Controlling Soil Erosion After Wildfire and Guiding Recovery in Southern Utah

Wildfires are a natural occurrence in many ecosystems across Southern Utah and the greater Colorado Plateau, which includes Northern Arizona, Southwest Colorado, and Northwest New Mexico. However, due to decades of fire suppression, wildfires are becoming more intense and larger (Singleton et al., 2019). This fact sheet offers information to help people in Southern Utah and the greater Colorado Plateau region understand the effects of wildfires on the land and the process of soil erosion. We discuss how wildfires affect soils and plants and offer suggestions for reducing soil erosion as needed. The information provided is relevant to private landowners and public land managers impacted by wildfires.

So, why should we care about soil erosion? Simply put, soil is the foundation of any piece of land. Maintaining topsoil is essential for maintaining healthy ecosystems. Unfortunately, soil erosion can increase dramatically after a wildfire, which can lead to the loss of topsoil and the formation of channels or rills that divert water. This process can significantly alter how water moves over a piece of land for years to come. Understanding the factors that contribute to soil erosion and learning how to reduce it when necessary can help guide land recovery after a wildfire (Ice, Neary, & Adams, 2004).

Progression of Recovery After Wildfire

Wildfires can quickly alter a landscape and cause soil erosion. However, many ecosystems have the ability to regenerate after a wildfire. The recovery process following a wildfire can be broadly divided into several stages. In the years following a wildfire, the amount of soil erosion can change significantly, and can vary with soil type, climate, and fire intensity. The stages of recovery may include the following phases:

1. Initial response
2. Regeneration
3. Stabilization

During the initial response phase, there may be increased soil erosion due to lost vegetation cover. In the regeneration phase, new vegetation may begin to establish, reducing soil erosion. Finally, in the stabilization phase, the soil and vegetation have reached a state of equilibrium, minimizing erosion and promoting stability. Understanding the different recovery phases can help guide post-wildfire management decisions to promote successful ecosystem restoration.

Immediately Following Wildfire Shortly after a fire, soil erosion is usually most severe, with levels often several times higher than pre-fire erosion rates (Cerdà & Doerr, 2005). In parts of Southern Utah wildfires can occur during the summer months, and monsoonal rains in late summer or fall can bring intense precipitation and winds that cause further erosion in recently burned areas (Underwood & Thomas, 2003). This is also when the potential for large, debris-filled flash floods is highest. Fall, spring, and summer convective storms, as well as the rainfall delivered by normal westerly storm tracks across the Colorado Plateau, can also cause increased post-fire soil erosion immediately after fires.

Figure 1. *Seedling Emergence After Wildfire*
Photo: Kristina Young

Years Following Wildfire One to four years after a fire, soil erosion rates begin to decline as vegetation regrows and becomes established (Figure 1). Two years after wildfire, erosion may be noticeably reduced compared to the year of the wildfire. However, erosion can still be a significant concern, depending on factors such as ecosystem type, precipitation intensity, and fire severity. The potential for intense rain events to cause large-scale erosion and flash floods typically persists for up to four years following a fire.

Longer-Term Recovery Four or more years after a fire, as plant succession continues and the burned area becomes filled in with plants, soil erosion gradually decreases and may eventually return to pre-fire levels. The amount of time this takes depends on factors such as ecosystem type, fire severity, weather patterns, and larger climate trends in the years following the wildfire. With proper post-fire management, burned areas can become healthier than pre-fire ecosystems that may have been overcrowded due to fire suppression efforts.

Fire and Climate Change

Wildfires are expected to become more severe, frequent, and larger in the Western U.S. due to climate change (Abatzoglou & Williams, 2016). This increase in fire intensity, coupled with a warmer and drier climate, will impact the amount of soil erosion that occurs after a wildfire and the recovery process for vegetation. While some information is available to guide decision-making in the face of new climate realities, there is still much uncertainty about how wildfires and climate change will transform landscapes in Southern Utah. When planning for post-fire restoration, it is important to recognize that some areas may not return to their pre-fire vegetation community type.

Understanding Soil Erosion After Wildfire

The vegetation, fallen leaves, and accumulated duff that slow and capture water during rainstorms and protect soil particles from the wind can be lost during wildfires. Without a protective layer over the soil, the soil becomes vulnerable to wind and water erosion (Canfield et al., 2005).

Soil Water Erosion Basics After Fire Soil water erosion after a fire occurs when raindrops hit exposed soil, dislodging soil particles that can move downslope as water flows over the soil surface, resulting in sheets of moving soil or concentrating soil and water into rills and gullies. Without plants or fallen leaves to slow the flow of soil and water after a wildfire, the amount of erosion and water that moves from burned slopes into water channels can be many times greater than before the fire.

Soil Wind Erosion Basics After Fire Soil wind erosion after a wildfire occurs when wind reaches a high enough velocity to pick up soil particles on exposed soil surfaces and send them airborne. These particles can become dust in the air or move horizontally along the soil surface. Fine ash produced after a wildfire is particularly prone to move by the wind. Soil wind erosion can redistribute soil nutrients and seeds and cause dust clouds near recently burned areas.

For more information about wind erosion after fire in shrubland regions, see Germino's (2015) fact sheet titled "Wind Erosion Following Wildfire in Great Basin Ecosystems."

Factors Influencing Soil Erosion

Figure 2. *Burned Area After the Pack Creek Fire in San Juan County, Utah*
Photo: Kristina Young

The amount of water and wind erosion that occurs after a wildfire depends on many different variables. Below we explore these variables and how they will likely affect soil erosion and land recovery.

Soil Burn Severity Burn severity indicates intensely an area has burned and how the burn has influenced the soil. Burn severity can be classified as either low, moderate, or high. Areas that experience a low-severity burn are less vulnerable to erosion than those that have been severely burned. The following are the different levels of burn severity (Keeley, 2009).

- **High burn severity:** All, or nearly all (> 80%), of the plants, leaves, duff, and fine roots have been consumed. Ash is generally uniformly grey or white. Soils are darkened and hydrophobic (water repellent) up to 2 inches into the soil. The likelihood of soil erosion is high.
- **Moderateburn severity**: Between 30%–80% of the plants, leaves, and duff have been burned. Some ground cover may remain, including scorched trees (Figure 2). Roots are alive below the soil surface. The soil color is changed, and the soils can be slightly hydrophobic.
- **Lowburn severity**: Less than 30% of the vegetation is burned. The litter or duff covering the soil may appear lightly charred. The soil color is normal. Some vegetation may appear green. Soil properties such as infiltration and erosion are not significantly changed.

Soil Type and Hydrophobicity The impact of wildfires on soils varies depending on the soil type and burn severity. High-severity burns can cause soils to become hydrophobic, meaning they repel water, resulting in increased runoff. Coarse-textured soils like sandy or sandy-loam soils common in semiarid regions are more likely to become hydrophobic after a fire (Natural Research Conservation Service [NRCS] and Soil Quality Institute, 2000). Moreover, fine-textured soils are more prone to erosion, specifically wind erosion, and may be more likely to blow or wash away after fire (Duniway et al., 2019).

Slope A hillside's slope affects the amount of runoff and erosion that can occur. Steep slopes will generally experience higher soil erosion for longer periods after a fire. Physical barriers that reduce erosion are more likely to fail on very steep slopes.

Drainage Area and Extent of Fire The burned area's size influences the extent of erosion. The speed and force of water and sediment increase as they move downslope, increasing the potential for more significant erosion and gully cutting in large burn areas.

Local Weather Patterns Areas that experience heavy precipitation or intense winds are more susceptible to severe soil erosion after wildfires. Monsoons are common in the Southwest and may occur intermittently on the Colorado Plateau after wildfire season. Over time, precipitation promotes plant regrowth, reducing soil erosion.

Ecosystem Type Different plants and soil communities respond differently to wildfires, and some ecosystems are more fire-adapted than others. For example, grasslands and oak woodlands can resprout quickly after a wildfire, whereas pinyon-juniper woodlands may take a long time to recover. The speed of vegetation recovery and the return of soil cover influence the amount of soil erosion over time.

Deciding When and How to Stabilize Soils and Guide Recovery in a Burned Area

After a wildfire, the best action is often to let the land recover naturally. If the burn was low or moderate severity and plant regrowth is visible in the weeks following the fire, intensive interventions may not be necessary. However, in cases of high-severity fires or when soil erosion or gully cutting is a concern, soil stabilization efforts can be implemented to slow erosion and steer land recovery. In some cases, treatments intended to enhance recovery after a wildfire can lead to further degradation due to mechanized disturbance of the soil surface. Consult post-fire professionals before taking actions that could have downstream or downslope consequences. Soil stabilization options vary in effort, cost, and utility, and often a combination of treatments is most effective in addressing erosion happening in different areas and at different scales. Give careful consideration when deciding what treatments to use in different contexts.

Assessing Immediate Risks Before taking actions after a wildfire, it is important to identify immediate or large-scale hazards, such as possible flooding or debris flows from upslope or upstream. County emergency managers and NRCS teams can identify these hazards and communicate with landowners after completing initial burned-area surveys.

Erosion Control Techniques

Each erosion control technique in Table 1 varies in effectiveness depending on the factors that influence soil erosion. Take care to weigh the pros and cons of each technique in deciding what is appropriate at different scales and locations.

Table 1. *Soil Erosion Control Techniques and Their Pros and Cons*

Erosion control type	Possible pros	Possible cons
Wood shred/ chips	Reduces erosion. Helps establish seedlings by providing microhabitats for seed germination.	Increases the presence of invasive species by retaining moisture and creating more habitat. Requires wood on site or wood to be brought in.
Straw and hay mulch	Reduces erosion. Provides ground cover and may provide microhabitats for seed germination.	Introduces invasive species. Susceptible to being blown away. Expensive over large areas.
Hydromulch and tackifiers	Stabilizes soils, especially around high-value areas like structures or near surface water.	Concentrates flows on long hillslopes. Breaks down quickly after application.

		Expensive.
Slash	Requires low cost and effort. Creates habitat for seedling reestablishment. Stabilizes soils. (marginally effective)	Moves downslope easily and builds up in undesired areas. Less effective than other erosion control treatments. Creates microhabitats where weeds may germinate.
Seeding	Stabilizes soils after establishment. Increases area's biodiversity. Provides pollinator and wildlife habitat.	Low germination success. Expensive. Takes multiple growing seasons for soil stabilization to occur.
Contour wattles	Intercepts water along slopes. Relatively easy to buy and use.	Not recommended over large areas because of low-cost effectiveness. Requires multiple rows to be effective.
Contour sandbags	Redirects water to secure high-value areas.	Only applies on moderate slopes in small drainage areas. Labor intensive.
Log terracing	Helps reduce overland water flow and collect water. Serves as a microhabitat in which to place seeds.	Can easily backfill and create gullying on either side of the structure. Difficult to secure.
On-site material	Helps reduce overland water flow and collect water. Serves as a microhabitat in which to place seeds.	Effectiveness will vary with material used. May backfill and create gullying on either side of the structure.

Mulching

Mulching can be a useful tool in reducing soil erosion after a wildfire, particularly when there is limited plant and litter cover left on the soil surface and limited regrowth occurring at the site. Here are some mulching techniques to consider:

Wood Shred and Wood Chip Mulch When immediate erosion control is needed, wood shred can be an effective technique to provide protective cover over the soil and reduce erosion (Grover, 2021). This mulch contains long, linear wood fragments that are less likely to wash or blow away and are less likely to introduce invasive plant species than other mulch types. Wood chips can also be used, but they may be less effective since they are uniform in size and don't interlock on the soil surface. Wood shred and wood chip mulch can be made on-site using a woodchipper.

Straw and Hay Mulch Straw or hay mulch is also effective in reducing erosion. Studies suggest that straw mulch is most effective when spread over 60%–80% of the ground surface within a given area, with a thickness of between 2–3 inches (Moench, 2012). It's important to ensure that the straw or hay is certified weed-free to reduce the potential for introducing invasive plants that can spread quickly in post-fire environments. Note that it's almost impossible to have completely weed-free mulch. Straw and hay mulches are more likely to blow away in high winds common in the Southwest (Beyers, 2004).

For more information about straw mulch and wood chip mulch, see New Mexico State Forestry's (n.d.) mulching fact sheet titled "Cover Applications."

Hydromulch and Soil Tackifiers Hydromulching and tackifiers involve applying a wet slurry of water, fiber mulch, and a tackifying agent over the soil surface. While they have been used to stabilize soils after a wildfire, they are not commonly used over large areas due to their tendency to concentrate water flows on long hillslopes and break down quickly after application (Napper, 2006;

Robichaud et al., 2013). Hydromulching may be most appropriate around structures or in areas near surface water sources.

For more information about hydromulching see the NRCS (n.d.-a) fact sheet titled "After the Fire - Hydromulching."

Distributing Slash is made up of tree limbs cut down from burned, dead, or living trees. It can be redistributed on the soil surface and used to reduce soil erosion and create sheltered areas that allow seeds to germinate (Jacobs et al., 2015). However, because it does not create a continuous cover over the soil surface, it is less effective than other types of mulch in reducing soil erosion. Slash is most effective in areas with little to no slope since unanchored slash can easily be moved during rainstorms and cause debris buildup downslope. If used, the slash pieces should have the most contact with the soil surface as possible (Pierson et al., 2013).

Mulching Considerations:

- Mulch that is deeper than 2 to 3 inches can reduce the ability of existing seeds in the soil to germinate and reduce the effectiveness of seeding efforts that may be applied along with mulch. Thick mulch can also hinder the presence or recovery of biological soil crust that stabilizes soils in some ecosystems on the Colorado Plateau.
- In some cases, mulch can facilitate invasive plant growth by keeping moisture close to the soil surface. In areas where weeds are a concern, weed barriers underneath the mulch or extremely thick mulch may reduce invasion.
- Mulching is best suited to areas of high erosion concern and areas that are carefully monitored for invasive plant growth. Extensive or thin mulching may be ineffective and promote the spread of invasive plants.
- Wood and straw mulch can be a fire hazard if a site still has the potential for fire. In such cases, exercise caution when using mulch around structures or near tree bases.
- Take care to minimize soil disturbance when distributing slash or other erosion control interventions. Generally, do not subject recently burned areas to heavy equipment due to the increased probability of soil erosion and potentially introducing invasive plants (Miller et al., 2012).

Seeding

A primary goal of post-fire recovery and erosion control is to restore plant cover to a burned area. Seeding with appropriate seed mixes can help achieve this restoration by returning plant cover and diversity to areas that have: (1) moderate- or high-severity burns; (2) large amounts of bare ground; (3) slow plant recovery; and (4) high risk of invasive plants. Seeds that successfully germinate typically begin to provide appreciable ground cover, soil protection, and competition with invasive species 1–3 years after distribution. Seeding is not considered an immediate solution to soil erosion or invasive species control due to the time it takes most native seeds to germinate and become established. The potential for low germination rates of distributed seeds, especially during drought years, means that seeding alone may not result in increased ground cover.

The dry climate and large weather fluctuations on the Colorado Plateau can make successful seeding a challenge (Winkler et al., 2018). Many times, seeds do not germinate or reach maturity when distributed haphazardly over an area (a process known as broadcast seeding) (Grover, 2021). Below are some techniques that can create opportunities for successful seed germination. Using these techniques in combination may provide the best chance of success.

- **Establish a protected area:** Seeding can be most successful when there is a protected area for seeds to germinate. Mulch, erosion barriers, and slash pieces can hold in water and provide microhabitats for seeds. Distributing seeds on the upslope side of these cover types can be an effective way to increase seed germination and establishment.
- **Provide supplemental water:** Providing supplemental water can help seeds become established. Although not practical everywhere, periodic gentle watering with a sprinkler that thoroughly saturates the soil multiple inches below the soil surface can increase seed germination and success in priority areas.
- **Provide raking:** Gentle raking with a hand rake to break up the top 4 centimeters of soil before seeding can increase seed contact with the soil and germination success in areas that have physical soil crusting or hydrophobic soils. This is most appropriate over small areas, as even minor disturbances to the soil over larger areas can increase soil erosion.
- **Apply seed during gentle rain periods:** Seeds may have a greater chance to successfully germinate when applied during times of the year when rain is expected to fall with low to moderate intensity. In burned areas, high-intensity rains, such as monsoonal rain, can wash seeds away (Neary et al., 2012), while dry times of year can limit

germination (Wagenbrenner et al., 2006). Adding seeds after the monsoon season but before snowfall in burned areas on the Colorado Plateau may allow seeds to take advantage of early spring snowmelt and gentle spring rains, if they occur.
- **Use adapted seeds:** Purchasing seeds that are adapted to the local climate can increase the likelihood of their germination and establishment. Seed mixes that offer diverse plant types and do not contain non-native or aggressive plant species provide the best opportunity to increase plant diversity in the long term.

For more information about seeding after wildfire, see the NRCS (n.d.-b) fact sheet titled "After the Fire - Seeding."

Tools to Help With Decisions

- ***EcoRestore Portal***The EcoRestore tool from Utah State University and the University of Arizona can recommend seed mixes specific to sites and management goals.
- ***Land Treatment Exploration Tool*** This tool is a resource from the U.S. Geological Survey for those planning restoration and rehabilitation actions using principles from adaptative management. While it is meant for public lands, private landowners may benefit from exploring this tool.

Erosion Barriers

Erosion barriers intercept sediment and slow water flow as it moves downhill and can be made of on-site or imported materials. These barriers secure upslope areas that do not have water run-on from large areas. However, they are not suitable for areas with significant water flow, such as in-stream channels or along stream banks.

Figure 3. *Log Terracing to Control Soil Erosion*
Photo: Kara Dohrenwend

Contour Wattles Contour wattles are cylindrical structures made of compressed weed-free straw encased in material such as jute or nylon. They are installed in shallow trenches across slopes to intercept water. Purchased wattles can range from around 8 to 12 inches in diameter and approximately 20 to 25 feet long. Contour wattles are secured with stakes pounded into the ground at least 8 inches into the soil. Tamp soil down on the upslope base of the wattle to ensure water does not flow beneath it. Generally, contour wattles should be placed on moderate slopes (about 50% or less) and have a contributing drainage area of 2 acres or less. Contour wattles work best on slopes that receive low amounts of flowing water (< 1 cubic foot per second) and are most effective during low-intensity rain events (< 1.8 inches per hour). Multiple rows of contour wattles may be needed, and the spacing between wattles should be determined by site and fire characteristics, such as burn intensity, slope, rainfall, and soil type. However, contour wattles are not highly recommended for large areas due to their low cost-effectiveness.

For more information and instructions for building contour wattles, please refer to the NRCS (n.d.-c) fact sheet titled "After the Fire - Contour Wattles."

Contour Sandbags Contour sandbags are biodegradable bags filled with on-site soil and used to construct a continuous barrier across a hillslope to catch water. These are most appropriate for deflecting runoff and erosion from impacting high-value areas such as houses. Contour sandbags are generally used on moderate slopes (about 10% or less) and in drainage areas of around 1 acre or less. Generally, a shallow depression along a slope's contour line should be dug about 2–3 inches into the soil using a hand level. Place sandbags within the depressions, and tamp soil down on the upslope base of the sandbags to prevent water from flowing beneath them. Multiple rows of sandbags may be needed, and the spacing between sandbag contours should be determined by site and fire characteristics, such as burn intensity, slope, rainfall, and soil type.

For more information and instructions for building contour sandbags, please refer to the NRCS (n.d.-d) fact sheet titled "After the Fire - Sandbag Barrier."

Log Erosion Barriers Log erosion barriers are logs placed in a shallow trench on the contour of a slope to intercept runoff (Figure 3). This type of terracing is generally most appropriate in places with low rainfall intensity (less than 1.8 inches per hour) and on moderate slopes (about 60% slope). Larger catchment areas require larger diameter trees to be the most effective. Generally, soil is backfilled where the log meets the ground, and multiple terraces are placed along a slope. Smaller catchment areas can use smaller-diameter logs, but smaller logs will have less capacity to retain water, require more barrier structures overall, and will be more likely to fail. It is best to remove as many branches from the log as possible so that it can rest on the soil surface and reduce water flow. Tree stumps or wooden stakes can be used to secure log barriers. However, this technique is no longer recommended by the National Forest Service because logs are often inadequately secured and can backfill, sidecut, or undercut quickly, resulting in accelerated or concentrated erosion.

For more information and instructions for building log erosion barriers, please refer to the NRCS (n.d.-e) fact sheet titled "After the Fire - Log Erosion Barriers."

Figure 4.*Terracing With On-Site Material to Control Soil Erosion*
Photo: Kara Dohrenwend

Barriers Using On-Site Materials Similar principles used in contour wattles, sandbags, and log erosion barriers can also be applied to other materials that are readily available on-site, such as contour rock structures, earthen berms, or secured bundles of brush (Figure 4). Although there is limited research on the effectiveness of these types of barriers in post-fire environments, they offer a cost-effective solution to reducing soil erosion and minimizing the risk of introducing invasive plants. However, as with all erosion barriers, exercise caution and consult post-fire professionals to ensure proper implementation.

Considerations for Erosion Barriers:

- It is crucial to minimize soil disturbance during the construction of erosion barriers. In recently burned areas, avoid using heavy equipment due to the increased likelihood of soil erosion and the potential introduction of invasive plant species.
- Poorly constructed erosion barriers or those built in inappropriate locations can cause downslope problems. These barriers can fail and release water and debris flows downslope, leading to cutting and accelerated erosion (Robichaud et al. 2010; Girona-Garcia et al. 2021).
- When selecting the appropriate erosion barrier type and determining where to construct them, it is essential to consider the catchment size and hillslope. Proper construction is crucial.
- Erosion barriers on the upslope side can provide protected habitats for seedlings to become established, making them a suitable place for seeding.

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