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WIND EROSION IN SEMIARID LANDSCAPES: PREDICTIVE MODELS AND REMOTE SENSING METHODS FOR THE INFLUENCE OF VEGETATION

Semiannual Status Report

for July 1, 1992 to December 31, 1992

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WIND EROSION IN SEMIARID LANDSCAPES: PREDICTIVE MODELS AND REMOTE SENSING METHODS FOR THE INFLUENCE OF VEGETATION

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OBJECTIVES

The objectives of this research are: (1) to develop and test predictive models for the quantitative influence of vegetation canopy structure on wind erosion of semiarid rangeland soils, and (2) to develop remote sensing methods for measuring the canopy structural parameters that determine sheltering against wind erosion. The influence of canopy structure on wind erosion will be investigated by means of wind-tunnel and field experiments using model roughness to simulate plant canopies. The canopy structural variables identified by the wind-tunnel and field experiments as important in determining vegetative sheltering against wind erosion will then be measured at a number of naturally vegetated field sites and compared with estimates of these variables derived from analysis of remotely sensed data.

STATUS

I. Wind-tunnel Experiments

A. Phase 1: Canopies Modeled as Solid Roughness Elements

This phase of experimentation was largely completed during summer and fall of 1992. The experiments were conducted at the USDA Wind Erosion Laboratory at Big Spring, Texas, with the generous assistance of USDA scientist Dr. W. D. Fryrear. Analysis of the results is continuing.

Experiments were designed to determine the influence on threshold friction velocity of three structural variables applicable to arrays of solid cylindrical roughness elements:

1) Lateral cover (or Frontal Area Index): the product of height, diameter, and number per unit area of roughness elements,

2) Element aspect ratio: the ratio of element height to element diameter,

3) Array scale: ratio of absolute dimensions for arrays identical in structural relationships but differing in absolute size.

We tested 27 combinations of these 3 structural variables, with 5 replicate determinations of threshold friction velocity for each combination.

Preliminary analysis confirms the findings of previous studies showing that lateral cover strongly determines protection against wind erosion. After error and uncertainty analysis, our results will be quantitatively compared with those of other investigators in an attempt to resolve the quantitative disparities among the results of previous studies. Preliminary analysis also indicates that the influence of element aspect ratio is less than expected and may perhaps be insignificant for all but some extreme cases. In general we found no significant effect of array scale, which suggests that scaling requirements for wind-tunnel modeling were met and supports extrapolation of the results to the field scale. There was one case of apparently significant scale effects which requires further investigation.

B. Phase 2: Canopies Modeled as Porous Roughness Elements

In our Phase 1 experiments, as in previous studies, individual plant bodies were modeled as solid objects. We proposed to model plant bodies more realistically as porous objects, and to determine the influence of canopy porosity on protection against wind erosion. Our experimental modeling of canopy porosity is a major advance beyond previous studies of this type.

Porous elements were constructed by mounting a varying number of narrow cylindrical objects vertically on a cylindrical base, thus forming a larger element that was cylindrical in overall shape. To isolate the effect of porosity, overall dimensions and aspect ratios of the porous elements, and lateral cover of the porous-element array, were made identical to those of solid cylinders used in our Phase 1 experiments. Arrays consisting of large numbers of these porous elements were placed on the floor of the wind tunnel, and threshold friction velocity was determined using the same procedures as in our experiments with solid elements.

The additional labor required for construction of porous elements limits the number of tests that can be performed within the scope of this study. We have thus far tested four different array configurations, but these were carefully selected to provide information on several key questions. A small number of additional tests will be performed in the forthcoming and final six-month period of this grant.

Preliminary results indicate that:

1) Relative to solid elements, slightly porous elements provide greater protection against wind erosion, while

highly porous elements provide equal or lesser protection; our prediction that the effect of porosity would not be monotonic was thus confirmed,

2) The effect of porosity is quantitatively great; slightly porous elements raised threshold friction velocities more than 1½ times as much as solid or highly porous elements,

3) Different results were obtained for two porous-element arrays having the same stem lateral cover but differing in porosity and in canopy lateral cover.

This last finding provides support for our approach in modeling vegetation as an array of discrete porous objects. Other investigators have proposed an alternative approach that models vegetation as an array of stems and leaves without regard to their aggregation into discrete individual plant bodies, and uses stem lateral cover as the structural variable.

We plan to conduct one or two additional wind-tunnel tests. We have identified a number of key questions that might be addressed, and one of these will be chosen as the subject of the additional experimentation.

II. Field Experiment

In late winter-early spring of 1993, we will conduct a full-scale field test of the relationships derived from our Phase 1 wind-tunnel experiments. An array of solid cylindrical objects of approximately the same size as natural plant canopies will be placed on a large cleared field at the USDA Jornada Experimental Range near Las Cruces, New Mexico. Four- or five-gallon plastic pails will be used as roughness elements. Threshold friction velocity will be determined by simultaneous monitoring of the wind profile and sand flux (Stockton and Gillette, 1990; Musick and Gillette, 1990), and the results compared with the wind-tunnel results.

To develop methods for analysis of the wind and sand flux data to be obtained in this experiment, we have begun (in collaboration with P. Helm, USGS Flagstaff) a detailed examination of similar data from two other field sites: a vegetated site near Yuma, monitored by the USGS Desert Winds Project, and a bare field previously monitored by D. W. Fryrear and P. H. Stockton as a validation site for the Sensit sand flux detection instrument. We have found that the relation of sand flux occurrence to friction velocity is not a simple step function, and we are developing methods to extract a useful measure of threshold friction velocity.

III. Remote Sensing

We have arranged for late winter-early spring acquisition of two SPOT scenes of the Jornada Experimental Range. From this combination of nadir-view and off-nadir-view scenes we will calculate an estimate of vegetation lateral cover. Accuracy of these estimates will be determined by comparison with lateral cover estimates derived from ground sampling of a number of sites.

PUBLICATIONS AND PRESENTATIONS

A. Completed or submitted

1. Musick, H. B. 1992. Effect of vegetation on surface stability. Presented at USGS Global Change/Arid Lands Processes Workshop, Flagstaff, Arizona, August 18-20, 1992.

2. Trujillo, S. M., C. R. Truman, and H. B. Musick. 1992. The effects of roughness element geometry on saltation threshold in a turbulent boundary layer (Abstract). Bulletin of the American Physical Society, Program of the 1992 Annual Meeting of the Division of Fluid Mechanics 37:1784. (Abstract enclosed)

3. Musick, H. B. 1993 (submitted). Monitoring vegetation and its role in surface changes. In Monitoring Land-Surface Processes and Synoptic Climatology at Desert Sites in Arizona and New Mexico, C. S. Breed (ed.). U. S. Geological Survey Bulletin ###.

B. Planned

1. Trujillo, S. M. 1993. Predictive modeling of the influence of vegetation on wind erosion in semiarid rangelands for remote sensing applications. M.S. Thesis.

2. Musick, H. B., and P. H. Helm. 1993. Saltation threshold response to wind at field sites. (to be submitted to Earth Surface Processes and Landforms)

3. Truman, C. R., S. M. Trujillo, and H. B. Musick. 1993. Wind-tunnel modeling of the the influence of vegetation structure on wind erosion thresholds:
   I. Effects of lateral cover and element aspect ratio.
   II. Effects of element porosity.
   (to be submitted as journal papers)

4. Musick, H. B. 1993. Wind erosion. to be presented at symposium "Approaching global sustainability from the

bottom up: preserving the soil" at Ecological Society of America Annual Meeting, August 1993.

5. Musick, H. B. 1993. Influence of vegetation structure on susceptibility to wind erosion. Poster presentation at Ecological Society of America Annual Meeting, August 1993.

REFERENCES CITED

Musick, H. B., and D. A. Gillette. 1990. Field evaluation of relationships between a vegetation structural parameter and sheltering against wind erosion. Land Degradation and Rehabilitation 2:87-94.

Stockton, P. H., and D. A. Gillette. 1990. Field measurement of the sheltering effect of vegetation on erodible surfaces. Land Degradation and Rehabilitation 2:77-85.

Published in Bulletin of the American Physical Society, Program of the 1992 Annual Meeting, v. 37, p. 1784.

The Effects of Roughness Element Geometry on Saltation Threshold in a Turbulent Boundary Layer

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ABSTRACT

Wind erosion in semi-arid regions is a significant problem for which the sheltering effect of rangeland vegetation is poorly understood. Individual plants may be considered as porous roughness elements which absorb or redistribute the wind's momentum. The saltation threshold is the minimum wind velocity at which soil movement begins. The dependence of the saltation threshold on geometrical parameters of a uniform roughness array was studied in a wind tunnel. Both solid and porous elements were used to determine relationships between canopy structure and the threshold velocity for soil transport. The development of a predictive relation for the influence of vegetation canopy structure on wind erosion of soil will be discussed.