hidalgo, H.G. Cayan, D.R., Swetnam, T.W. Warming and earlier spring increase western U.S. forest wildfire activity. Science. 18 August 2006: 940-943.

Name: ______________________________ Date: ______________________ Period: _____________

Climate Change

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MODEL	BEGINNING MASS (g)	END MASS (g)	MASS OF WATER LOST (g)	END TEMPERATURE (° C)	OBSERVATIONS FROM BURNING
CONTROL: Room Temperature					
CONTROL: Climate Change					
YOUR MODEL: Climate Change + 1 variable change					

EXPERIMENT SET UP

A. Circle the variable you will change.

More Grass	More Shrubs	More Trees	More Water
Less Grass	Fewer Shrubs	Fewer Trees	Less Water

B. Build your ecosystem model, changing the variable you circled above.

Control Model:	**My Model:**
1 small aluminum pie plate	1 small aluminum pie plate
1/2 cup of sand	1/2 cup of sand
1 spoonful of paper shreds (grass)	___________ paper shreds (grass)
1 cotton ball pulled apart into about 12 pieces (shrubs)	___________ cotton balls
15 toothpicks (trees)	___________ toothpicks (trees)
5 sprays of water	___________ sprays of water

C. After spraying your model with water, take the mass and record it in the table above.

D. Place your model under a lamp, and place a thermometer next to your model.

E. Fill out the model description and place it next to your model.

F. Answer questions 1-3 on page 2.

1. Look at the models other groups have made. Describe the model you think has the lowest fire risk and what makes it low risk.

2. Look at the models other groups have made. Describe the model you think has the greatest fire risk and what makes it high risk.

3. Draw a picture of an ecosystem that is at high risk of fire due to climate change. Make sure you:
   - Label the fuel types (what types of plants)
   - Note the moisture level

CONCLUSIONS

4. Compare the control model and the climate change model. Based on the class results, what was the overall effect of increased temperature on fire danger?

5. Based on the class results, how did changing the fuel load affect fire danger?

6. Based on the class results, how did changing the moisture levels affect fire danger?

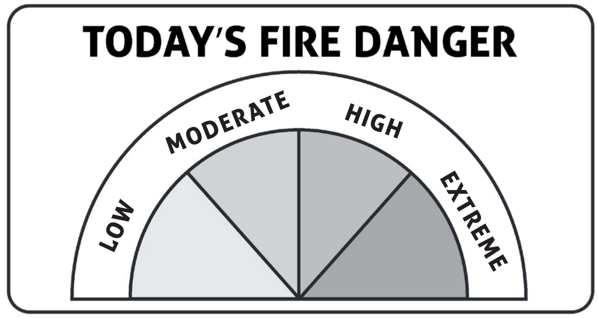
MODEL DESCRIPTION

1. Group Names: ____

2. Circle the variable you changed in your model.

More Grass	More Shrubs	More Trees	More Water
Less Grass	Fewer Shrubs	Fewer Trees	Less Water

3. Fire danger: Make a hypothesis about the fire risk in your model ecosystem and draw an arrow on the Fire Danger sign to show your hypothesis.



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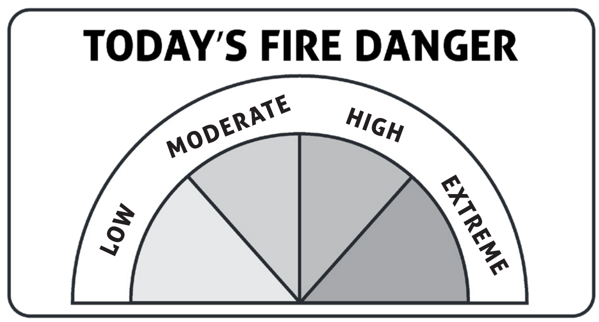

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