

Information and tools to conserve and restore Great Basin ecosystems

Wind Erosion Following Wildfire in Great Basin Ecosystems

Purpose: Wind erosion is a problem in Great Basin shrublands, particularly following large wildfires or other disturbances that remove the protective cover plants provide to soil. This factsheet aims to introduce the basic patterns, concepts, and terminology of wind erosion and to provide a basic framework for erosion risk assessment and response.

Soil resources and context for wind erosion in the Great Basin

Soil structure and function are important to the resistance, resilience, and overall function of semiarid ecosystems of the Great Basin, and soil erosion can have large ecosystem effects. Much of the Great Basin is flat or gently sloped, so erosion is often wind driven (aeolian or eolian) rather than water driven. Wind erosion occurs semi-regularly in playas, sand dunes, some salt desert sites, and croplands, but shrub and grasslands of the Great Basin usually do not have appreciable wind erosion in their undisturbed state. In fact, soils in sagebrush steppe often have a loam component that is at least partly comprised of loess derived from long-term aeolian deposition. However, very high levels of erosion can occur in sagebrush steppe (and related grass or shrublands) following major disturbances, such as large wildfires or cheatgrass die-off (Sankey et al. 2009).

Episodic erosion and redistribution of soils can have significant impacts on sites where soil is lost or redistributed, and on downwind air, water, and land resources. Wind erosion has led to loss of topsoil from burned sagebrush steppe, reducing critical organic matter, nutrients, and hydrological permeability of eroded sites and polluting downwind airsheds (Hasselquist et al. 2011, Ravi et al. 2011). However, not all sites are “damaged” by erosion. Sites in good ecological condition with higher resilience experienced appreciable post-fire wind erosion, yet had only minimal loss of the desirable perennial species and patterning of plants and soils that are important to ecosystem function (Hoover 2010).

The Bureau of Land Management’s Emergency Stabilization and Rehabilitation (ESR) program makes appreciable investments into plant and soil treatments with the stated objective

In Brief:

- Although soil stability is a major concern following wildfire, efforts to monitor, report, and evaluate wind erosion are rare. These actions are needed to respond to wind erosion events and to enable adaptive management.
- Wind erosion occurs in a variety of forms and impacts ranging from innocuous to severe, such as removal of topsoil, and degradation of downwind air, water, and land resources.
- A variety of indirect and direct methods can be used to measure soil stability, such as time-lapse photography, erosion bridges or pins, collectors that trap soil from passing air, and soil pedon classifications.
- Managers may reduce erosion impacts by avoiding destabilizing burned areas that are prone to erosion through treatments that further disturb soil or prolong bare soil exposure, and by avoiding putting investments like seedings and plantings where wind erosion may degrade them.



Episodic erosion in the Great Basin can have significant impact on sites where it occurs, as well as downwind air, water, and land resources.

of stabilizing soils. Many of these treatments are in low-elevation, dry, and flat areas that normally support Wyoming big sagebrush and have low resilience to disturbance. However, awareness and understanding of the magnitude of erosion after large wildfires and post-fire rehabilitation in these and other Great Basin shrublands are still in development. Aside from occasional estimates of potential soil loss, direct monitoring or reporting of soil stability is rare on ESR or other restoration projects. This factsheet describes key points for assessing the risk and occurrence of wind erosion.

Awareness, detection, and measurement of wind erosion

Generally, some wind erosion is inevitable following wildfires, as combustion leaves a layer of lightweight, buoyant char and ash that is easily swept away by wind. Of greater concern to management is severe wind erosion that removes inches of topsoil before vegetation recovers after fire. Identifying the potential for erosion, and evaluating any initial erosion, can help managers plan post-fire treatments and explain treatment outcomes in project reporting. Managers need to measure actual erosion rates to evaluate the stability of soils on a site.

A range of methods for monitoring wind erosion are available to land managers, and they differ considerably in cost, sophistication, and in how directly they measure soil movement (Zobeck et al. 2003). Satellite imagery (MODIS AQUA or TERRA, or LANDSAT) or radar imagery (NOAA National Weather Service) can be used to view dust plumes or haboobs if they are sufficiently dense (Figure 1; Wagenbrenner et al. 2012). Highway cameras or automated game cameras capable of time lapse photography can provide another way to observe dust in particular landscapes and relate it to weather records. Repeated aerial photographs (or imagery such as Geoeye®) can allow identification of areas where black charring is lost more quickly after wildfire due to relatively greater erosion.

Transport modes in wind erosion

Several different terms are used to explain how soil moves (Figure 1). Creep refers to the rolling of large particles short distances. Saltation refers to the bouncing of sand-sized particles across the landscape – up to about 300 foot (100 m) distances with 3 to 6 foot (1-2 m) heights in each bounce. Suspension refers to lofting of buoyant silt and clay-sized sediment into the air for longer-range transport. These smaller particles comprise dust, or particulate matter. Each saltating particle causes movement or loosening of more sand, silt, and clay particles through momentum and static electrical effects. Saltation is considered central to all modes of erosion, and it imparts a cascading effect in which erosion begets more erosion downwind. The increase in the amount of soil moving downwind has been compared to lateral landslides following large wildfires in the Great Basin.

Suspended particles may move in a diffuse haze, or denser clusters of various forms. Dust devils are most common, but they generally redistribute small amounts of soils within sites, and typically are not indicative of appreciable erosion. Dust plumes are similar in form to smoke moving downwind, and are indicative of more intense erosion and site impacts, often extending hundreds of miles beyond burned areas. Perhaps the most intense short-duration movement of soils are dense walls of lofted soils known as haboobs, which are well known in warmer deserts but have recently been observed in the cold desert of the Northern Great Basin. A haboob traveled with the outflow of a collapsing thunderhead from the 560,000 acre Long Draw fire in southeast Oregon and northwest Nevada and delivered record particulate matter levels to a three-county area including Boise, Idaho (Figure 2).

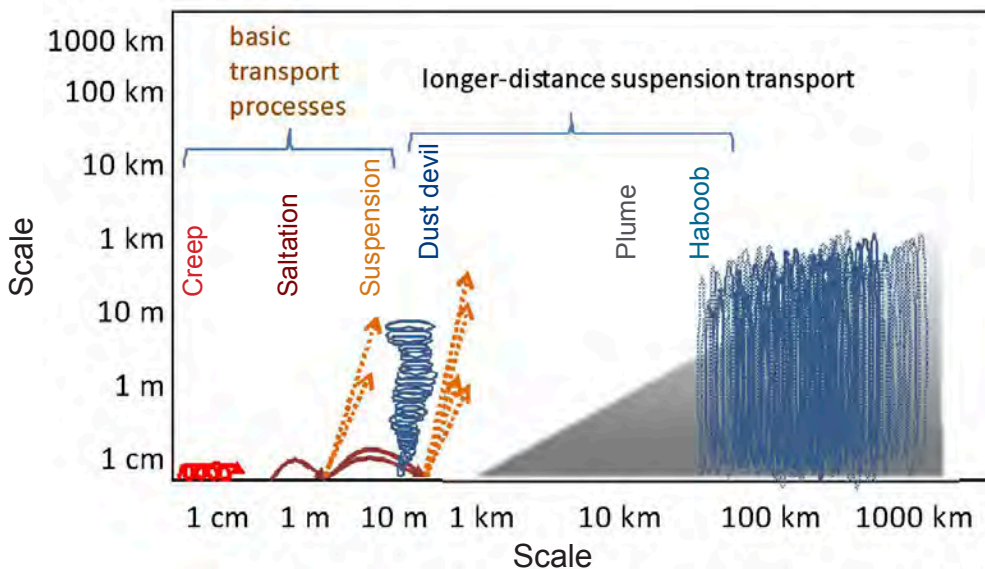


Figure 1. Depiction of the scale of the three modes of sediment transport by wind (creep, saltation, and suspension), and three primary means of medium to long-range transport of suspended sediment (dust devil, plume, and haboob). Scales shown are generalized and refer to height and downwind distance of impact. Colors match terms to specific transport types.

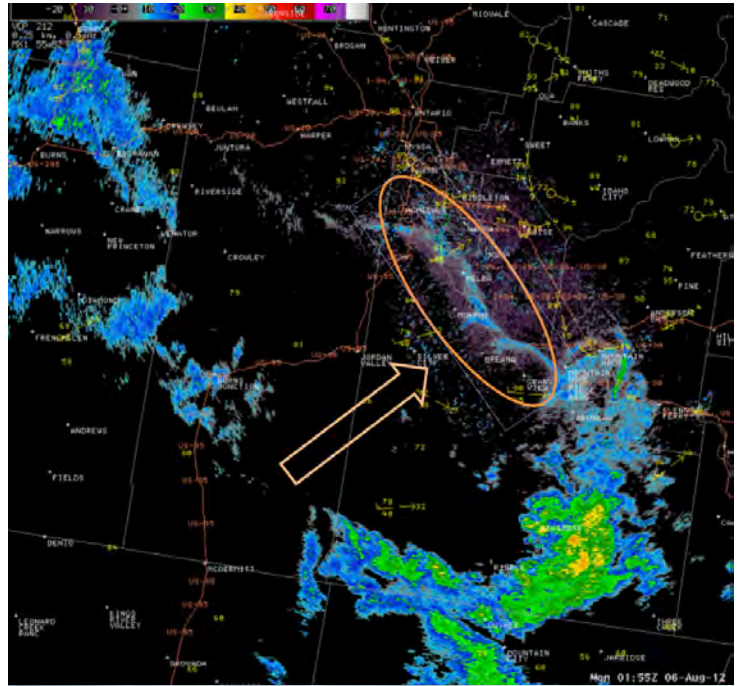
Changes in the amount of soil (lost or gained) over time can be assessed directly using a ruler relative to fixed pins (erosion bridges or nail-and-washer technique, e.g. Sankey et al. 2010). Past erosion can be inferred from soil “pedoderm” classifications and loss of the dark color of soil that is associated with organic matter (Burkett et al. 2015, Hasslequist et al. 2011), or from pedestalling of plants as soil is eroded from around their roots (Figure 2). Also, several direct but more sophisticated measurements of soil movement exist, including measurement of: 1) creep, with simple PVC pipe traps that have openings at the soil surface; 2) saltation, passively over longer times with collectors that trap sediment as air flows through them (e.g., BSNE or MWAC collectors, see Sankey et al. 2009) or actively in real-time with an electric sensor (e.g., Sensit©) connected to datalogger; and 3) suspended dust (particulate matter, usually 2.5 or 10 μm), with standard air-quality sensors (e.g., Met-One Esampler, Wagenbrenner et al. 2012). Erosion bridges and dust collectors (BSNE) have been used by agency field offices (BLM), while the other techniques listed above, as well as advanced remote sensing (Lidar), have been applied to a number of ESR projects by researchers.

Predicting where and when erosion risks are likely after disturbance

Factors to consider in assessing erosion risks include climate and weather/wind forecasts, overall site condition and resilience, upwind saltation sources, and any downwind concerns such as cities and intact vegetation (e.g., Miller et al. 2015). Erosion requires erosivity (wind, lack of plant cover), erodibility (loose, buoyant soil), and a sustained supply of erodible soil to the airstream. High winds are a function of local convection driven by temperature equilibration, thunderstorms, cold fronts or storm fronts, and regional weather patterns.

Vegetation cover protects the soil surface from the shear stresses of wind. Wind erosion usually occurs in the first nine to ten months after a wildfire when the soils are bare and the vegetation has yet to recover. Threshold amounts of plant cover for wind erosion have been determined for sagebrush steppe for only one site (Sankey et al. 2009), and several indicators suggest that the type of vegetation before and after fire is important. Sites where shrubs existed before fire produce the greatest erosion, but intact shrub stands provide significant protection from erosion (Sankey et al. 2012).

Figure 2. Effects of a haboob that occurred after the 560,000 acre Long Draw Fire in southeast Oregon and northwest Nevada in 2012. The top photo shows National Weather Surface RADAR imagery; dust is outlined by an ellipse and arrow shows path of travel and state boundaries are shown for reference. The middle photo is of the same haboob on the ground. The bottom photo shows burned and pedestalled sagebrush after several inches of soil, including all topsoil, were eroded in the month following burning (108,000 acre Jefferson Fire in south central Idaho in 2010).



Perennial grasses or cheatgrass that resprout or germinate in fall can shorten the number of months that soils are bare and exposed to wind after wildfire. High burn severity that results in high plant mortality increases erodibility, but mapping burn severity is challenging in sagebrush sites.

A wide range of soil types can be eroded, regardless of their sand or clay content, degree of particle aggregation (slaking, or aggregate breakdown in water), or “K” value assigned to the soil mapping unit in the USDA Natural Resources Conservation Service, Web Soil Survey and Soil Data Viewer (USDA NRCS 2013). Biotic soil crusts, physical crusts, and gravel or other highly aggregated soil surface conditions inhibit erosion (Ravi et al. 2011). However, sediment supply can increase as a result of factors that loosen soil, such as physical disturbance from hooves, tires, and rain or hail. Saturated soil surfaces have low wind erodibility. However, erodibility has complex responses to sub-saturated soil moisture, and can either increase or decrease following rain (Sankey et al. 2009).

Landscape-scale factors are very important for predicting wind erosion on rangelands. Erosion of sites that are otherwise stable can be induced if the site is bombarded by saltating particles originating upwind. Many rangelands are flat and have long wind fetches that lack hills, gullies, or waterways that disrupt the continuity and cascading of saltation flow. Thus, larger and flatter burned areas can exhibit greater erosion per unit ground area and have appreciable erosion events.

Several quantitative models are available to simulate and predict erosion, but probably are not practical for most field office or district level applications such as ESR projects. The USDA Wind Erosion Equation (WEQ), which crudely predicts erosion based on an index of soil erodibility, surface roughness, fetch, and vegetation cover, has been replaced by the more sophisticated and resolute Wind Erosion Prediction System (USDA NRCS 2014). These and other models require substantial parameterization efforts to validate them in burned sagebrush steppe. In semiarid ecosystems of the Great Basin a better approach may be coarser mapping of erosion risk that excludes non-erodible surfaces (e.g., gravel or firmly crusted soils) and uses topography and weather forecasts to predict high wind exposure and connectivity of wind and saltation flow.

Management actions

If wind erosion becomes appreciable on large burn areas, there is often little that can be done to control it, and so managers are left with focusing on 1) assessing where and when erosion risks are greatest, 2) avoiding actions that worsen the erosion and associated resource losses, and 3) protecting small areas or features from erosion. A primary management concern is often protecting staff and the public from dust storms, which reduces visibility and has caused highway

fatalities and respiratory stress. Post-fire management actions to address wind erosion, including deferral of soil-disturbing treatments, may also be rationalized based on protection of human health and safety or loss of seedlings. Use of rangeland seed drills, chaining or harrowing can impact the soil surface and influence erodibility, but longer term enhancement of perennial vegetation and reduced fire may offset the initial erosion risks posed by these treatments. Wind erosion may complicate the effectiveness of post-fire treatments, particularly through seed loss or transport of herbicide to non-target areas. Unfortunately, direct monitoring of soil stability and wind erosion is rare for post-fire treatment projects in the Great Basin. Also, few research projects have assessed whether or not soil-disturbing treatments implemented after fires have a net stabilizing effect on soils, and those projects show mixed results (Miller et al. 2012, Germino, in prep).

Based on the available information, several considerations are provided for implementing restoration/rehabilitation projects after wildfire in areas where wind erosion is a threat. Further assessment is needed to test their effectiveness across the Great Basin:

- It is important to consider net risks and benefits of actions that may destabilize soils (e.g., vehicle traffic on burned areas, soil disturbances associated with seeding). If soil disturbances are necessary, they can be guided by developing provisional wind-erosion risk maps.
- If seed drills are necessary, using imprinting or minimum-till drills and avoiding disking (particularly parallel with wind direction) may be advisable depending on site conditions.
- Use of species with larger and heavier seed, combined with seed burial, may result in less seed redistribution by wind after seeding. Also, perennials that tiller or form adventitious roots may be more adapted to shifting soils (e.g., western wheatgrass).
- On sites dominated by invasive annual grasses, a two-step process could be tested in areas with greater than ten inches of precipitation in which a sterile cover crop (e.g., winter wheat) is used to stabilize soils and preempt annual grasses, and then desirable perennials are later seeded into its stubble (Jones et al. 2015).
- In situations where drought may prolong erosion past the first post-fire year, rows of seeded or transplanted shrubs interspersed with bunchgrasses could be tested as semi-natural wind fences to reduce downwind erosion for small areas.
- Undesirable species like cheatgrass may quickly provide a net stabilizing benefit if left untreated after wildfire, although longer-term risks of low plant cover may result from drought, stand failure (die-off), probability of reburning, and fire spread beyond the impacted area.

- Artificial wind protection such as plastic snow fences or rows of straw bales can be cost effective for reducing erosion or drifting onto roads for areas up to a few acres. Fencing that allows plantings to establish may be particularly worthwhile.
- Soils may be stabilized locally through spraying polyacrylamide (FC2712) onto the surface or applying heavy mulches (wood chips), but these approaches are not well tested and are not economical over large areas.

The magnitude of wind erosion after large fires in the recent decade is a significant problem in the Great Basin, and information to help guide risk assessments and treatment plans is becoming available. Due to the lack of previous assessments and dearth of knowledge, most new management actions targeting wind erosion will have an experimental aspect to them. Monitoring and adaptive learning about wind erosion on ESR and related projects, including monitoring of soil movement and changes, are key steps forward.

Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Author

Matthew J. Germino
U.S. Geological Survey
Forest and Rangeland Ecosystem Science Center
mgermino@usgs.gov

References

Burkett L. M., B. T. Bestelmeyer, and A. J. Tugel. A field guide to pedoderm and pattern classes. Version 2.2 Accessed 1 March 2015, <http://jornada.nmsu.edu/files/FieldGuidePedodermPattern.pdf>

Hasselquist N., M. J. Germino, J. Sankey, N. Glenn, and J. Ingram. 2011. High potential for nutrient redistribution in aeolian sediment fluxes following wildfire in sagebrush steppe. *Biogeosciences* 8: 3649-3659.

Jones, R. O., J. C. Chambers, D. I. Board, D. W. Johnson, and R. R. Blank. 2015. [The role of resource limitation in restoration of sagebrush ecosystems dominated by cheatgrass \(*Bromus tectorum*\)](#). *Ecosphere*. 6: Article 107.

Miller R. F., J. C. Chambers, and M. Pellant. 2015. [A field guide for rapid assessment of post-wildfire recovery potential in sagebrush and piñon-juniper ecosystems in the Great Basin: Evaluating resilience to disturbance and resistance to invasive annual grasses and predicting vegetation response](#). Gen. Tech. Rep. RMRS-GTR-338. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Miller, M. E., M. A. Bowker, R. L. Reynolds, and H. L. Goldstein. 2012. [Post-fire land treatments and wind erosion – lessons from the Milford Flat Fire, UT, USA](#). *Aeolian Research* 7:29-44.

Ravi, S., P. D’Odorico, D. D. Breshears, et al. 2011. [Aeolian processes and the biosphere](#). *Reviews of Geophysics* 49:1-45

Sankey J., M. J. Germino, and N. F. Glenn. 2009. [Relationships of post-fire aeolian transport to soil and atmospheric moisture](#). *Aeolian Research* 1: 75-85

Sankey J., N. F. Glenn, M. J. Germino, A. Gironella, and G. Thackray. 2010. [Relationships of aeolian erosion and deposition with LiDAR-derived landscape surface roughness following wildfire](#). *Geomorphology* 119: 135-145

Sankey J., M. J. Germino, and N. J. Glenn. 2012. [Dust supply varies with sagebrush microsites and time since burning in experimental erosion events](#). *Journal of Geophysical Research-Biogeosciences* 117:1-13

Wagenbrenner N., M. J. Germino, B. Lamb, P. Robichaud, and R. Foltz. 2013. [Wind erosion from a sagebrush steppe burned by wildfire: Measurements of PM10 and horizontal sediment flux](#). *Aeolian Research* 10:25-36

Zobeck, T. M., G. Sterk, R. Funk, J. L. Rajot, J. E. Stout, and R. S. Van Pelt. 2003. [Measurement and data analysis methods for field-scale wind erosion studies and model validation](#). *Earth Surface Processes and Landforms* 28: 1163-1188.

Websites

USDA Natural Resources Conservation Service (USDA NRCS). 2013. Web Soil Survey. Online 5 Sept 2015; <http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm>.

USDA Natural Resources Conservation Service (USDA NRCS). 2014. Wind Erosion Prediction System. Online 5 Sept 2015; http://www.nrcs.usda.gov/wps/portal/nrcs/detail/wi/about/?cid=nrcs142p2_020798.