A History of USDA-ARS Wind Erosion Research at Manhattan, Kansas 1947 - 2005

by
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Introduction

The removal, transport, and deposition of soil by wind, also known as wind erosion, has long been a problem that has plagued mankind. Even before agriculture, wind erosion was an important natural process as evidenced by the vast areas of loess soils throughout the world. With the introduction of cultivated agriculture, soils normally covered by natural vegetation were exposed to the forces of the weather resulting in greatly accelerated erosion by wind.

Substantial portions of Asia, the Middle East, and North Africa were once fertile lands supporting prosperous populations. But soil erosion by wind depleted the fertility of the soil and in some areas it transformed once fertile lands into sandy deserts (Lowdermilk, 1984).

Probably the first known writings about wind erosion in the U.S. appear in Zebulon Pike's journals of 1807 where he writes of “hills of sand” at what is now know as the Great Sand Dunes National Park in southern Colorado (Pike, 1996). Chepil (1957) cites weather records from the 1890's which indicate dust storms occurred in the region of Dodge City, Kansas at a time when virtually no cultivation of land in the southwestern U.S. had begun. The problem of wind erosion on cultivated land was first reported by King (1894) in Wisconsin, followed by Free and Westgate (1910) who described control measures for blowing soil.

Events during the 1930's, a period known as the Dust Bowl with its “Black Blizzards”, created public awareness of the damaging effects wind erosion can have on both the soil and environment. The Dust Bowl, caused by an extended drought and over-cultivation of the land, was centered in Morton County, Kansas and affected thirteen Great Plains states from Texas to North Dakota and also affected Canada. Although most dust storms were local, some were as large as 600 by 400 miles with many lasting more than 10 hours (Clements, 1938) and one lasting as much as 908 hours (Hurt, 1981). The USDA "Yearbook of Agriculture" for 1934 announced, "Approximately 35 million acres of formerly cultivated land have essentially been destroyed for crop production; 100 million acres now in crops have lost all or most of the topsoil; 125 million acres of land now in crops are rapidly losing topsoil”. In 1935, experts estimate that 850 million tons of topsoil had blown off the Southern Plains during the course of the year (USDA, 1935). Dust from one Great Plains storm deposited an estimated 12 million pounds of dust on Chicago - four pounds for each person in the city and went on to darken the skies of the U.S. Capitol where Hugh Bennett used the descending dust cloud to successfully argue for the creation of the U.S. Soil Conservation Service. By 1938, an average 480 tons per acre had been lost (Hansen and Libecap, 2004).

Early in-depth, scientific work on wind erosion processes was reported in “The Physics of Blown

Sand and Desert Dunes" by British researcher, Ralph Bagnold (1941). Much additional research followed to expand knowledge about wind erosion and its control on agricultural lands (Chepil, 1958; Chepil and Woodruff, 1963).

Today wind erosion is still a dominant problem on 75 million acres of land in the U.S. alone, with four to five million acres moderately to severely damaged each year. Wind erosion damages the soil by physically removing the most fertile part, lowering water-holding capacity, degrading soil structure, and increasing soil variability across a field, resulting in reduced crop production. It tends to remove silts and clays making the soils more sandy. It also causes plant damage from abrasion, blowouts, and deposition. In addition, some soil enters the atmosphere where it obscures visibility, pollutes the air and water, causes automobile accidents, fouls machinery, and imperils animal, plant, and human health.

1947 - 1953

The Dust Bowl helped to stimulate serious attention on the fundamental importance of our land as a resource. As a result, the Research and Marketing Act of 1946, popularly known as the Flannagan-Hope Bill, provided funding for the establishment of a research program to study regional wind erosion problems (Koury, 1947). Because of its proximity to the heart of the Dust Bowl and being the location of a Land Grant University, the Wind Erosion Project was established on the campus of Kansas State Agricultural College in Manhattan, Kansas in 1947. The project was administered by the Research Division of the Soil Conservation Service of the USDA in cooperation with the Department of Agronomy in the College of Agriculture and called for two agricultural engineers, two soil physicists, and four "sub-professional men". Austin W. Zingg, agricultural engineer, was the first supervisor and held that post until 1953. E.A. Engdahl was the second engineer and also started work in 1947. William S. Chepil, a soil scientist and pioneer of wind erosion research in Canada, was hired in 1948. The project was first officially known as the High Plains Wind Erosion Laboratory and was located in the Farm Machinery Hall on campus where the laboratory wind tunnel and related equipment were housed (Figs. 1 & 2). Early work focused on setting up research facilities as well as basic research into the mechanics of soil erosion by wind, delineating the factors with major influences on wind erosion, and developing methods to control soil loss by wind. This research contributed a considerable volume of knowledge including aerodynamics of soil surfaces, soil erodibility factors, effects of wind breaks, erosion and soil measurement techniques, and climatic influences on wind erosion. At some later time, the Laboratory was named the Wind Erosion Research Unit (WERU).

Figure 1. Farm Machinery Hall - ca. 1948.

Figure 2. Original wind tunnel.

1953 - 1963
William S. Chepil (Fig. 3) became the leader of the research program in 1953. During this period Chepil and colleagues set out to develop the Wind Erosion Equation (WEQ) that would parallel the Universal Soil Loss Equation (USLE) used for predicting water erosion. The development of this equation led to an understanding of the fundamental factors that cause wind erosion as well as those that control it. The factors that influence erosion include soil cloddiness, ridge roughness, field length, climate, and vegetative materials. Numerous laboratory studies were conducted aimed at discerning the basic processes affecting these factors. Many studies, with both laboratory and portable field wind tunnels, were also conducted to verify the factors and their effect on soil loss by wind (Figs. 3 & 4). Another focus was the development of equipment used in wind erosion research such as a rotary sieve to determine aggregate size distribution and dry aggregate stability (Fig. 5). Most of the work developing WEQ was completed under the direction of Dr. Chepil. However, he died of cancer in 1963 at age 59 before he could see the first publication of the equation. A new laboratory facility, which Dr. Chepil planned, was completed just prior to his death. The new laboratory was located just to the northeast of Weber Hall on the University campus. The building and original wind tunnel is still used today. Administrative and some scientist offices were established in East Waters Hall.

Figure 3. W.S.Chepil.

Figure 4. Field wind tunnel.

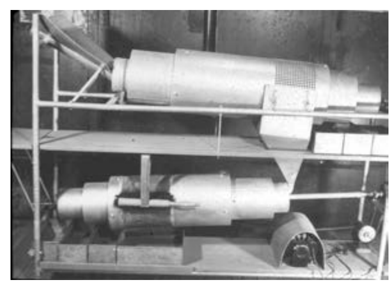

Figure 5. Rotary sieve.

1963-1975
Neil P. Woodruff was research leader of the wind erosion research program from 1963 until 1975. The Wind Erosion Equation (WEQ), designed to estimate soil loss on an average annual basis from cultivated fields, was published in 1965. WEQ was actually a series of equations and functions that required the use of tables and figures to obtain loss estimates. It became the standard for predicting soil loss from wind erosion in the United States and around the world and could also be utilized for designing control practices. It was used in the US primarily by the USDA Soil Conservation Service in assisting farmers to develop conservation plans, classify the erodibility of soils, and estimate crop tolerances to wind erosion. Other uses of the equation include (a) determining spacing for barriers in narrow strip-barrier systems, (b) estimating fugitive dust emissions from agricultural and subdivision lands, (c) predicting horizontal soil fluxes to compare with vertical aerosol fluxes, (d) estimating the effects of wind erosion on soil productivity, (e) delineating those croplands in the Great Plains where various amounts of crop residues may be removed without exposing the soil to excessive wind erosion, and (f) estimating erosion hazards in a national inventory. This period saw continuation of research into the

process and control of wind erosion as well as efforts to improve the predictive capabilities of WEQ. Research also included investigations into the sandblast damage to plants (Fig. 6), climate effects on wind erosion, wind barriers, residue management, and the development of dust sampling equipment. The awkwardness of the manual solution of WEQ prompted a computer solution to the model known as WEROS (Fig. 7). Laboratory research facilities known as the Wind Erosion Laboratory (Fig. 8) continued to expand on the northeast corner of campus while offices continued to be housed in Waters Hall although location of offices within Waters Hall changed over the years.

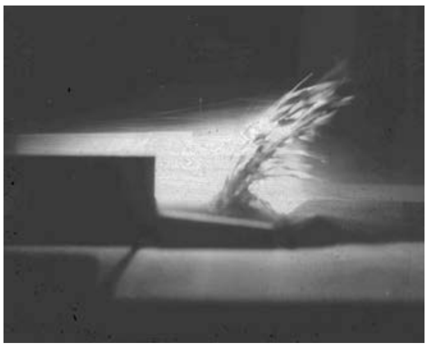

Figure 6. Plant damage studies.

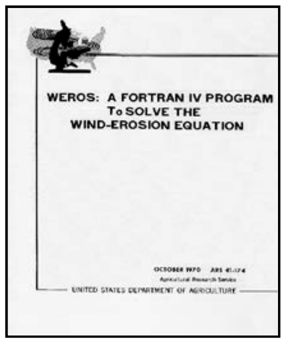

Figure 7. WEROS.

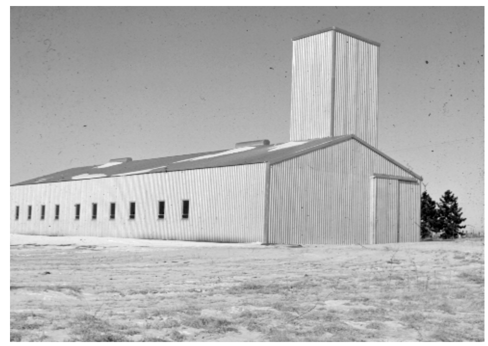

Figure 8. Wind tunnel laboratory.

1975 - 1988

Leon Lyles served as research leader from 1975 until 1988. Despite the many improvements to WEQ, complex interactions between variables were not accounted for in calculation procedures and it was not easily adapted to untested conditions or climates far different from those of the central Great Plains where WEQ was developed. To overcome the shortfalls of WEQ, the Wind Erosion Prediction System (WEPS) project was initiated in 1985. George W. Cole was first leader of the WEPS project which had the goal of replacing WEQ by developing a process-based, computer simulation model that would compute surface conditions, weather, management, and erosion on a daily basis. Advances in erosion science and increased power in personal computers allowed the development of this more flexible, processed-based erosion prediction technology. Field, laboratory, and office research needed for WEPS commenced, including studies into the temporal changes of surface properties such as soil aggregation, ridge roughness, plant growth, and residue decomposition, tillage effects on soil and plant residues, the simulation of climate and wind in particular, and erosion processes such as aggregate abrasion and soil transport (Fig. 9). Since WEPS was a long term project, work also continued on improving WEQ including enhancements to the climatic factor, small grain equivalents for additional crops, development of period based version of WEQ, and accounting for preponderance, field shape and orientation, and row direction. Other research included continued studies into plant damage, barriers, and the development of research equipment such as a soil aggregate crushing energy meter (SACEM), and an automated system for determining soil roughness from pin meter photographs (Fig. 9). In 1986, Lawrence J. Hagen became leader of the WEPS project. Research facilities continued to reside in the Wind Erosion Laboratory with offices in Waters Hall.

Figure 9. Research for WEPS.

1988 - 1994

Upon the retirement of Leon Lyles in 1988, Lawrence J. Hagen became research leader. At the same time he continued as the WEPS project leader. Research focused heavily on the development of the WEPS model which included considerable work on the model framework and design. Field and laboratory research included studies of aggregate abrasion by wind eroded material, generation of PM10 (particulate matter less than ten microns), the development of a wind simulator and associated database, overwintering of soil aggregates, soil roughness and trapping of eroding particles, tillage effects on aggregation, soil hydrology and surface wetness, plant canopy measurement and effects on wind erosion, and several field validation studies for WEPS (Figs. 10, 11 12). Considerable effort was also put into developing the source code for the model which included a rudimentary user interface. Limited research continued on improving WEQ including the development of small grain equivalents for shrub dominated rangeland and coupling WEQ with the EPIC model. Offices were moved from East Waters Hall to the newly expanded Throckmorton Plant Science Center in 1993. Throckmorton Hall included several research laboratories used by WERU scientists.

Figure 10. Ridge studies.

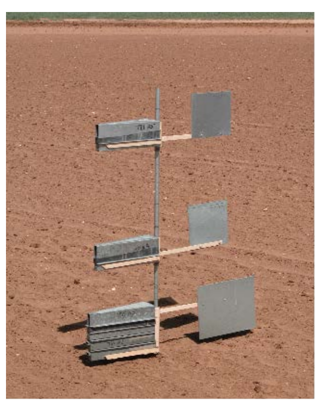

Figure 11. WEPS validation.

Figure 12. Aggregate studies.

1994 - present

Edward L. Skidmore has served as the WERU Research Leader since 1994. A highlight of this period was the 50th Anniversary of wind erosion research by WERU in cooperation with Kansas State University. WERU celebrated this milestone by hosting an International Symposium held in June 1997 on the campus of Kansas State University (Fig. 13). Over 100 wind erosion scientists from 25 countries participated. Research continued into the development of WEPS including work on plant canopy measurement and effects on wind erosion, reduction of plant residues by tillage, soil database development, PM10 generation by wind erosion, wind erosion effects on air quality, revision of the WEPS wind simulator and database, wind erosion of organic soils, wind erosion risk assessment mapping, and WEPS applications to non-cultivated lands. Researchers also developed a user-friendly graphical interface for WEPS (Fig. 14) and the WEPS technical documentation. Larry Wagner became WEPS project leader in 1999. A second highlight of the period was the official hand-off of WEPS by WERU to the NRCS in 2005 (Fig. 15). NRCS is currently in the process of field testing WEPS. WERU offices moved from the KSU campus to the USDA Grain Marketing and Production Research Center in 2002 which is located off campus about one mile to the west.

Figure 13. International symposium.

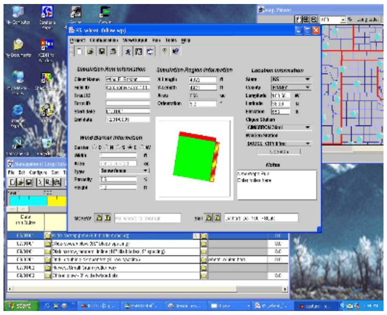

Figure 14. WEPS interface.

Figure 15. WEPS hand-off to NRCS.

Summary

During the 58 years of wind erosion research in cooperation with Kansas State University, Wind Erosion Research Unit scientists (Table 1) have published over 428 peer-reviewed journal articles, proceedings, and book chapters (see the complete WERU bibliography at: **http://www.weru.ksu.edu**). WERU scientists have been invited to visit over twenty countries to present workshops, teach courses, and cooperate in research projects. International scientists from more than thirty one countries have traveled to WERU since 1997. Research generated has included seventeen Masters Thesis projects and nine PhD Dissertations. Many WERU research scientists have adjunct professor appointments in the Department of Agronomy and the Department of Biological and Agricultural Engineering at Kansas State University (Table 1). Many have served as either major professors, members of graduate committees, or adjudicators of graduate students abroad. The number of scientists at the unit in any given year has ranged from one in 1947 (the initial project supervisor) to ten in 1967, with five scientists currently on staff. WERU is currently the only laboratory in the United States with a sole purpose of wind erosion research and it has become known as the center of wind erosion research in the US and the world.

Table 1. Past and Present WERU Research Scientists and Research Leaders (RL).

Dean V. Armbrust, Soil Scientist	1961 - 1963 & 1966 - 2001
William S. Chepil, Soil Scientist & RL 1953-1963	1948 - 1963
George W. Cole, Agricultural Engineer	1980 - 1988
Jerry D. Dickerson, Agricultural Engineer	1963 - 1979
Lowell A. Disrud, Agricultural Engineer	1966 - 1976
E. A. Engdahl, Agricultural Engineer	1947 - 1948
C. L. Englehorn, Soil Scientist	1949 - 1951
Fred A. Fox, Agricultural Engineer	1998 - present
Donald W. Fryrear, Agricultural Engineer	1960 - 1962
Lawrence J. Hagen *, Agricultural Engineer & RL 1988 - 1994	1967 - present
R. K. Krauss, Soil Scientist	1965 - 1970
Leon Lyles, Agricultural Engineer & RL 1975 - 1988	1957 - 1960 & 1964 - 1988
R. D. Lynch, Soil Scientist	1956 - 1957
C. S. Parsons, Soil Scientist	1953 - 1954
Francis H. Siddoway, Soil Scientist	1957 - 1963
Edward L. Skidmore *, Soil Scientist & RL 1994 - present	1963 - present
R. M. Smith, Soil Scientist	1962 - 1967
John Tatarko *, Soil Scientist	1980 - present
Gary L. Tibke, NRCS Cooperating Agronomist	1996 - 2004
Page C. Twiss, Geologist	1966 - 1968
Simon J. van Donk, Agricultural Engineer	1999 - present
Larry E. Wagner *, Agricultural Engineer	1988 - present
Neil P. Woodruff, Agricultural Engineer & RL 1963 - 1975	1949 - 1975
Austin W. Zingg, Agricultural Engineer & RL 1947 - 1953	1947 - 1953

* Current or Past Adjunct Professor in Agronomy.

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