



## 10. Fire, Soil, and Water Interactions

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

**Subjects:** Science, Mathematics, Reading, Writing, Speaking and Listening, Health Enhancement

**Duration:** One half-hour session

**Group size:** Entire class

**Setting:** Classroom

**Vocabulary:** *burn severity, erosion, litter, soil burn severity, vegetation burn severity*

**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=im4HVXMG168>. **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 4-8 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, even within small areas.
- Students understand that if fires consume the litter, duff, and plant cover on the ground, this increases the chances of soil erosion.

| Standards: |                                | 6th               | 7th               | 8th               |
|------------|--------------------------------|-------------------|-------------------|-------------------|
| CCSS       | Reading Informational Text     | 1, 2, 4, 7, 10    | 1, 2, 4, 10       | 1, 2, 4, 10       |
|            | Writing                        | 2, 4, 7, 10       | 2, 4, 7, 10       | 2, 4, 7, 10       |
|            | Speaking/Listening             | 1, 2, 4, 6        | 1, 2, 4, 6        | 1, 2, 4, 6        |
|            | Language                       | 1, 2, 3, 4, 6     | 1, 2, 3, 4, 6     | 1, 2, 3, 4, 6     |
|            | Reading Standards Science/Tech | 1, 2, 3, 4, 7, 10 | 1, 2, 3, 4, 7, 10 | 1, 2, 3, 4, 7, 10 |
|            | Writing Standards Science/Tech | 1, 2, 4, 7, 10    | 1, 2, 4, 7, 10    | 1, 2, 4, 7, 10    |
| NGSS       | Earth's Systems                | ESS2.D            |                   |                   |
|            | Earth and Human Activity       | ESS3.B            |                   |                   |
| EEEGL      | Strand 1                       | A, B, C, E, F, G  |                   |                   |

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**Teacher Background:** Soil burn severity is the degree of change in soil characteristics caused by fire. These include the depth of char, loss of organic matter, alteration of color and structure, and reduction of infiltration.

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; 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 **Activity M05** covers many of these factors. For more detailed information about fire and soils, view the presentation provided below: ***M10-1\_FireSoilAndWater.pptx***. Supplemental information is available in the article by Parsons and others (2010) cited below, which provides extensive descriptions and photographs of soils burned with different severities.

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. This topic is covered briefly in the presentation ***M10-1\_FireSoilAndWater.pptx***. Ecological effects of fire on streams and aquatic organisms are not covered in this curriculum, but the articles by Rieman and others (2012) and Howell (2006) cited below provide an overview and one example of primary research on this complex topic.

**Activity M15. Bark and Soil: Nature's Insulators** is a good companion lesson to this one. It provides information about heat transfer in the soil under a protective layer of duff.

#### **Sources and additional reading:**

Parsons, Annette; Robichaud, Peter R.; Lewis, Sarah A.; Napper, Carolyn; Clark, Jess T. 2010. Field guide for mapping post-fire soil burn severity. Gen. Tech. Rep. RMRS-GTR-243. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 49 p. <http://www.treesearch.fs.usda.gov/pubs/36236>

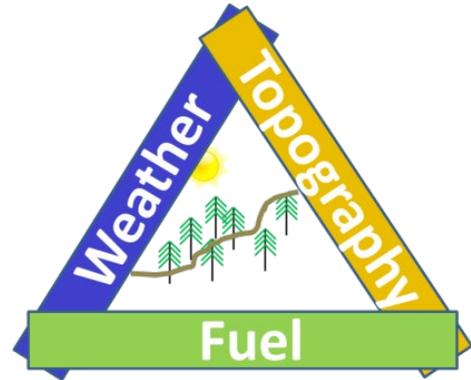
Rieman, Bruce; Gresswell, Robert; Rinne, John. 2012. Fire and fish: a synthesis of observation and experience. In: Luce, Charles; Morgan, Penny; Dwire, Kathleen; Isaak, Daniel; Holden, Zachary; Rieman, Bruce, eds. Climate change, forests, fire, water, and fish: building resilient landscapes, streams, and managers. General Technical Report RMRS-GTR-290. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 159-175. [https://www.fs.usda.gov/rm/pubs/rmrs\\_gtr290/rmrs\\_gtr290\\_159\\_175.pdf](https://www.fs.usda.gov/rm/pubs/rmrs_gtr290/rmrs_gtr290_159_175.pdf)

Howell, Philip J. 2006. Effects of wildfire and subsequent hydrologic events on fish distribution and abundance in tributaries of North Fork John Day River. North American Journal of Fisheries Management. 26: 983-994. <https://www.tandfonline.com/doi/abs/10.1577/M05-114.1>

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**Materials and preparation:**

1. Display the Fire Environment Triangle (AKA Fire Behavior Triangle) poster (*M05\_FireEnvironmentTriangle.pdf*).
2. One copy of **Handout M10-1. Fire and Soil** per student.
3. Download and view the presentation: *M10-1\_FireSoilAndWater.pptx*. The presentation and handout are used together in Step 4 below. Each slide contains a little information, a question that students should answer on their handouts, and discussion points.



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 as it is shown in the video. If you do the activity, you will need:
  - Three empty-2 liter plastic soda bottles
  - Three empty plastic soda bottles (about 1 liter size)
  - Three pieces of string/yarn
  - Soil
  - Dead leaves/needles
  - Grass seed (planted in the soil 4-8 weeks ahead of time)
  - 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 (*M05\_FireEnvironmentTriangle.pdf*): 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 go through a presentation. You'll use information from each slide to answer questions on the handout. After you answer each question, we'll discuss the answer.
3. Give each student a copy of **Handout M10-1. Fire and Soil**.
4. Show the presentation. On each slide:
  - a. Introduce the new information using the slide notes (in black print below).
  - b. Have students answer the associated question on the handout.
  - c. Do a short follow-up discussion (using the notes in red print below).

d. If you wish, let students revise their answers on the handout.

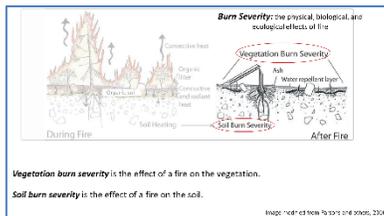
Slide  
1



Explain: 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 much of the fire's heat up, away from the soil. Conduction and radiation are transferring heat into the surrounding fuels and the soil.

Slide  
2



Ask/explain: What does the heat from burning fuels do to plants, ground cover, and soil? **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-hand diagram, we can see how the ecosystem has changed as a result of the fire. This is burn severity.

Vegetation burn severity describes the effects of fire on the 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.

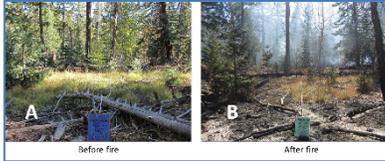
Slide  
3



Explain: 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 M07 about fuel properties. The logs in the right photo (B) 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. (Litter is the layer of dead leaves and other plant matter, not yet decayed, that lies at the top of the forest floor.)

Slide  
4



Explain: Let's think about soil burn severity in a small area, not much bigger than our classroom. The left photo (A) shows this area before it was burned by a prescribed fire. The right photo (B) 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 soil burn severity.

Slide  
5



Explain: Here is a video of a fire moving through 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 burn severity will probably be low. 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.

Slide  
6



Explain: This is a photo of that same fire. The fire is spreading forward and to the left. The area to the right and in the background has already burned. **Answer Question 6 on the handout.**

**Discussion:** The flames have gone out in many patches behind the flaming front. We can see how the flames are concentrated in stumps and logs. The areas where the fire has gone out will probably have low soil burn severity. The areas that still show flaming combustion and glowing fuels – mostly stumps and downed logs - will probably have high soil burn severity.

Slide  
7



Explain: We've seen that soil burn severity can vary greatly even over small areas. In this photo, which areas do you think have the highest soil burn severity? Which areas burned less severely? **Answer Question 7 on the handout.**

**Discussion:**

- You can see lightly burned surface and ground fuels in the back-left corner of the photo. Chances are the soil there 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. You can also see white lines where logs have been completely consumed, leaving nothing but white ash. If the site had duff cover before the fire, it is all gone from these patches. Underneath some of these white ash patches may be patches of severely burned soil.
- In the left foreground, it looks like some of the surface fuels are consumed and some remain. Maybe the soil burn severity was moderate.

Note that, just because the vegetation appears severely burned, the soil burn severity may not be great, and vice-versa. That is, VEGETATION BURN SEVERITY DOES NOT EQUAL SOIL BURN SEVERITY. Why? It could be caused by variation in soil composition, texture, moisture content, or other factors.

Slide  
8



Explain: Both of these photos show places where most of the vegetation and ground cover have burned away. There seems to be very little duff on the ground. With no cover, the soil does not have any protection from raindrops. **Answer Question 8 on the handout.**

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

Slide  
9



Explain: 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.

Slide  
10



Explain: This photo is on your handout. **Use what you have learned in this activity to answer Question 10.**

5. Either watch this video as a class: <https://www.youtube.com/watch?v=im4HVXMG168> OR do the activity in the video.

**Assessment: Handout M10-1. Fire and Soil.**

**Evaluation:** See **Answer Key M10-1. Fire and Soil.**

Most of the answers to the handout were covered in the presentation, so you use a fairly high standard for grading:

- 9-10 correct: excellent
- 7-8 correct: acceptable
- <7 correct: poor

## Handout M10-1. Fire and Soil

Name: \_\_\_\_\_

1. What 2 forms of heat transfer are able to move heat down into the soil?
2. Write the definition of each term:
  - a. Burn severity:
  - b. Vegetation burn severity:
  - c. 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 soil burn severity? Why?

6. In the area behind the flaming front, where the fire has already passed through, what fuels are continuing to burn and produce heat?
7. In the photo, circle and label an area likely to have:
  - a. *low soil burn severity*
  - b. *high soil burn severity*



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



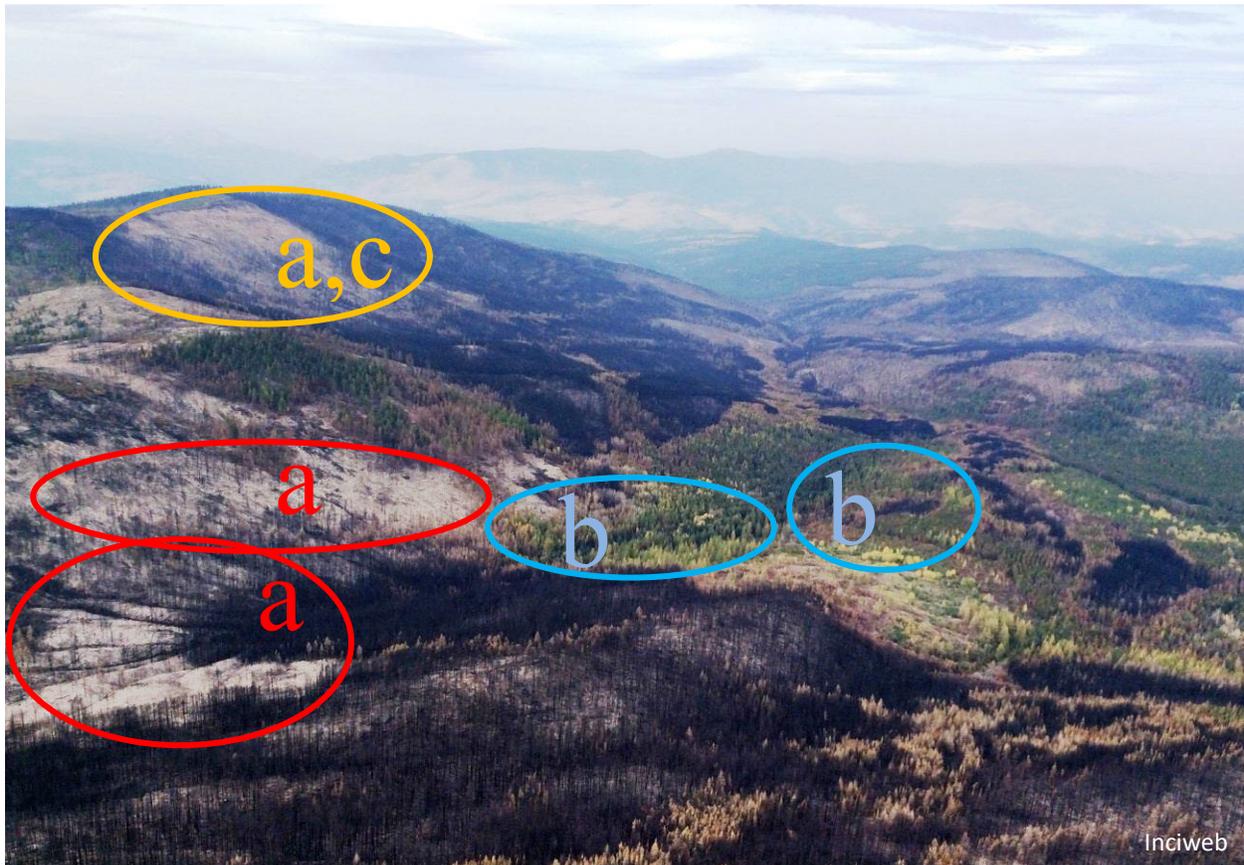
## Answer key for Handout M10-1: Fire and Soil

1. What 2 forms of heat transfer are able to move heat down into the soil? **Conduction and radiation.**
2. Write the definition of each term:
  - a. Burn severity: **the physical, biological, and ecological effects of a fire**
  - b. Vegetation burn severity: **the effect of a fire on the vegetation**
  - c. 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 (once ignited) than the fuels in photo A.**
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 are covered with black ash, and they have some large pieces of wood left. Other areas are covered with white ash. In some places, white ash is all that remains of large logs.**
5. What places in the video will probably experience low soil burn severity? Why? **Places without large fuels will probably experience low soil burn severity because the flames will pass through too quickly to transfer a lot of heat into the soil.**
6. In the area behind the flaming front, where the fire has already passed through, what fuels are continuing to burn and produce 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 *erosion* (washing 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 3 areas:
  - a. A place that is likely to have high soil burn severity
  - b. A place that is likely to have low soil burn severity
  - c. A place that is likely to have severe erosion



Red circles (a) indicate areas that are likely to have high soil burn severity. Where they are on steep slopes (golden circle, c – and also steep areas within the “a” circles), they also have high risk of soil erosion. Blue circles (b) indicate areas that are likely to have low soil burn severity. In this picture it is difficult to tell if the 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). Most of the areas with blackened trees probably burned in crown fire; many of them have patches of both black ash and white ash on the ground, suggesting that they burned with a mixture of soil burn severities.