Soil and Water Resources Conservation Act
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Rangeland Conservation Analysis #4
Controlling Wind Erosion on Rangelands through Establishment and Maintenance of Healthy Plant Communities

The Issue

In the arid and semiarid parts of the country, where rangelands dominate, wind erosion can generate dust storms that cause significant health and property damage (fig. 1). In July 2011, for example, several dust storms known as haboobs hit southern Arizona, resulting in airport and highway closures, multi-vehicle accidents, and loss of life due to low visibility. High dust concentrations also negatively affect human health, particularly for those with respiratory ailments (Nordstrom and Hotta 2004; Smith and Lee 2003). Wind erosion produces particulate matter smaller than 10 micrometers (PM_{10}) that can be breathed deep into the lungs, causing or exacerbating respiratory disease. Wind erosion also degrades soil health. Soil carbon and nitrogen contents of wind-eroded sediments are often much higher than those of the remaining soil, as wind preferentially removes the lighter, soil organic matter-rich material at the surface (Lal 2003). These degraded soils support less plant production, reducing plant cover and further increasing risk of future wind and water erosion.

Wind erosion involves two types of soil movement. *Horizontal flux* is dominated by larger particles, most of which move less than a few inches above the soil surface. Horizontal flux does not affect air quality, but can result in significant redistribution of soil, including both loss and deposition as illustrated by the coppice dunes in fig. 1 (right image), as well as other impacts on rangeland plants. *Vertical flux* refers to the smaller particles that remain suspended and are transported long distances. Horizontal and vertical fluxes both degrade soil health by redistributing or removing topsoil. The 'Black Sunday' dust cloud of April 14, 1935, was the result of vertical flux carrying soil particles from the Midwest high into the atmosphere, where they were transported by westerly winds to the Nation's Capital. This, together with images of soil scoured from farm fields, helped prompt Congress to pass the Soil Conservation Act later that year (Helms 1990). The maps and results presented below are based on vertical flux because vertical flux is more directly related to the amount of dust in the air and the resultant human health and environmental impacts.

The rangeland wind erosion model (WEMO)[1] used for estimates in this report indicates that wind erosion can be a

[1] WEMO is a process-based wind erosion model designed for rangelands. It predicts horizontal dust movement (flux) based on wind velocity, the size-class distribution of intercanopy gaps, total plant cover, and threshold shear velocity, which is a function of soil erodibility. Vertical flux is calculated as a function of horizontal flux and a soil-specific factor (Okin 2008).

Figure 1. Dust storms in west Texas (left and center, photographs by Agricultural Research Service) and southern New Mexico (right, photograph by Nicole Hansen)

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significant cause of soil loss where vegetation cover is inadequate to protect the soil surface. This means that targeting conservation practices designed to address wind erosion could be most effective for those regions and soils where the potential for proportional and absolute reductions in current wind erosion are greatest, and where the costs of these interventions are relatively low. High returns on investments in conservation practices can also be realized where they reduce the risk of future increases in wind erosion.

Conservation Practices

Healthy plant communities offer the most cost-effective means of limiting dust storms and coincident wind erosion damage for rangelands. Consequently, conservation practices should be designed to increase plant cover, and to reduce the length of gaps between plants. Even minor changes in plant cover can significantly reduce average wind erosion on rangelands. Effects of increasing plant cover are maximized when new plants establish in the center of large gaps.

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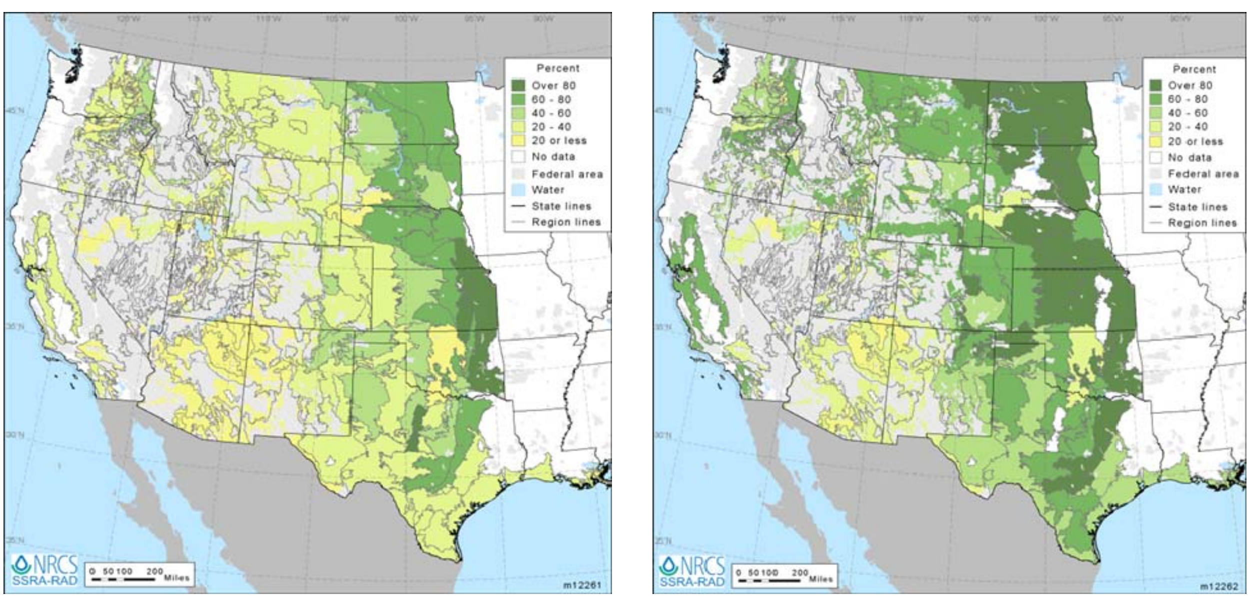
The most cost-effective practices for increasing plant cover vary among regions, soils, and plant communities, and their effectiveness depends on the state of the ecosystem relative to its ecological potential. Short-term increases in plant cover during the periods of greatest risk are most rapidly achieved through relatively simple changes in grazing timing, frequency, and intensity, targeting the most wind-erodible soils. Because plant cover declines during drought periods, destocking early in drought can be very effective. These changes in grazing management can also result in long-term increases in average plant cover. In areas where shrub invasion increases the size of the gaps between plants, such as occurs in much of the Southwest, shrub control can have positive long-term impacts. A well-developed conservation plan should take into account landscape-scale variability in current wind erosion and in the potential reductions that could be achieved by increasing plant cover in different parts of the landscape.

Proportional Reductions in Wind Erosion: The Great Plains

Increasing plant cover provides the greatest *proportional* reduction in the Great Plains (fig. 2), where plant cover is already high and current rangeland wind erosion is relatively low. Where plant cover is high, gaps are fewer and shorter, so adding vegetation closes a greater percentage of the remaining gaps. In many areas of the Great Plains, it is possible to increase average plant cover by over 10 percent (as a proportion of existing cover[2]). Depending on current soil and vegetation factors, this can reduce dust flux by over 50 percent.

[2] For an area that currently has 60 percent plant cover, a 10 percent relative increase would result in 66 percent of the area having plant cover.

Figure 2. Percent reduction in vertical dust flux for 10 percent (left) and 25 percent (right) increases in plant cover



Source: USDA-NRCS National Resources Inventory Rangeland Regional Assessment

Absolute Reductions in Wind Erosion: The Southern Great Plains and the Southwest

While the relative reductions in wind erosion tend to be lower in the arid and semiarid southern Great Plains and the Southwest, the *absolute* reductions can be much greater due to greater overall susceptibility of these lands to wind erosion (fig. 3). In many places in these regions, soil is exposed in large unvegetated gaps between plants. Therefore, even a relatively small increase in cover can significantly reduce wind erosion if the plants establish in the middle of the gaps, thereby reducing gap size (Li et al. 2007). This is because large (over 3 feet long) gaps between plants are the source of most windborne sediment. Achieving increased plant cover can, however, be more challenging in the Southwest due to the difficulty in establishing plants in areas of low and variable precipitation.

Dealing with Drought

Another cost-effective strategy is to help maintain plant cover during drought by reducing grazing pressure (destocking). Plant cover is often reduced during drought even without grazing due to plant mortality, making landscapes more susceptible to wind erosion. Management plans on highly wind erodible soils should focus on reducing grazing during these critical periods. Planting drought-adapted species to increase plant cover can also help ensure that plant cover is maintained during droughts. In addition to impacting vegetation cover, grazing and other activities disturb the soil surface and make it more susceptible to wind erosion (see "*Soil Surface Disturbance*" below).

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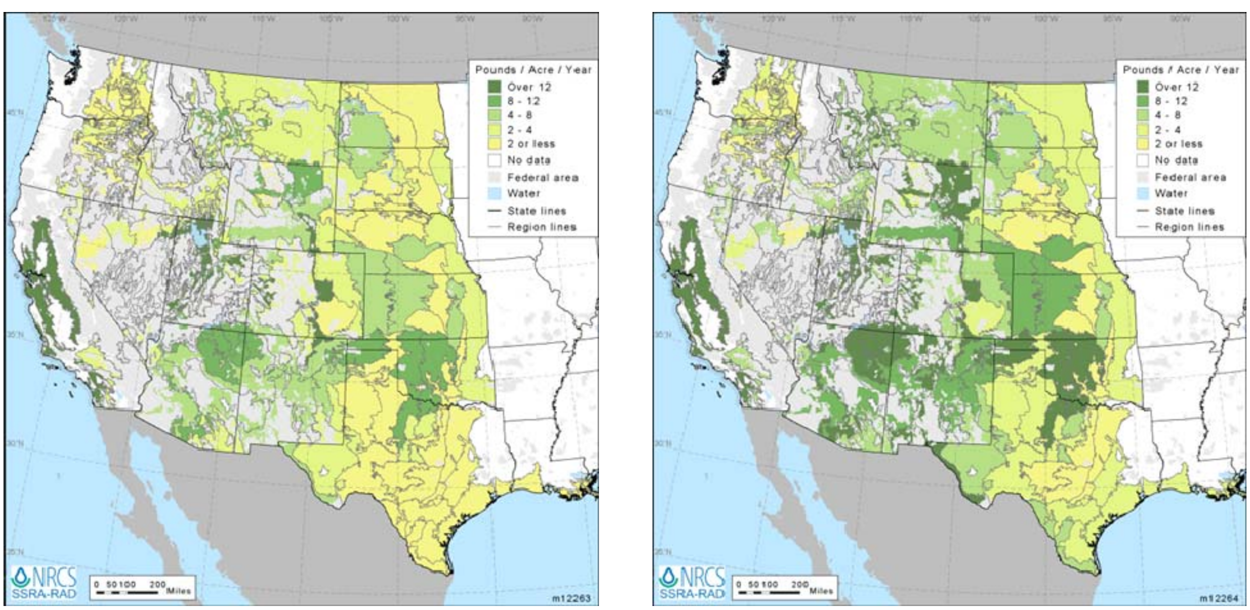
Reducing the Risk of Future Increases in Wind Erosion

Sometimes, the most cost-effective approach is to develop management plans and systems that reduce the risk of significant, long-term reductions in plant cover. A 30-percent decrease in cover can increase dust emissions by a factor of 5 to 10 or more (fig. 4). Drought, overgrazing, wildfire, and changes in species composition (e.g., shifts from grass- to shrub-dominated plant communities) can all increase the amount and size of patches of bare ground exposed to wind. Conversion of Great Plains soils to cultivated agriculture dramatically increases wind erosion risks, as illustrated by the Dust Bowl. Maintaining residue cover is critical but more challenging when these more arid soils are cultivated. Improved agricultural practices can reduce these risks by increasing soil cover and surface roughness (Stout and Lee 2003; Nordstrom and Hotta 2004) but still provide far less cover than perennial rangeland vegetation, particularly during droughts when crop failures occur. This was seen recently during the dust storms that resulted from the large-scale drought in Texas in 2011.

Soil Surface Disturbance

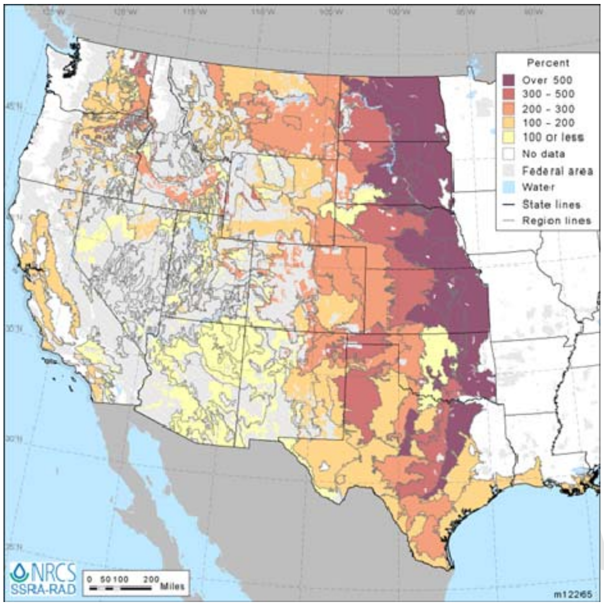
Soil surface disturbance, another factor that can be mitigated, has a significant impact on erosion potential. Even

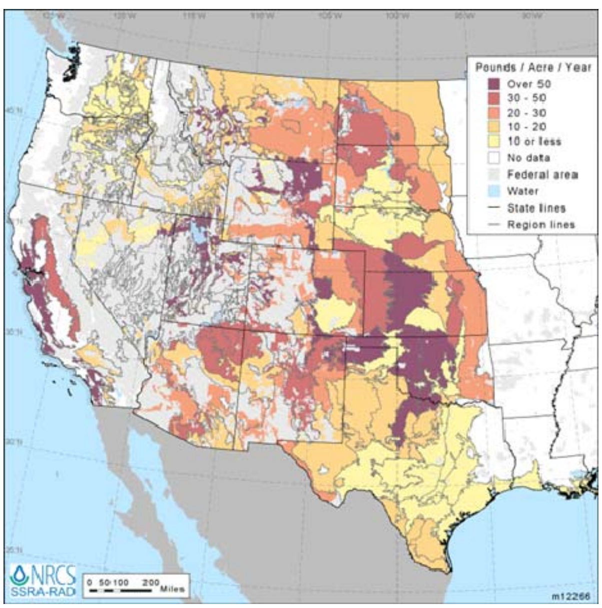
Figure 3. Potential *absolute* reduction in dust emission (vertical dust flux) by wind from non-Federal rangelands if vegetative cover were increased by 10 percent (below left) or 25 percent (below right) through adoption of appropriate conservation practices.



Source: USDA-NRCS National Resources Inventory Rangeland Regional Assessment

Figure 4. Relative (top) and absolute (bottom) increases in dust flux by wind on non-Federal rangelands if vegetative cover were reduced by 30 percent through any combination of drought, overgrazing, wildfire, or changes in species composition





Source: USDA-NRCS National Resources Inventory Rangeland Regional Assessment

activities such as grazing, off-road vehicle use, and oil and gas exploration disturb physical and biological soil crusts and can increase soil erodibility, leading to increases in dust emission that can be either long- or short-lived. In addition, although post-fire rehabilitation activities can reduce wind erosion in the long term by increasing vegetation cover, they are also associated with large increases in risk associated with wind erosion, especially when they reduce the cover of slow-growing biological soil crusts (Miller et al. 2010). Even where plant cover cannot be increased because of limited precipitation, managing the spatial distribution of plants can reduce wind erosion by reducing the size of bare ground gaps between plants (Okin et al. 2006; Okin et al. 2009). This can be achieved, for example, by restoring shrub-dominated plant communities to grasslands, as the Bureau of Land Management is doing on over 1 million acres through its “Restore New Mexico” program. This approach is limited by site-specific ecological potential. Some areas, including much of the Mojave Desert and parts of the Chihuahuan and Sonoran Deserts, are too dry or the soils are too poor to support perennial grasslands. In these areas, maintaining the existing shrub community while minimizing surface disturbance are often the best available strategies.

Conclusion

Wind erosion can be minimized by reducing soil disturbance, maintaining existing plant cover, and, where possible, increasing plant cover. Investments in conservation practices will have the greatest impact on soils that are highly susceptible to wind erosion where current plant cover is below the ecological potential. Increasing plant cover is most effective if it results in reduced intercanopy gap size—in other words, establishing new plants between, rather than adjacent to, existing plants.

In general, priority lands for increasing cover and gap size include those with soils that are highly vulnerable to wind erosion and that have plant cover below the ecological potential. Rangeland Ecological Site Descriptions (ESDs) describe the ecological potential for ecological sites, which are groups of soils with similar potential and response to management. ESDs identify potential thresholds, which are relatively irreversible transitions among ecological states (groups of plant communities). Degraded states often have increased susceptibility to wind erosion (Miller et al. 2011; Li et al. 2007). ESDs include descriptions of the types of management and other factors, such as fire and extreme drought, which can accelerate degradation. Priority acreage should not be so degraded as to have crossed an ecological threshold, as this would lessen the chances of success and lower the potential benefits. Priority acreage should have a high probability of recovery with relatively simple changes in management, such as improved grazing management.

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