WIND EROSION CLIMATIC EROSIVITY

E. L. SKIDMORE

ARS, USDA, Kansas State University, Manhattan, Kansas 66506, U.S.A.

Abstract. A physically based wind-erosion climatic factor has been derived:

\[ CE = \rho \int \left[ u^2 - \left( u_T^2 + \frac{\gamma_1}{\rho a^2} \right) \right]^{3/2} f(u)du \]

where \( \rho \) is the air density, \( a \) is a constant made up of other constants (von Karman, height of wind speed observation, roughness parameter), \( u \) is the horizontal wind speed, \( u_T \) is threshold wind speed, \( f(u) \) is a wind speed probability density function, and \( \gamma_1 \) is the cohesive resistance caused by water on the soil particles. Cohesive resistance is proportional to the square of water content relative to water content at \(-1500 \text{ J kg}^{-1}\). Relative water content is approximated from the Budyko dryness ratio and the Thornthwaite \( PE \) index with similar results. \( CE \) is calculable from wind speed and other generally available meteorological data, and is usable in the wind erosion equation without some of the limitations of a previously used wind erosion climatic factor.

1. Introduction

Wind erosion climatic erosivity is a measure of the climatic tendency to produce conditions conducive to wind erosion. Wind erosion occurs when the shear stress exerted on the surface by the wind exceeds the ability of the surface materials to resist detachment and transport. Strong winds erode, and dryness increases the susceptibility of the surface to erosion.

The aridity of an environment is often evaluated by the Budyko dryness ratio (Budyko, 1958; Hare, 1983). The dryness ratio at a given site indicates the number of times the net radiative energy could evaporate the mean annual precipitation. Semi-arid zones where wind erosion is likely to be a serious problem have a dryness ratio between 2 and 7 (Hare, 1983). Areas with dryness ratios larger than 7 are in the desert and desert margin zones. Most of the Great Plains of the USA has dryness ratios between 2 and 5. The Sahara Desert in North Africa has a maximum dryness ratio as high as 200 (Henning and Flohn, 1977).

Chepil et al., (1962) proposed a climatic factor to estimate average annual soil loss by wind for a range of climatic conditions. This factor, an index of wind erosion, is a function of soil moisture and average wind speed. The wind speed term was based...
on the rate of soil movement being proportional to the cube of average wind speed (Bagnold, 1943; Chepil, 1945; Zingg, 1953). The soil moisture term was developed on the basis that soil erodibility varied inversely with the square of water content in the upper few millimeters of soil which was assumed to vary as the Thornthwaite effective precipitation index (Chepil, 1956).

The climatic factor as proposed by Chepil (1962) was one of the five independent variables of the wind erosion equation which has been used widely during the past 20 years (Woodruff and Siddoway, 1965). Other variables of the wind erosion equation are identified in a companion paper (Skidmore, 1986, 'Wind Erosion Control', in this issue).

This research develops a method to characterize the climate's tendency to cause wind erosion based on the mechanics of the wind erosion process. This procedure is usable as a climatic factor in the wind erosion equation (Woodruff and Siddoway, 1965; Skidmore and Woodruff, 1968) for long and short term and event soil loss estimates. It can be used at various levels of sophistication and availability of climatic data and it provides a framework for research to better understand wind erosion variables.

2. Model

In the first part of this section (Equations 1 through 11), I review wind erosion climatic indices and present some fundamentals of wind erosion process. In the second part, I derive some new relationships aimed at accomplishing the objective of this paper.

The climatic factor as proposed by Chepil (1962) was expressed as:

\[ C = 386 \frac{u^3}{(PE)^2} \]  

(1)

where \( u \) is the mean wind speed and \( PE \) is the Thornthwaite (1931) index. A summary of notation is given in Annex. The term 386 indexes the factors to the conditions at Garden City, Kansas. Thornthwaite's index to evaluate precipitation effectiveness expressed the \( P/E \) ratio to temperature and precipitation as:

\[ P/E = 0.316 \left( \frac{P}{1.8T + 22} \right)^{10/9} \]  

(2)

where \( P \) is the mean monthly precipitation, in mm; \( E \) is the monthly evaporation, in mm; and \( T \) is the temperature, in °C. Monthly values were added to obtain an annual value and multiplied by 10 to avoid fractions to give:

\[ PE \text{ index} = 3.16 \sum_{i=1}^{12} \left( \frac{P_i}{1.8T_i + 22} \right)^{10/9} \]  

(3)

Equation (3) was used in Equation (1) to determine wind erosion climatic factors for many locations in the U.S. (Chepil et al., 1962; Lyles, 1983; Skidmore and Woodruff, 1968).