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The National Wind Erosion Research Network: Building a standardized long-term data resource for aeolian research, modeling and land management

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ABSTRACT

The National Wind Erosion Research Network was established in 2014 as a collaborative effort led by the United States Department of Agriculture's Agricultural Research Service and Natural Resources Conservation Service, and the United States Department of the Interior's Bureau of Land Management, to address the need for a long-term research program to meet critical challenges in wind erosion research and management in the United States. The Network has three aims: (1) provide data to support understanding of basic aeolian processes across land use types, land cover types, and management practices, (2) support development and application of models to assess wind erosion and dust emission and their impacts on human and environmental systems, and (3) encourage collaboration among the aeolian research community and resource managers for the transfer of wind erosion technologies. The Network currently consists of thirteen intensively instrumented sites providing measurements of aeolian sediment transport rates, meteorological conditions, and soil and vegetation properties that influence wind erosion. Network sites are located across rangelands, croplands, and deserts of the western US. In support of Network activities, http://winderosionnetwork.org was developed as a portal for information about the Network, providing site descriptions, measurement protocols, and data visualization tools to facilitate collaboration with scientists and managers interested in the Network and accessing Network

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products. The Network provides a mechanism for engaging national and international partners in a wind erosion research program that addresses the need for improved understanding and prediction of aeolian processes across complex and diverse land use types and management practices.

1. Introduction

Land use and land cover change have potentially massive impacts on global rates of wind erosion and dust emission (Neff et al., 2008; Marx et al., 2014). Together, these aeolian sediment transport processes influence climate, ecosystem dynamics and land productivity (Ravi et al., 2011). Dust emissions from disturbed surfaces can impact air quality, human health and transportation systems (Sharratt and Lauer, 2006; Sprigg et al., 2014). Wind erosion can moderate the effectiveness of climate change mitigation and adaptation strategies, and contribute significantly to the global cost of land degradation (ELD Initiative, 2015). Land managers require information on wind erosion to assess the impacts of policy and management strategies and the economics of remedial action or inaction.

Managing and planning for the impacts of wind erosion requires an understanding of the underpinning sediment transport processes and their interactions. This understanding is derived from field and laboratory studies of aeolian processes (e.g., Zobeck et al., 2003), and through conceptual and numerical models that explore interactions with biogeochemical, ecological and human systems (e.g., Shao et al., 2011a). Application of this understanding requires that knowledge of aeolian processes can be reliably up-scaled to represent the many complex dynamic interactions within fields, across regions, and globally (Raupach and Lu, 2004). Predictive models, developed from theory and empirical observation, play an important role in up-scaling process understanding.

While numerous aeolian sediment transport models exist, their direct application to policy, planning and decision making has been limited. Considerable attention has been given to modeling wind erosion in croplands (e.g., Tatarko et al., 2013; Wagner, 2013; Sharratt et al., 2015). Nonetheless, many model applications have been driven more by scientific questions and hypothesis testing than to inform management or policy. Synthesizing complex systems knowledge in models is effective to identify knowledge gaps and investigate the nature of fine (cm) and broad (km) scale aeolian processes and interactions (Shao et al., 2015). However, integrating results of aeolian research to inform management and policy has met with a number of important and non-trivial challenges.

The first major challenge for wind erosion modeling, management, and policy development has been the use of non-standardized methods in field studies and monitoring programs, which makes it difficult to compare results and outcomes across land use systems (Barchyn et al., 2011). Flexibility in research methods, including data collection and analysis, is clearly necessary to meet individual study needs and to increase basic scientific understanding. However, in many cases the long-term benefits of methods standardization outweigh the costs (Toevs et al., 2011). Without standardized methods, for example in measuring sediment transport rates and atmospheric conditions, it is very difficult to derive robust regional or national scale assessments of wind erosion and dust emission from existing data. Consequently, knowledge of the magnitude and relative rates of wind erosion and dust emission across land cover types, their likely responses to land use and management change, and sensitivity to climate variability and change remains limited (Flagg et al., 2014).

Second, many monitoring studies have been limited by sampling designs that lack statistical rigor and reveal little about the spatial and temporal variability in sediment transport that drives patterns of wind erosion and dust emission (e.g., Chappell et al., 2003). Without knowledge of the variability (including within-site and between-site variances) in sediment transport, it is very difficult to elucidate differences in wind erosion across land use and land cover types, or in response to management treatments or other environmental perturbations (e.g., Belnap et al., 2009). Development of management strategies and policy on the basis of limited measurements in space and time can be risky (Herrick et al., 2010). Knowing data representativeness, accuracy, and precision is also critical for testing predictive models, which in the absence of reliable and scalable monitoring data often serve as the basis for wind erosion assessments and planning (e.g., Leys et al., 2010; Wagner, 2013; Borelli et al., 2014).

A third limitation to wind erosion modeling, management and policy development is the availability of quality data for assessing model performance. Indeed, many aeolian sediment transport models have not undergone rigorous accuracy assessment due to the lack of appropriate data (Shinoda et al., 2011). Despite efforts to test models against field data (e.g., Shao et al., 2011b; Li et al., 2013), uncertainty in model outputs is largely unknown. Application of wind erosion and dust emission models for decision making requires an understanding of uncertainty so that model outputs can be interpreted to appropriately manage the risk of adverse decisions (Walker et al., 2003). Model evaluation through assimilation of surface air quality observations and satellite imagery has improved the situation by providing supporting information on sediment transport rates (e.g., Leys et al., 2008; Yumimoto et al., 2008), but has yet to provide the necessary user confidence in regional, national or global simulations. Robust model evaluation requires that the frequency and magnitude of sediment transport estimates from models have been tested in space and time, across the range of intended application environments, and are conducted using methods that are informative to the application (Rykiel, 1996). This requires consistent and high quality measurements of aeolian sediment transport rates and the factors that control them. Unfortunately, the cost of data collection to conduct such analyses is often prohibitive for individual studies. Decision makers undoubtedly discount the power of modeling when output accuracies are unknown or unreported.

Finally, the selection of models that can be used to assess wind erosion and dust emission presents a challenge for land managers and policy makers. Aeolian sediment transport models have traditionally been developed to assess gross or net wind erosion from agricultural fields (Tatarko et al., 2013; Wagner, 2013), or horizontal and vertical sediment mass fluxes (Marticorena and Bergametti, 1995; Shao, 2008). There are fundamental conceptual differences between wind erosion (soil loss), which is often of interest to land managers, and the sediment mass fluxes output by most models; as well as practical differences in how the processes are represented in models and applied to inform management or policy. Extension of wind erosion concepts and models to rangelands and deserts is particularly challenging because these settings have poorly defined or non-existent 'field' boundaries (Li et al., 2014), aeolian processes appear to be dominated by soil redistribution at different spatial scales (Okin et al., 2015), and current