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Review

A history of wind erosion prediction models in the United States Department of Agriculture prior to the Wind Erosion Prediction System ☆

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ABSTRACT

The Great Plains experienced an influx of settlers in the late 1850s–1900. Periodic drought was hard on both settlers and the soil and caused severe wind erosion. The period known as the Dirty Thirties, 1931–1939, produced many severe windstorms, and the resulting dusty sky over Washington, DC helped Hugh Hammond Bennett gain political support for the Soil Conservation Act of 1937 that started the USDA Soil Conservation Service (SCS). Austin W. Zingg and William S. Chepil began wind erosion studies at a USDA laboratory at Kansas State University in 1947. Neil P. Woodruff and Francis H. Siddoway published the first widely used model for wind erosion in 1965, called the Wind Erosion Equation (WEQ). The WEQ was solved using a series of charts and lookup tables. Subsequent improvements to WEQ included monthly magnitudes of the total wind, a computer version of WEQ programmed in FORTRAN, small-grain equivalents for range grasses, tillage systems, effects of residue management, crop row direction, cloddiness, monthly climate factors, and the weather. The SCS and the Natural Resources Conservation Service (NRCS) produced several computer versions of WEQ with the goal of standardizing and simplifying it for field personnel including a standalone version of WEQ was developed in the late 1990s using Microsoft Excel. Although WEQ was a great advancement to the science of prediction and control of wind erosion on cropland, it had many limitations that prevented its use on many lands throughout the United States and the world. In response to these limitations, the USDA developed a process-based model know as the Wind Erosion Prediction System (WEPS). The USDA Agricultural Research Service has taken the lead in developing science and technology for wind erosion prediction.

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1. Introduction

Wind erosion has been an agricultural issue in the semi-arid central United States Great Plains since settlers first plowed prairie grasslands to produce food and fiber. The years from 1931 to 1939 saw very low rainfall in the U.S. High Plains region centered in Texas, New Mexico, Colorado, Oklahoma, and Kansas. The resulting severe wind erosion caused concern over the loss of our soil resources, and a national effort to quantify and control the amount of wind erosion on our nation's farmland began. The US Soil Erosion Service established in 1933, later know as the Soil Conservation Service (SCS) and now the Natural Resources Conservation Service (NRCS), along with the Agricultural Research Service (ARS) and land grant universities have worked 75 years to advise growers about the care of wind-erodible land. Throughout this time, research has been conducted and many soil loss prediction methods have been developed to better understand and predict soil erosion. This paper summarizes the development of wind erosion prediction models in the United States Department of Agriculture prior to the development of the current Wind Erosion Prediction System (WEPS) model in the mid-1980s. The history and development of the WEPS model is described in detail in a separate work by Wagner (see this issue).

2. Early observations of wind erosion

Farmers and ranchers settled the US Great Plains region in the late 1800s. From 1850 to 1900, the population of the area increased from 300,000 to 7,000,000 (Anderson and Hill, 2004) with a concurrent large increase in the land converted to cropland, most of which was planted to wheat. Mechanization using tractors allowed farmers to cultivate previously unplowed areas of the short grass prairie (Armbrust, 1999).

Early wind erosion literature focused on the scope of the problem and control measures. The first scientific report of wind erosion on cultivated US land was made by King (1894) in Wisconsin. King recommended strip-cropping, green manure, roughening the surface, and windbreaks to control wind erosion. Udden (1896) published some of the first quantitative estimates of solid, suspended material in dust storms. He reported 160 to 126,000 tons per cubic mile of dust and indicated that an average of 850 million tons of dust was being carried 1440 miles each year in the Western United States. Free and Westgate (1910) discussed four actions to control soil blowing: (1) increasing the water content of the soil, (2) increasing the amount of humus (organic matter in soil), (3) providing a cover of growing vegetation; and (4) leaving the stubble of the last crop standing on the land until next planting. A comprehensive review of wind erosion science from the perspective of Aeolian geology was published by Free (1911) with additional control methods to those mentioned by Free and Westgate (1910) including decreasing summer fallow and planting trees in rows to slow the wind. Free was also one of the earlier writers to describe wind erosion and windblown dust as an agent of soil formation and modification. Several periods of dry conditions from 1890s as well as the 1910s caused severe wind erosion (Chepil, 1957).

3. The impacts of the Dust Bowl on research and modeling

Probably the most severe period of wind erosion occurred in the 1930s in the US Great Plains. Fig. 1 shows the rainfall patterns for southwest Kansas that resulted in the severe erosion of the 1930s. Starting in 1931, rainfall was below average for the subsequent 9 years. Rainfall in 1937 was 208 mm (8 inches) below the average of 478 mm (18.8 inches), which resulted in consecutive years of winter wheat crop failure. At that time, knowledge of wind erosion soil loss was limited. The Great Depression compounded the difficult times brought on by the drought's effects.

The severity of the drought resulted in large amounts of erosion throughout the Great Plains of North America with the most severe damage occurring in New Mexico, Colorado, Kansas, Oklahoma, and Texas. Fig. 2 is a typical photograph of the Dust Bowl era (USDA-NRCS, 2012). Even before the Dust Bowl, Hugh Hammond Bennett, a soil scientist at the US Bureau of Chemistry and Soils, thought much more could be done to manage natural resources wisely. Bennett and Chapline (1928) made their case for soil conservation in *Soil Erosion: A National Menace*. Later, in April, 1935, Bennett used a big dust storm to persuade Congress to address the problem (Brink, 1951; Egan, 2006). On a day he was testifying before Congress in support of the Soil Conservation Act, Bennett was able to prolong his presentation long enough for legislators to see a large storm settle dust over the Capitol as the bill came to a vote. The act which was, in part, intended to reduce the nation's soil loss also established the United States Soil Conservation Service (SCS) and was the first soil conservation act in history (Brink, 1951). Bennett served as the first chief of the SCS until his retirement in 1951. Later, the SCS published several regional guides for wind erosion control, including "The Guide for Wind Erosion Control in the Northeastern States" (Hayes, 1966) and "The Guide for Wind Erosion Control on Cropland in the Great Plains States" (Craig and Turelle, 1964).

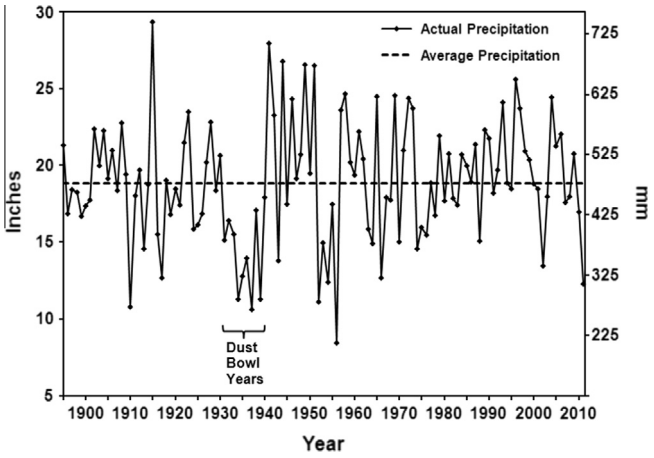

Fig. 1. Southwest Kansas Rainfall, 1895 to 2011 (data from NOAA, 2012). Note the dry years of 1931 to 1940.

Fig. 2. Typical dust storm from the 1930s (USDA-NRCS, 2012).