Enhancing Wind Erosion Monitoring and Assessment for U.S. Rangelands

By Nicholas P. Webb, Justin W. Van Zee, Jason W. Karl, Jeffrey E. Herrick, Ericha M. Courtright, Benjamin J. Billings, Robert Boyd, Adrian Chappell, Michael C. Duniway, Justin D. Derner, Jenny L. Hand, Emily Kachergis, Sarah E. McCord, Beth A. Newingham, Frederick B. Pierson, Jean L. Steiner, John Tatarko, Negussie H. Tedela, David Toledo, and R. Scott Van Pelt

On the Ground

- Wind erosion is a major resource concern for rangeland managers because it can impact soil health, ecosystem structure and function, hydrologic processes, agricultural production, and air quality.
- Despite its significance, little is known about which landscapes are eroding, by how much, and when.
- The National Wind Erosion Research Network was established in 2014 to develop tools for monitoring and assessing wind erosion and dust emissions across the United States.
- The Network, currently consisting of 13 sites, creates opportunities to enhance existing rangeland soil, vegetation, and air quality monitoring programs.
- Decision-support tools developed by the Network will improve the prediction and management of wind erosion across rangeland ecosystems.

Keywords: dust, air quality, soil health, network, Long-Term Agroecosystem Research.

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Wind erosion is a major contributing factor to rangeland soil degradation. The process is highly sensitive to variability in soils, weather, and climate, which influence wind erosivity, protective vegetation cover levels, and soil susceptibility to entrainment and transport downwind (see Box 1 for definitions of terms). Wind erosion is also highly sensitive to patterns of land use and land management, which influence vegetation cover and soil erodibility. While croplands have been the focus of wind erosion research in the United States for many years, wind erosion impacts in U.S. rangelands and the effects of management practices on erosion rates are now widely recognized. Episodes of drought and changing land use pressures have significantly impacted dust emissions following the expansion of ranching and agriculture into the American West.[1] Dust concentrations monitored across the United States (1995–2014) show a trend of increasing dustiness, particularly in the southwest.[2] The Dust Bowl of the 1930s is perhaps the most dramatic example of how inappropriate management practices, unchecked during intense drought, can result in massive regional wind erosion.[3]

Locally, wind can redistribute and erode soils resulting in the loss of fine soil particles and resources such as nitrogen, phosphorous, and carbon (Fig. 1), thereby impacting soil quality and soil health. These changes can influence ecosystem dynamics and alter provision of ecosystem services. Dust emissions may be localized or associated with dust storms that can travel thousands of kilometers, impacting biogeochemical cycles,[5] the hydrologic cycle, and climate.[6] Wind erosion and dust emissions also directly impact human systems. For example, dust degrades air quality, transports fungal spores (e.g., causing Valley fever) and aggravates respiratory diseases affecting human health,[7] and reduces visibility impacting transportation and tourism (Fig. 2). Dust deposition on snowpack in mountainous areas can change the surface albedo and increase the rate of snowmelt, affecting runoff and water supplies.[8] Managing wind erosion and dust impacts has become a significant challenge for natural resource managers because 1) the impacts are so diverse and widespread, and 2) changing land use pressures make wind erosion difficult to anticipate and manage or avoid.

Many land uses and natural disturbances in U.S. rangelands can increase wind erosion depending on how they are managed. Livestock grazing, oil, gas and alternative energy development, graded road networks, off-road vehicles, abandonment of croplands due to changing water availability or economic factors, expansion of exurban developments, and

Box 1
Definitions of Terms Used to Describe Wind Erosion Processes

Aeolian – processes relating to or arising from the action of the wind.
Entrainment – to lift and transport (soil grains) by the flow of a fluid (the wind).
Dust emission – the entrainment of fine soil particles and aggregates (dust), typically regarded as being smaller than 62.5 μm in diameter (e.g., silt and clays).
Dust deposition – the settling of dust particles to the land surface under the force of gravity or in rainfall.
Particulate matter (PM) – solid and liquid particles in the air, comprising the particulate portion of aerosols. PM_{10} particles have an aerodynamic diameter < 10 μm and may be inhalable.
Saltation – the movement of soil grains and aggregates along the soil surface in a leaping or hopping motion, typically larger than 62.5 μm and within ~1 m of the surface.
Sediment mass flux – the mass of soil grains in saltation and/or suspended in the air (dust) per unit length or area per unit time; often separated into saltation ($g\ m^{-1}\ s^{-1}$) and dust ($g\ m^{-2}\ s^{-1}$) components.
Wind erosion – the net loss of soil from an area, considered the sum of all saltation and dust emission out of the area (loss) and deposition (gain) of sediment into the area from upwind sources (e.g., $t\ ha^{-1}$).

wildfire are examples of common land use change and disturbances that can increase wind erosion. These activities often have overlapping and competing management needs that must be met within policy and regulatory frameworks that determine resource condition, erosion targets, and air quality standards (e.g., 1977 Clean Air Act and National Ambient Air Quality Standards). Routine monitoring and assessment of wind erosion and dust emission can help inform resource management and policy decisions to help minimize wind erosion.

In this paper we 1) identify strengths, weaknesses, and opportunities for existing programs that contribute to wind erosion monitoring and assessment in U.S. rangelands, and 2) address the role of the National Wind Erosion Research Network[8] as a mechanism for enhancing wind erosion monitoring and assessment capabilities. The Network can provide new opportunities for i) conducting basic research on wind erosion and dust emission processes at different scales in space and time, ii) development of new wind erosion monitoring and assessment approaches, and iii) improvement in decision-support tools for the prediction and management of wind erosion impacts across rangeland ecosystems.

Wind Erosion Monitoring and Assessment in U.S. Rangelands

Although historically there has been no centralized effort to monitor wind erosion, other programs provide information that can be used to support wind erosion monitoring and assessment in U.S. rangelands. For example, the Bureau of Land Management (BLM) Assessment, Inventory, and Monitoring (AIM) Strategy[10] and the Natural Resources

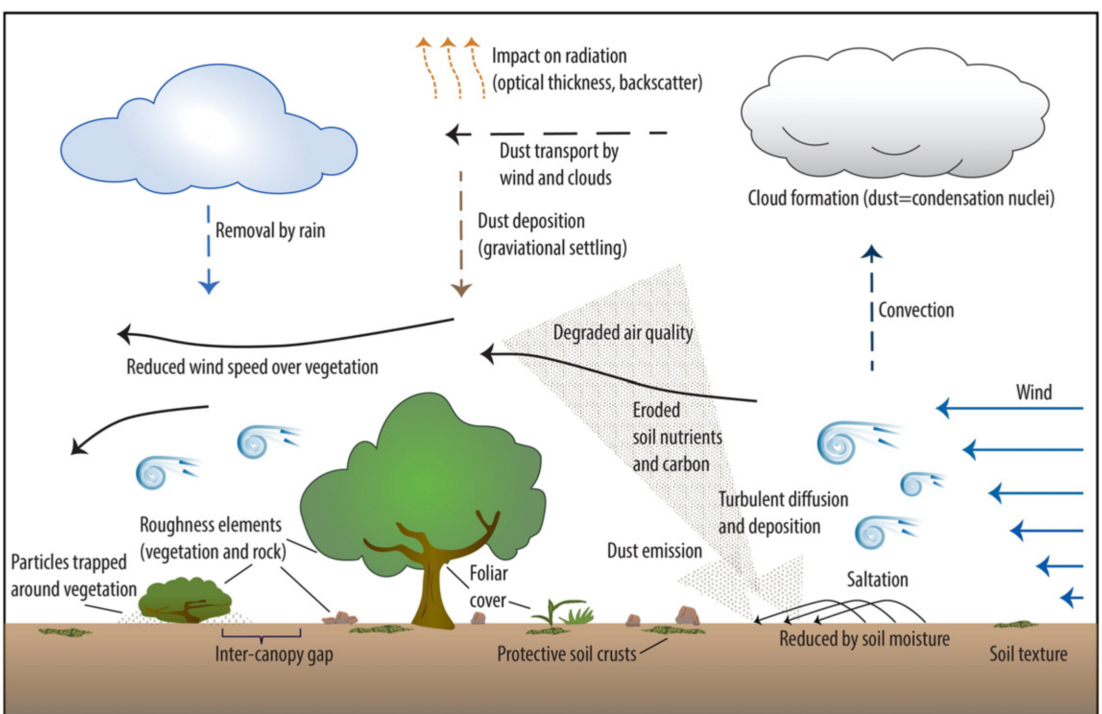


Figure 1. Schematic showing the physical processes that influence wind erosion and dust emission (after Lu and Shao[4]). Core indicators of the surface resistance to wind erosion include the amount of foliar cover, the size and distribution of intercanopy gaps, vegetation height, and soil surface properties such as texture and physical and biological crust cover.

Figure 2. A haboob rolling into Phoenix, Arizona on 21 August 2016. Haboobs in the southwest United States are typically intense localized events that occur in summer when thunderstorms collapse, producing strong winds that gust outward from the storm and lifting a thick cloud of dust. Traversing urban areas, haboobs can disrupt traffic, close airports, and present a health risk to people with allergies or respiratory problems. Photo courtesy of R. Vermillion.

Conservation Service's (NRCS) National Resources Inventory (NRI[11]) collect data that can be used to estimate the in situ susceptibility of U.S. rangelands to wind erosion. These programs employ standardized data collection methods[12] to monitor vegetation properties, such as foliar cover, height, and canopy gap size and distribution, which influence wind erosion. Rangeland health assessments implemented by the BLM, NRCS, and other federal and state agencies and private organizations provide additional indicators of the presence of active and historic wind erosion.[13]

The strength of the AIM and NRI monitoring programs lies in the broad utility of their data, which enables simultaneous assessment for multiple management objectives from the same dataset (e.g., for AIM – habitat quality, grazing permit renewal, and restoration effectiveness). The programs enable focused monitoring in areas of interest, such as restoration treatments, for which wind erosion may become a problem. The spatially balanced and stratified-random sampling designs used by AIM and NRI also enable point estimates of wind erosion based on their data to be scaled up for landscape and regional scale assessments (e.g., 2011 NRCS Resources Conservation Act Appraisal[i]). Although these monitoring programs have enabled basic and broad-scale wind erosion assessments, a weakness remains in their undersampling of the factors controlling wind erosion, which have large variability in space and time. As neither of the programs actively measures wind-driven soil loss or dust emission, field-based wind erosion assessments in the United States have tended to rely on qualitative interpretation of vegetation indicators and observations within Rangeland Health assessments.[13] These approaches can be inaccurate as wind erosion is a complex process that responds nonlinearly to wind conditions and vegetation and soil properties. Quantifying wind erosion rates is necessary in addition to vegetation measurements to provide site-level information to assess the effectiveness of management on U.S. rangelands.

Atmospheric aerosol and particulate matter (PM) loads are measured across the United States by multiple groups with interests in air-quality monitoring and regional dust forecasting. The Interagency Monitoring of Protected Visual Environments (IMPROVE) is a network of aerosol monitoring sites to establish PM and visibility tracking in national parks and wilderness areas. IMPROVE data have been used to evaluate patterns and trends in $PM_{2.5}$ (particulate matter with aerodynamic diameter <2.5 μm) dust concentrations across the United States (Box 2), providing some insights into regional climate drivers of dust emission.[2] However, IMPROVE and other state-level dust monitoring programs do not provide a direct connection between air quality and site-level management actions in eroding areas.

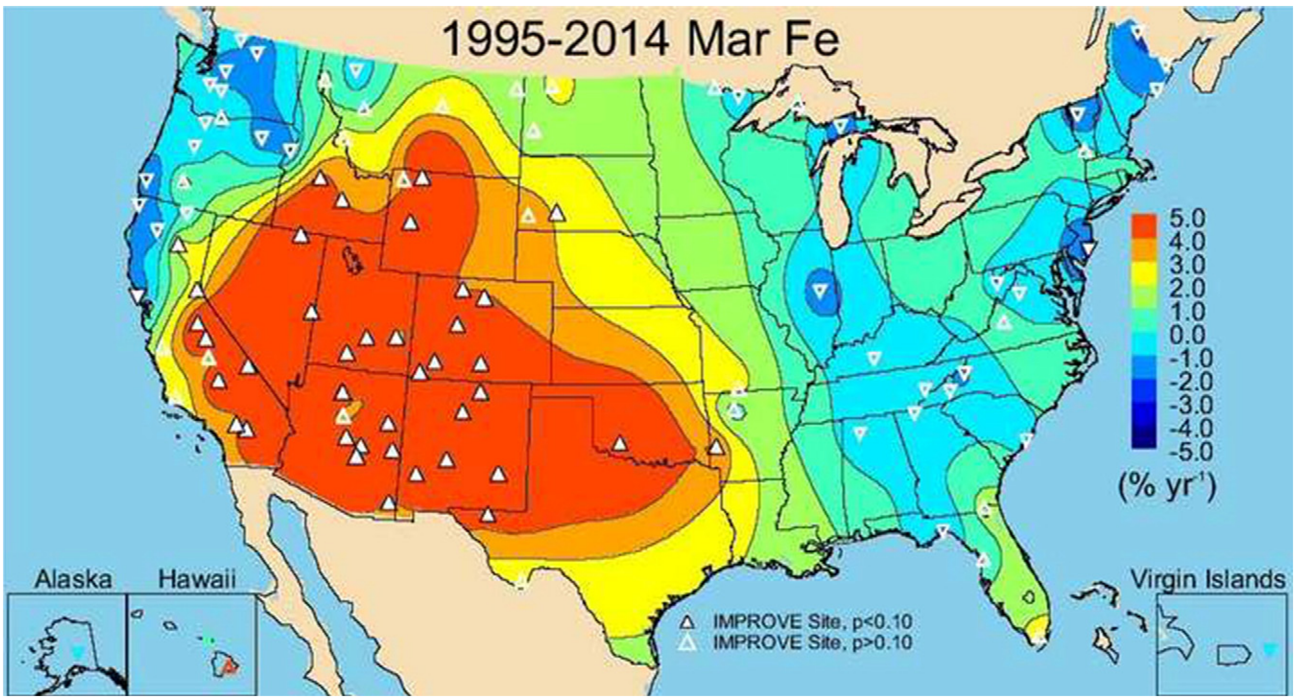
Aerosol monitoring by the Aerosol Robotic Network (AERONET) and Environmental Protection Agency (EPA) provide data that have been used to test dust-forecasting models such as the Dust Regional Atmosphere Model (DREAM[7]). While these forecasting models support air quality assessments for health and transportation applications, the models do not represent the impacts of land use activities on wind erosion in sufficient detail to inform land management. The utility of existing dust models for wind erosion assessments has been further limited by their coarse spatial resolutions (e.g., > 1–100 km) and lack of sensitivity to changes in soil and vegetation conditions.

Thus, a large disconnect remains between rangeland monitoring programs like AIM and NRI, aerosol monitoring

[i] Read more about the 2011 Soil and Water Conservation Act (RCA) Appraisal at: https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/rca/.

Box 2
IMPROVE Trends in Spring Fine Dust Concentrations (1995–2014)

Fine mineral dust concentrations impact air quality, visibility, transport, and potential deposition of dust on snow and therefore hydrology in mountainous regions (e.g., Rocky Mountains). Long-term trend analyses (1995–2014) of IMPROVE monitoring data[2] revealed that concentrations are highest in the southwestern United States during spring (March, April, and May) due to wind patterns that transport dust across the region. The data also showed regionally extensive positive trends (% yr^{-1}) in iron (Fe, a surrogate for dust) across the western United States in March, and less so in April or May. Increased March concentrations reflected an early onset of the spring dust season over the period by approximately 10 days on average across the region. The trend was associated with large-scale climate variability (i.e., the Pacific Decadal Oscillation and El Niño Southern Oscillation) that produced drier conditions, more barren land surfaces, and higher wind speeds in March. Knowledge of these patterns supports management of wind eroding areas and the development of dust early warning systems.



networks like IMPROVE and AERONET, and dust models that can support wind erosion assessments. Together, monitoring programs and models have the potential to provide new information about spatial patterns and temporal trends in wind erosion, how much dust is emitted into the atmosphere, and the climate and land management drivers of wind erosion. Connecting these programs could significantly enhance wind erosion monitoring and assessment capabilities in the United States.

Opportunities therefore exist for improving wind erosion monitoring and assessment in U.S. rangelands that build on the strengths and overcome weaknesses of existing efforts. In particular, modeling can be used to integrate multiple types of monitoring data (e.g., AIM, NRI, aerosol monitoring programs, and remote sensing) for wind erosion assessments. To realize this opportunity, three challenges must be met. First, improved models are required that can represent land management, soil, vegetation, and wind erosion interactions that occur in rangelands. Second, these models will need to be tested under the range of conditions (landscapes and management strategies) to which they will be applied. Thus, standardized long-term measurements of wind erosion, dust emission, and their controlling factors are needed to support model applications. Third, to be successful, these activities all require improved coordination and collaboration among the various stakeholders including scientists, land users, and resource management agencies. The National Wind Erosion Research Network[ii] was established in 2014 to tackle these requirements and enhance wind erosion monitoring and assessment capabilities in the United States.

National Wind Erosion Research Network Objectives and Sites

The National Wind Erosion Research Network is a multipartner collaboration that addresses the need for improved monitoring and assessment tools to meet wind erosion management challenges in the United States, while

[ii] Access the National Wind Erosion Research Network at: http://winderosionnetwork.org.

providing information that can be used to improve wind erosion models globally. The Network has three primary objectives:

1. Provide standardized data to support understanding of wind erosion processes across land use and land cover types and for different management strategies;
2. Support the development of open-access technologies to assess wind erosion and dust emission that integrate new data sources and complement existing monitoring programs; and
3. Encourage collaboration among scientists, resource managers, and policymakers to develop opportunities for enhancing wind erosion monitoring and assessment for scientific and land management applications.[9]

Partners in the National Wind Erosion Research Network include the U.S. Department of Agriculture's Agricultural Research Service (ARS) and NRCS, the Department of the Interior's BLM and U.S. Geological Survey (USGS), the Department of Defense (DoD), and The Nature Conservancy (TNC). The National Wind Erosion Research Network is part of the ARS Long-Term Agroecosystem Research (LTAR) network,[14] but is not limited to LTAR sites. Being part of LTAR enables incorporation of wind erosion research into LTAR experiments to evaluate options for building sustainable agricultural systems, including both rangelands and croplands. Network coordination is provided by the ARS Jornada Experimental Range in Las Cruces, New Mexico. The diverse Network partnership enables sharing of knowledge and data among sites and agencies about how climate and land management influence wind erosion patterns and processes across the United States. To support knowledge sharing, the Network has an open-access data policy and provides a coordinated infrastructure to build research collaborations.

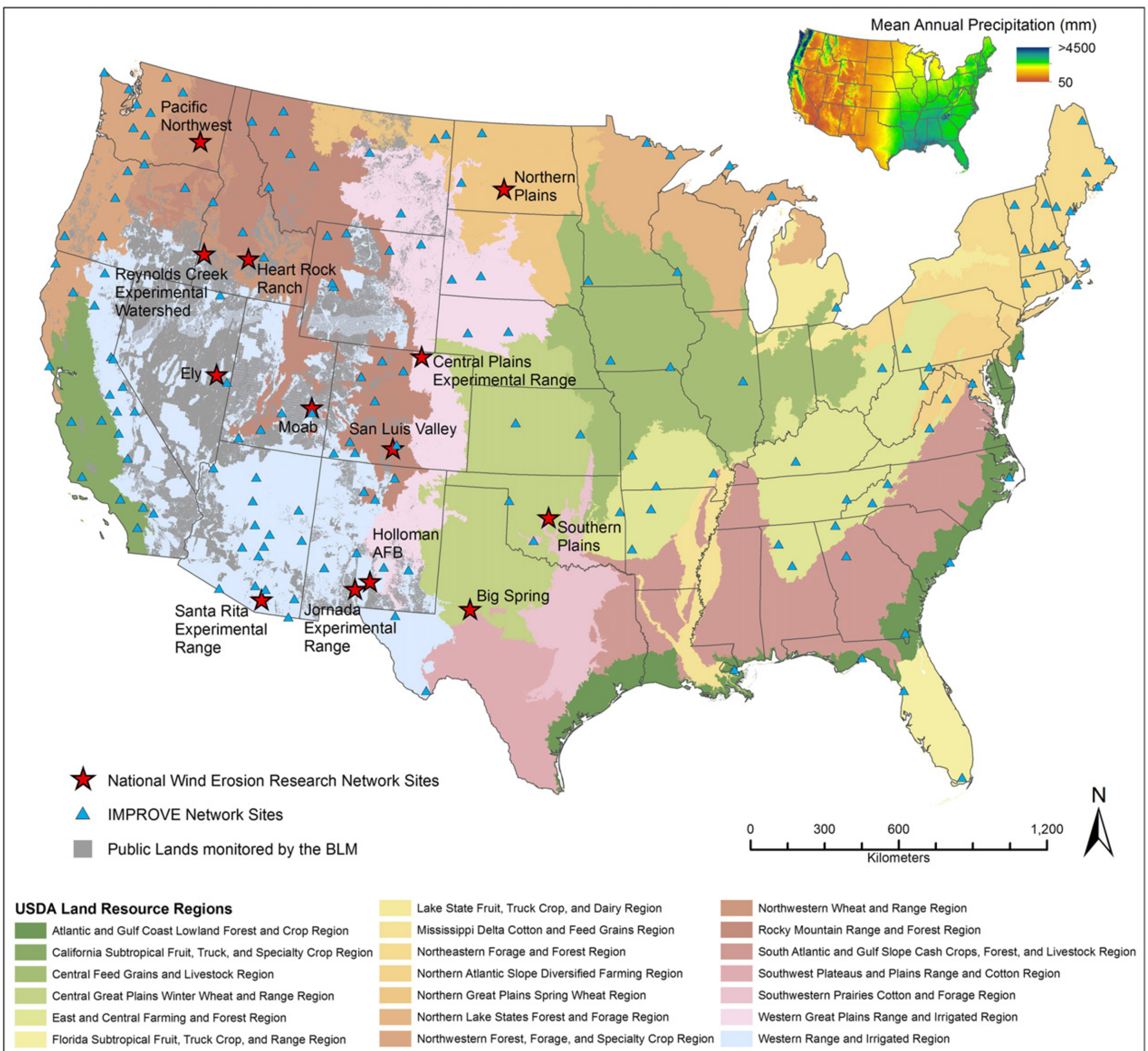


Figure 3. Locations of the current National Wind Erosion Research Network sites and Interagency Monitoring of Protected Visual Environments (IMPROVE) network sites across the contiguous United States. National Wind Erosion Research Network sites are operated across a range of Land Resource Regions. Inset map shows mean annual precipitation.[15]

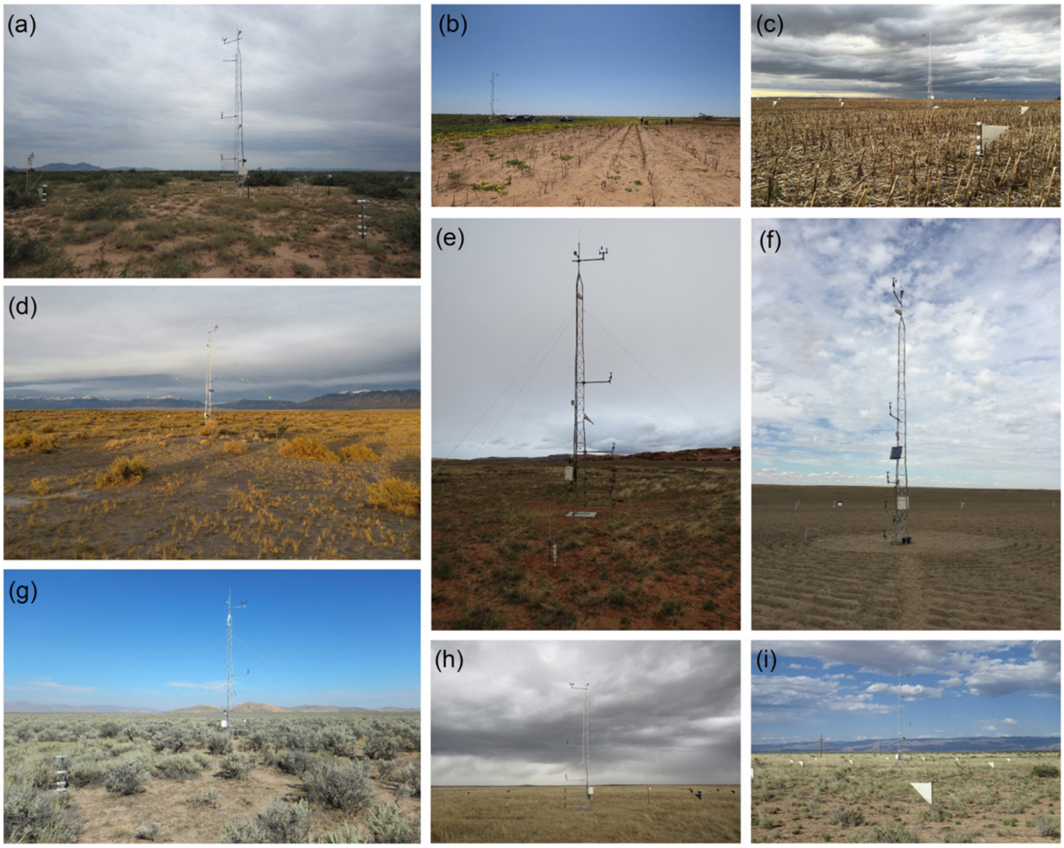


Figure 4. National Wind Erosion Research Network sites including: **a**, Jornada Experimental Range, New Mexico; **b**, Big Spring, Texas; **c**, Northern Plains, North Dakota; **d**, San Luis Valley, Colorado; **e**, Moab, Utah; **f**, Pullman, Washington; **g**, Heart Rock Ranch, Idaho; **h**, Central Plains Experimental Range, Colorado; and **i**, Holloman Air Force Base, New Mexico. Table 1 describes the Network site instrumentation.

Currently, 13 sites contribute to the National Wind Erosion Research Network (Fig. 3). These sites represent a diversity of soil types, vegetation communities (plant species composition, growth form, and distribution), and land use activities across the central and western United States. Site locations also compliment those of the existing AIM, NRI, and IMPROVE monitoring networks. Land uses around the Network sites include crop and rangeland livestock production, energy development (oil, gas, and solar), recreation (e.g., off-road vehicles), and agricultural research. Including such diverse land uses and land cover types will enable the Network to obtain new insights to wind erosion processes and, at the site-scale, the effects of climate and land management practices (Fig. 4). In doing so, the Network will produce data that can be used to support broader (e.g., landscape and regional scale) research and modeling across agroecological systems. For example, lessons learned at cropland sites can inform management of rangeland sites that employ similar tools (e.g., disking, blading, and drilling) for vegetation restoration, reclamation, and management, and to help assess the impacts of land use change. Additional sites may be added to the Network to fill gaps in our understanding of wind erosion processes across land cover types and to support wind erosion management and model applications.

Standardized Methods to Complement National Monitoring Programs

The National Wind Erosion Research Network implements a sampling design and employs data collection methods at all sites that follow a standard methods protocol.[16] The protocol defines procedures for 1) site characterization, 2) site design and layout, 3) meteorological and wind erosion threshold measurements, 4) measurement of sediment mass fluxes and wind erosion, and 5) land surface measurements, including vegetation, soils, and land management. Methods standardization ensures both rigor and consistency in data collected across the diverse sites sampled by the Network. Standardization also ensures that Network measurements and data are compatible with those of existing rangeland monitoring programs.[10]

All vegetation indicators adopted by the Network (Table 1) have the same core measurement methods as the AIM and NRI programs, allowing for cross-program data sharing.[12] This data compatibility will also enable analyses of wind erosion processes using Network data, and models supporting those analyses, to be directly applicable to the extensive monitoring data already collected by the BLM and NRCS.[9] In addition to maintaining compatibility, the AIM program and the Network both utilize the same field methods calibration procedures and the same data quality assurance and quality

Table 1. Standardized indicators, data collection methods, and instrumentation for the National Wind Erosion Research Network

Type	Indicator	Method/Instrument	Sampling frequency
Vegetation	Amount of bare ground*	Line-point intercept (LPI)	Four times per year (minimum), to coincide with vegetation phenology and site management
	Vegetation composition*		
	Non-native invasive species*		
	Plant species of management concern*		
	Vegetation height*	Height at selected line-point intercept (LPI) points	
	Size and distribution of intercanopy gaps*	Canopy gap intercept	
Soil	Loose erodible material	Line-point intercept (LPI)	
	Physical and biological* crust cover		
	Soil surface texture*	Collection of physical samples for laboratory analysis of dry (minimally dispersed) and wet (fully dispersed) particle size distributions	Once, at site establishment
	Soil oriented roughness	Measurement of soil ridge height, ridge spacing, and ridge azimuth	Event basis, following management
Meteorological	Wind direction	Wind vane mounted at 10 m height	Sampling at 1 Hz, data logged at 1 min resolution
	Atmospheric stability	Derived from air temperature gradient (2 - 10 m) measured with three temperature sensors	
	Aerodynamic roughness length (z_0)†	Derived from wind speed profile measurements (0.5 - 10 m) with six cup anemometers	
	Wind friction velocity (u_*)†		
	Relative humidity	Relative humidity sensor mounted at 4 m height	
	Precipitation	Tipping bucket rain gauge	
Sediment transport	Soil entrainment threshold (u_{*t})†	Sensit saltating mass flux sensor	
	Horizontal (saltation) sediment mass flux	Modified Wilson and Cooke (MWAC) type passive sediment samplers (27)	Monthly collection
	Vertical (dust) sediment mass flux	Light-scattering laser photometers (2)	Sampling at 1 Hz, data logged at 1 min resolution
	Dust deposition	Marble pan type passive sediment samplers (3)	Four times per year (quarterly)

(continued on next page)

Table 1 (*continued*)

Type	Indicator	Method/Instrument	Sampling frequency
Site condition	Time-lapse photography	Game camera	Six photographs per day, on the hour around solar noon (10:00 AM to 3:00 PM)

* Core Indicators for the AIM and NRI monitoring programs.
† See the Landscape Toolbox for an explanation of terms: http://www.landscapetoolbox.org/winderosionterms.

control processes. Standardized meteorological and sediment mass flux instrumentation and measurement methods adopted by the Network generally follow World Meteorological Organization (WMO) standards and conventions within the aeolian research community.

Adopting existing standardized methods allows the Network to address sampling design challenges that may not be possible in a management context. A challenge for both scientists and managers is to understand the variability in wind erosion due to different (and changing) vegetation cover types and wind conditions. To address this issue, the Network uses a stratified-random sampling design with 27 sediment sampler masts to measure aeolian sediment mass flux profiles (Fig. 5).[9] This design enables quantification of the spatial variability in sediment fluxes and provides statistically robust change detection over time.

To better understand how land cover and land management affects wind erosion, vegetation and soil surface characteristics are measured along three 100-m transects. The transect design enables comparison of vegetation foliar cover and the size and distribution of canopy gaps with the measured patterns of wind erosion. The spatial arrangement and structure (e.g., height) of vegetation are important controls on wind erosion rates and their spatial variability. Developing a better understanding of this relationship will be important for improving assessment tools and management options. The Network transect data can also be related to remote sensing estimates of vegetation cover and structure at different scales (cm to m) that can be integrated into models to support wind erosion assessments. Overall, the Network sampling design is intended to produce core data needed to build knowledge about wind erosion processes across land cover types, under diverse climates and management, while providing information to support development and application of wind erosion and dust emission models.

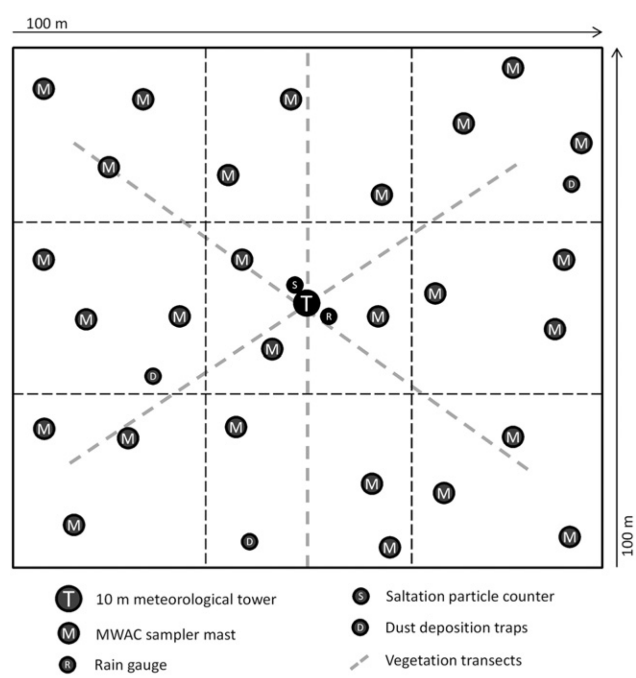


Figure 5. Illustration of the National Wind Erosion Research Network sampling design showing the virtual grid used to stratify sampling of the horizontal sediment mass flux (Modified Wilson and Cooke samplers), three 100 m transects for measuring indicators of vegetation and soil surface conditions, and the central meteorological tower (after Webb et al.[9]).

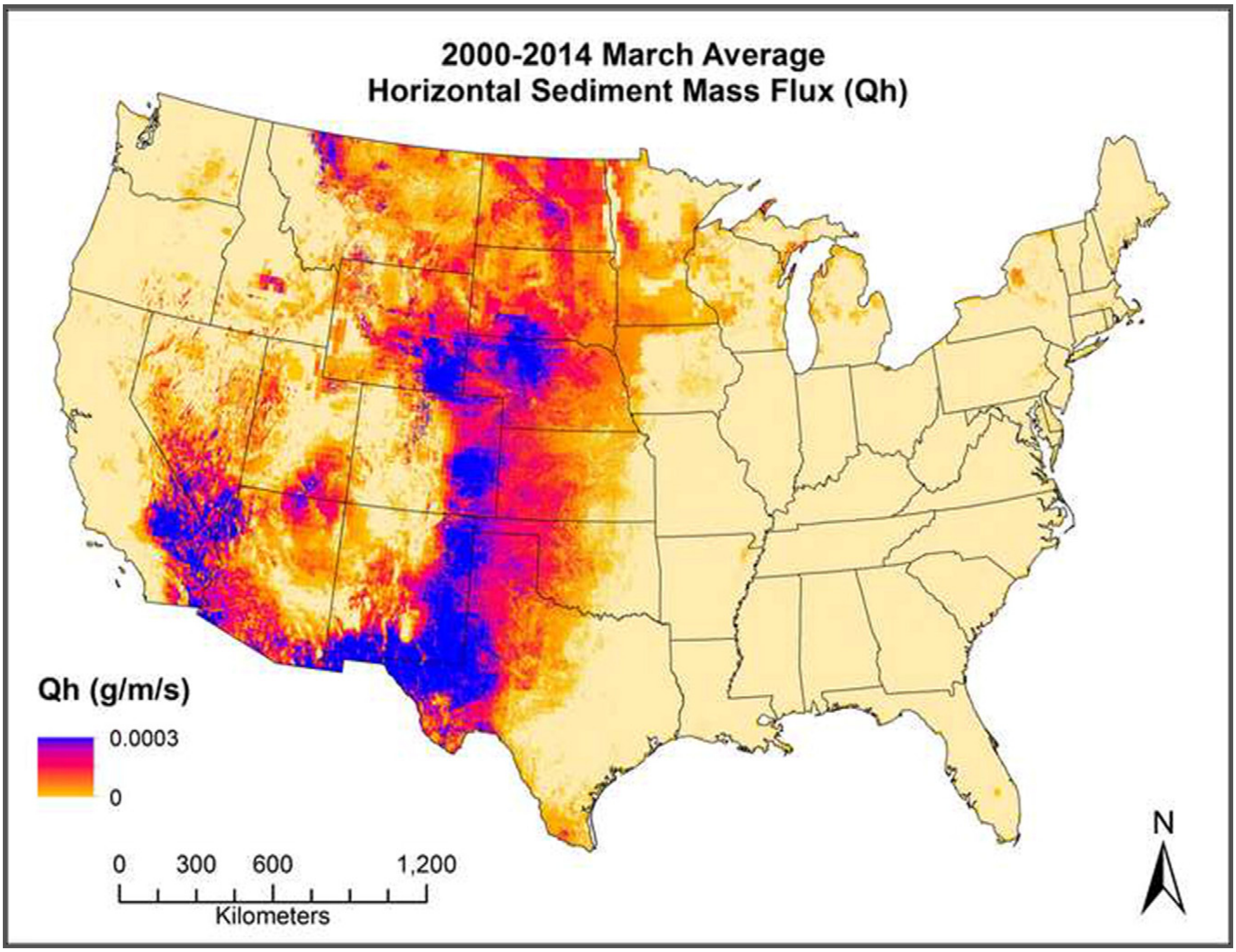
Enhancing Wind Erosion Monitoring and Assessment Capabilities

The National Wind Erosion Research Network is most likely to succeed in enhancing wind erosion monitoring and assessment in the United States if it can address key knowledge gaps and provide technologies that are adopted to evaluate and mitigate wind erosion at different spatial scales. A primary motivation for the Network was to build a collaborative research infrastructure for addressing multiscale and management-relevant questions to inform management decisions that could minimize wind erosion. This collaboration and research-driven approach will support iterative and therefore adaptive wind erosion monitoring, assessment, and management. New Network capabilities can be incorporated to address new research questions and to provide new monitoring and assessment technologies.

Enhanced wind erosion monitoring and assessment capabilities in the United States will enable us to determine, for example: 1) which landscapes are eroding, by how much, and when; 2) the linkages between climate variability and soil and vegetation conditions that influence patterns of wind erosion; 3) the relative effects of land use and land management on wind erosion in different landscapes and landscape settings; 4) how, and where, the interactions between climate variability and management may impact U.S. wind erosion and dust emission under climate change; and 5) benchmarks for erosion and dust emission rates that enable wind erosion to be addressed as a land management issue in addition to an air quality problem. By providing detailed long-term measurements of wind erosion processes and their responses to climate and land use across diverse land cover types, the Network will support efforts to address these

Box 3
Using Remote Sensing to Quantify Wind Erosion Rates

Measuring wind erosion over large areas can be difficult, so models are often used to support regional wind erosion assessments. However, many models have limited ability to detect differences in wind erosion across land cover types (e.g., shrublands, grasslands, and croplands). Data from the National Wind Erosion Research Network are being used to calibrate a new remote sensing-based model, which shows promise for more accurately estimating wind erosion in vegetated landscapes.[20] Using land surface aerodynamic properties derived from Moderate Resolution Imaging Spectroradiometer (MODIS) albedo data, the new model enabled sediment mass fluxes (g m^{-1} s^{-1}) to be estimated for January 2000 to December 2014.The modeled sediment fluxes show a similar spatial pattern to the region of elevated fine dust concentrations detected by the IMPROVE monitoring network (Box 2). The model also enables dust sources to be resolved for the first time in the United States at a management-relevant scale. Using remote sensing data, the new model will provide managers with the capability to assess the impacts of vegetation change on wind erosion at a much higher frequency (e.g., every 8 days) than field monitoring programs.



questions through field research at Network sites, model development, and model applications at local, landscape, and regional scales.

Mapping spatial and temporal patterns of wind erosion across the United States at moderate to high spatial resolutions has been prioritized by the Network for building our understanding of wind erosion processes at management-relevant scales. Improving our understanding of the role of climate variability at different temporal scales will also allow us to separate naturally occurring wind erosion and its variability from land use impacts. This is necessary to determine when a change in management is—and is not—likely to make a difference and to identify management options.

At the regional scale, patterns of wind erosion, together with its drivers, need to be evaluated in the context of regional climate variability and land cover change. At the landscape scale, integrating wind erosion assessments into ecological models will enable exploration of the interactions between wind erosion and ecosystem dynamics. Such approaches could draw on ecological site concepts and state-and-transition models[17] that inform AIM and NRI monitoring and which provide a framework for connecting climate variability and resource management with wind erosion.[18,19]

Wind erosion assessments would benefit greatly from the integration of available monitoring data with models implemented at different spatial scales. A number of wind erosion models are available, for example Shao et al.,[20] Okin,[21] and the Wind Erosion Prediction System (WEPS),[22] that are being enhanced by the Network to assimilate monitoring data and improve wind erosion assessment accuracy across land cover types. Site- and landscape-scale assessments could draw directly on AIM and NRI data to evaluate wind erosion responses to local drivers of change (e.g., grazing and vegetation clearing such as tree or shrub removal or for energy development). Model applications with AIM and NRI data can also be extended to landscape and regional scales and over time by drawing on remote sensing inputs to assess wind erosion patterns and processes (Box 3).[23] Such approaches would enable a fuller assessment of the biophysical and human impacts of wind erosion at the site level and downwind. For example, models might relate vegetation changes to soil loss due to wind erosion, dust emission, and air quality. AIM and NRI monitoring data could be used to aid interpretation of the causes and effects of modeled and observed wind erosion. Similarly, aerosol-monitoring data (e.g., IMPROVE and AERONET) could be integrated into model testing, as well as providing an independent source of measurements to support interpretation of modeled wind erosion patterns, processes, and their causes. The Network sites can provide further insights into cropland wind erosion processes and the potential effects of land use change (e.g., conversion of range to cropland and vice versa) on wind erosion.

The research and assessment activities we identify here will provide multiple benefits to resource managers. Incorporating wind erosion information into rangeland resource assessments, regional management plans, and evaluations of land health and soil conservation effectiveness would significantly strengthen existing natural resource assessment approaches. Network-supported research and assessments will enable resource management-wind erosion trade-offs to be considered explicitly in land use and management planning.

Future Opportunities

The National Wind Erosion Research Network was established to address major challenges in our understanding and management of wind erosion in the United States. By developing a collaborative approach guided by research questions that target knowledge gaps, the Network will enhance wind erosion monitoring and assessment capabilities in three ways. First, the Network provides new opportunities for conducting basic research into wind erosion and dust emission processes at different spatial and temporal scales. This will enable the Network to build our understanding of where, when, and why wind erosion occurs across the United States and the effects of climate, management, and land use changes. Knowledge of these patterns and processes will be essential for interpreting existing AIM, NRI, and air quality monitoring data and identifying options to minimize potential negative impacts of different resource management approaches and future climate change.

Second, basic research conducted by the Network will inform the development of new wind erosion monitoring and assessment approaches. Relevant questions include: 1) how can we best measure and model wind erosion processes to detect management effects? 2) how can remote sensing technologies be better used to measure indicators of wind erosion risk? 3) how can different types of monitoring data be used to build a more complete understanding of wind erosion and dust emission across landscapes and over time? 4) how can information about wind erosion be used to develop management objectives and to manage the effects of wind erosion? and 5) how can wind erosion information be effectively communicated to resource managers and agencies to inform management and policy decisions?

Finally, through the development of decision-support tools (e.g., online models) that address these questions, the Network can both support existing rangeland and air quality monitoring programs and enhance the utility of their data for wind erosion assessments and management. Delivering new models, assessment approaches, and data may require expertise that does not currently exist within the Network. Therefore, opportunities will continue to arise to build new connections among Network partners and to expand the Network to form new collaborations.

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Authors are Research Associate Professor, Jornada Experimental Range, New Mexico State University, Las Cruces, NM 88003, USA (Webb, nwebb@nmsu.edu); Soils Biologist, Jornada Experimental Range, USDA Agricultural Research Service, Las Cruces, NM 88003, USA (Van Zee); Research Ecologist, Jornada Experimental Range, USDA Agricultural Research Service, Las Cruces, NM 88003, USA (Karl); Research Soil Scientist, Jornada Experimental Range, USDA Agricultural Research Service, Las Cruces, NM 88003, USA (Herrick); Information Technology Specialist, Jornada Experimental Range, USDA Agricultural Research Service, Las Cruces, NM 88003, USA (Courtright); AIM Vegetation Monitoring Lead, Bureau of Land Management, San Luis Valley Field Office, Monte Vista, CO 81144, USA (Billings); Branch Chief, Bureau of Land Management National Operations Center, Denver, CO 80225, USA (Boyd); Reader, School of Earth and Ocean Sciences, Cardiff University, UK (Chappell); Research Ecologist, Southwest Biological Science Center, US Geological Survey, Moab, UT 84532, USA (Duniway); Supervisory Research Rangeland Management Specialist and Research Leader, Rangeland Resources and Systems Research Unit, USDA Agricultural Research Service, Cheyenne, WY 82009, USA (Derner); Research Scientist, Cooperative Institute for Research in the Atmosphere, Colorado State University, Fort Collins, CO 80523, USA (Hand); Landscape Ecologist, Bureau of Land Management National Operations Center, Denver, CO, 80225 USA (Kachergis); Ecologist, Jornada Experimental Range, New Mexico State University, Las Cruces, NM 88003, USA (McCord); Research Ecologist, Great Basin Rangelands Research, USDA Agricultural Research Service, Reno, NV 89512, USA (Newingham); Research Leader and Supervisory Research Hydrologist, Northwest Watershed Research Center, USDA Agricultural Research Service, Boise, ID 83712, USA (Pierson); Supervisory Soil Scientist, Grazinglands Research Laboratory, *USDA Agricultural Research Service, El Reno, OK 73036, USA (Steiner); Research Soil Scientist, Rangeland Resources and Systems Research Unit, USDA Agricultural Research Service, Fort Collins, CO 80526, USA (Tatarko); Hydrologist, Bureau of Land Management, San Luis Valley Field Office, Monte Vista, CO 81144, USA (Tedela); Research Rangeland Management Specialist, USDA-ARS Northern Great Plains Research Laboratory, Mandan, ND 58554, USA (Toledo); Research Soil Scientist, USDA-ARS Wind Erosion and Water Conservation Unit, Big Spring, TX 79720, USA (Van Pelt).*