Lesson Overview: In this activity, students view and take notes on a presentation. Then they either observe or conduct an experiment that illustrates how wildland fires affect the potential for soil erosion. They learn that soil burn severity varies greatly and that when fires remove the litter, duff, and plant cover on the ground, the risk of soil erosion increases.

Lesson Goal: Increase students’ understanding of the effects of wildland fire on soil properties and the likelihood of erosion after fire.

Before beginning this lesson, watch the video demonstration of precipitation’s impact on bare soil versus vegetation-covered soil: [https://www.youtube.com/watch?v=im4HVXMGI68](https://www.youtube.com/watch?v=im4HVXMGI68). Decide if you want to do the demonstration in class or just view the video. If you decide to do the demonstration in class, you need a container containing young grass stems that were started from seed 2-4 weeks before. You may be able to use a cut piece of sod instead.

Objectives:
- Students understand how fires affect the soil.
- Students understand that the effects of fire on soils are variable.
- Students understand that if fires consume the litter, duff, and plant cover on the ground, this increases the chances of soil erosion.

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Teacher Background: Soil burn severity is the degree of change of ground surface characteristics, including char depth, organic matter loss, altered color and structure, and reduced infiltration, caused by fire.
After fire, common changes to the soil include:
- loss of ground cover due to consumption of litter and duff;
- surface color change due to char, ash cover, or soil oxidation;
- changes in soil structure due to consumption of soil organic matter;
- consumption of fine roots in the surface soil horizon; and
- formation of water repellent layers that reduce infiltration.

The degree of soil burn severity varies widely from fire to fire, and within individual burns. It depends on many factors, including the weather at the time of burning, fire behavior, the amount, type, and distribution of fuels, type of soil, and slope. Notice that the Fire Environment Triangle studied in Unit III covers many of these factors.

The more severe fire’s effects on the soil, the more likely those soils will erode in subsequent rainstorms – especially in places with steep slopes. Erosion after fires can cause tremendous damage to people’s homes and other structures in the first year or two after a fire.

You can find more detailed information about fire and soils in PowerPoint M10-1_FireSoilAndWater.pptx, the presentation used in this activity.

Consider doing Activity M15 (Bark and Soil: Nature’s Insulators) to learn about heat transfer in the soil under a protective layer of duff.

Source and additional reading:

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**Materials and preparation:**
1. Display the Fire Environment Triangle poster *(FireEnvironmentTriangle.pdf)*.

2. One copy of Handout M10-1. Fire and Soil per student.

3. Download and view PowerPoint M10-1_FireSoilAndWater.pptx. The notes for the presentation (shown below) are written to guide discussion and to prompt students to answer questions on their handout. On each slide:
   a. you introduce the new information;
   b. then you have students answer a question on the Handout M10-1. Fire and Soil;
   c. then you do a short follow-up discussion.
d. If you wish, you can then let students revise their answers on the handout.

4. View this video about the relationship between vegetation cover and soil erosion: https://www.youtube.com/watch?v=im4HVXMGi68 Decide whether you will watch the video in step 3 (below) OR do the activity that is shown in the video. If you do the activity, you will need:
   o Three empty-2 liter plastic soda bottles
   o Three empty plastic soda bottles (about 1 liter size)
   o Three pieces of string/yarn
   o Soil
   o Dead leaves/needles
   o Grass seed (planted in the soil a couple of weeks ahead of time)
   o Pitcher of water

Procedures:
1. Explain: Fires change more than the plants above ground; they change the soil too. Think about the three parts of the Fire Environment Triangle: fuels, weather, and topography. All of these things influence how fires affect soils. That’s what we’ll learn about today.

2. Explain: We’ll start with a presentation that goes together with a handout. You’ll answer 1 question on the handout for each slide in the presentation.

3. Give each student a copy of Handout M10-1. Fire and Soil.

4. Show PowerPoint M10-1_FireSoilAndWater.pptx, using the notes below and stopping for students to answer the question posed for each slide.

5. Either watch this video as a class: https://www.youtube.com/watch?v=im4HVXMGi68 OR do the activity in the video as a class.

Assessment: Handout M10-1. Fire and Soil.

Evaluation: See Handout M10-1_Fire and Soil_ Answer Key.
Slide 1

This image shows where the heat from wildland fire goes. **Recall the 3 methods of heat transfer: convection, conduction, and radiation. Answer Question 1 on the handout.**

Discussion: Convection is lifting some of the fire's heat up, away from the soil. Conduction and radiation are transferring heat into the soil.

Slide 2

What does the heat from burning wildland fuels do to plants, ground cover, and soil after a fire? It depends on many things, so it varies! The physical, biological, and ecological effects of fire – all lumped together – are called **burn severity**.

Use this slide to answer Question 2 on the handout.

Discussion: In the right diagram, we can see the how the vegetation changed as a result of the fire. **Vegetation burn severity** describes the effects of a fire on vegetation. Vegetation burn severity is likely the first thing you notice when you look at burned forest, and we’ll study it more in later lessons. But we can also see changes in the soil surface and even deep into the soil. This is **soil burn severity** - the effects of fire on the soil. That’s what we’ll study today.

Slide 3

**Soil burn severity** depends mainly on 2 things: amount of heat and duration of heating. If a fire burned the surface fuels in these 2 photos under the same conditions, which fire would produce more heat? Which would burn for a longer time? **Answer Question 3 on the handout**

Discussion: **Recall lesson M7 about fuel properties.** The logs in the right photo would produce more heat and would burn longer. So it is likely that a fire burning the heavy fuels in the right photo would cause much higher soil burn severity than a fire in the pine litter in the left photo.
Let’s look at soil burn severity in a small area – not much bigger than a classroom. The left photo shows this area before it was burned by a prescribed fire. The right photo shows what it looked like afterward. Look for diversity in soil burn severity. **Answer Question 4 on the handout.**

**Discussion:** Can you find patches that show no evidence of fire? How about patches that are “lightly burned” – that is, the ground surface is black and some woody fuels remain? How about patches that are “severely burned” – that is, the ash is completely white (no carbon left) and woody fuels are nearly gone? The lines of thick white ash, where the logs were before the fire, are places where the soil probably experienced hotter temperatures for longer periods of time than most of the other areas in this photo. That is, the areas underneath the logs experienced very high burn severity.

Here is a video of a fire moving though a forest. **Answer Question 5 on the handout.**

**Discussion:** Notice how the flames appear to be moving through the surface vegetation relatively quickly. If there is not much heavy fuel (like logs) underneath the vegetation, the soil may burn only lightly. Notice all of the heavy fuels from a previous fire. These include snags, stumps, and fallen logs. After the flames move through the vegetation, the logs and stumps will continue to flame and smolder, causing high soil burn severity in those spots.
This is a photo of that same fire. **Answer Question 6 on the handout.**

**Discussion:** You can see how the flames are concentrated in stumps and logs. In the foreground, the fire is actively spreading forward. The flames have gone out in many patches behind the flaming front. Where the fire has gone out, those areas will probably have low soil burn severity. In the background, flames are still burning in some stumps and logs. Those patches will probably have high soil burn severity.

Soil burn severity varies greatly even over small areas within a fire. Which areas of soil do you think burned most severely? Which areas burned less severely? **Answer Question 7 on the handout.**

**Discussion:**
- You can see lightly burned surface and ground fuels on the back-left side of this photo. Chances are the soil experienced low or moderate burn severity.
- In the middle of the photo, you can see areas of white ash and no remaining stems of small trees or shrubs. Underneath some of these white ash patches may be patches of severely burned soil.
- In the very foreground, it looks like some of the surface fuels aren’t completely consumed, so maybe the soil was only moderately burned.
- In the middle, you can see lines where logs have been completely consumed, leaving nothing but white ash. These areas likely have severely burned soil beneath.

You may want to mention that, just because the vegetation appears severely burned, the soil may not be and vice-versa (i.e., vegetation burn severity does not equal soil burn severity). How could that happen? **It could be caused by variation in soil composition, texture, moisture content, or other factors.**
Both of these photos show places where most of the vegetation and ground cover has burned away. The soil does not have any protection from raindrops. **Answer Question 8 on the handout.**

**Discussion:** Loss of ground cover is the aspect of soil burn severity that is most likely to increase soil erosion and runoff. If there is no litter, duff, or plant cover and roots to hold the soil in place after fire, the soil is vulnerable to washing away especially after heavy rains.

In the corner, you can see the splash from a single raindrop. What happens when lots of rain falls on an area with severely burned soils? What if the area is on a steep hillside? **Answer Question 9 on the handout.**

**Discussion:** Areas with severely burned soils on steep slopes are the most vulnerable to erosion. Sometimes heavy rain on these soils causes big mudslides.

This photo is on your handout.

**Use what you have learned in this activity to answer Question 10 on the handout.**
Handout M10-1. Fire and Soil

1. What 2 forms of heat transfer move heat down into the soil?

2. Write the definition of each term:
   a. Vegetation burn severity:
   b. Soil burn severity:

3. Which photo shows a place that is likely to experience high soil burn severity? Why?

4. Describe the soil burn severity in the photo on the right (B).

5. What places in the video will probably experience low burn severity? Why?

6. After the flames have passed, what fuels are likely to keep on burning and producing heat?

7. In the photo, circle and label an area likely to have:
   a. low soil burn severity
   b. high soil burn severity

Photo by Michael Yager
8. What is likely to happen if it rains after a fire has removed all of the litter, duff, and plant cover from the soil?

9. After a fire, what kinds of places are most likely to have severe erosion?

10. In the photo, circle and label 3 areas:
   a. A place likely to have high soil burn severity
   b. A place likely to have low soil burn severity
   c. A place that is likely to have severe erosion
Handout M10-1: Fire and Soil Answer key


2. Write the definition of each term:
   c. Vegetation burn severity: the effect of a fire on the vegetation
   d. Soil burn severity: the effect of a fire on the soil

3. Which photo shows a place that is likely to experience high soil burn severity? Why? The photo on the right (B) has a lot of large, heavy fuels. They would produce more heat and burn for longer time (if they were ignited) than the fuels in photo A. The amount of heat and the duration of heating affect soil burn severity.

4. Describe the soil burn severity in the photo on the right (B). Soil burn severity varies a lot. In some areas, the forest floor is unburned. Some areas look lightly burned, and some areas look severely burned.

5. What places in the video will probably experience low soil burn severity? Why? Places without a lot of big fuels will probably experience low soil burn severity because the flames will pass through quickly and not burn very long.

6. After the flames have passed, what fuels are likely to keep on burning and producing heat? Large fuels like stumps and logs.

7. In the photo, circle and label an area likely to have:
   a. low soil burn severity
   Blue circle is an example - the fire burned around or under small trees without burning their foliage, and the ash is black.
   b. high soil burn severity
   Red circle is an example - the fallen logs have burned and the ash around them is white.

8. What is likely to happen if it rains after a fire has removed all of the litter, duff, and plant cover from the soil? If there is no litter, duff, or plant cover to hold the soil in place, the soil is vulnerable to erode (wash away), especially after heavy rains.
9. After a fire, what kinds of places are most likely to have severe erosion? Areas on steep slopes with severely burned soils are the most vulnerable to erosion.

10. In the photo, circle and label 2 areas:
   a. A place that is likely to have high soil burn severity and high risk of erosion
   b. A place that is likely to have low burn severity and low risk of erosion
   c. A place likely to have very high risk of erosion because it has high soil burn severity and is on a steep hillside.

Red circles indicate areas that likely have high soil burn severity. They all have high risk of soil erosion, especially the one at the top because it seems to have the steepest slope. Blue circles indicate areas that likely have low soil burn severity. In this picture it is difficult to tell if these green patches of forest are unburned or experienced a surface fire and have surviving trees in the canopy. These areas are at low risk for erosion because they are relatively flat and likely have something covering the forest floor (litter, duff, live plants).