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# Wind erosion research--past, present, future

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When wind erosion occurs, it drastically and often dramatically affects the quality of our environment. Because dust often travels thousands of miles, it affects urban as well as rural people. Airborne soil, polluting the air we breathe, is both an irritant and a health depressant. It obscures visibility and interferes with air traffic, causes automobile accidents, fouls machinery bearings and electrical switching apparatuses, and deposits dust in homes, offices, schools, and stores.

Blowing soil sandblasts, abrades, and kills plants, reducing the quantity and quality of food supplies. Left uncontrolled, it buries irrigation ditches, fences, and roads. Removing soil from its source also ruins agricultural land and reduces crop yields by removing silt, clay, organic matter, and plant nutrients. The result can be economic disaster to individuals and, in extreme cases, to whole societies.

During the 1930s, a great drought demonstrated the tremendous power of the weather to affect the quality of our environment and to control the lives of individuals and communities. The "black blizzards" of the dust bowl of the 1930s inflicted great hardship on people and brought about the mass exodus so well described in John Steinbeck's *The Grapes of Wrath*. Nearly 95 percent of the 6.5 million acres of land put out of production suffered serious wind erosion damage (*34*). Dodge City, Kansas, had 120 days of blowing dust during the fall-to-spring blow season of 1935-36. Some animals suffocated, and sickness noticeably increased among the people. Their sickness seemed to be directly attributable to the dust-laden air (*6*).

In 1935, hospitals in the heart of the dust bowl reported 233 patients suffering from acute respiratory infections and 367 with blocked air tubes leading to the lungs. Thirty-three of those patients died. No records are available of those who suffered similarly but who did not enter hospitals. Few people had funds for medical care. Conditions were nearly as bad in 1934 when 115 patients were reported with similar ailments and 15 died.

The situation was so bad that the young farmer, Lawrence Svobida, closed his book *An Empire of Dust* (*52*), written after he had endured 9 years of extreme hardship in the dust bowl at Meade, Kansas, with the words, "My own humble opinion is that with the exception of a few favored localities, the whole Great Plains region is already a desert that cannot be reclaimed through the plans and labors of man."

Yet, within the decade, that area was an abundant supplier of food to "win the war and write the peace." A little later, when people became concerned about the quality of the environment, Chambers of Commerce talked about what a wonderful place Kansas is for living because of its clean air. In 1973, Kansas produced record-breaking wheat and sorghum crops valued at nearly $2 billion.

What brought about the change? It was a unique combination of the resilient resourcefulness of the people, new research findings, availability of better farm machinery, irrigation, and economic assistance in the form of government conservation programs that reversed Svobida's 1938 evaluation of the Plains. In assessing the relative importance of each of those factors on the resurgence of the Great Plains, it must be recognized that both extremely adverse climatic forces and nationwide economic debacle, the "Great Depression," were at work. The situation, therefore, was not altogether a sudden disaster when Svobida formed his opinion. Symptoms of distress were evident during the early twenties. By the early thirties the Great Plains was recognized as a major problem area. The economic and physical declines that preceded the duststorms were caused largely by lack of information about dealing with semiarid environments. Research that began with the early efforts of the dryland experiment stations and continues today seems to deserve an inordinate amount of credit for the vibrant resurgence of the Great Plains.

### *Past Research Programs*

Droughts and wind erosion during the latter part of the 19th century caused some concern about wind erosion and some recognition that the activity of wind is an important geologic phenomenon.

King (*36*) published a bulletin in 1894 about wind erosion and methods of controlling the sandy lands of Wisconsin. Udden (*54*) published some of the first quantitative estimates of solid, suspended material in duststorms in 1896. He reported 160 to 126,000 tons per cubic mile of dust and indicated an average of 850 million tons of dust were being carried 1,440 miles each year in the Western United States.

In 1911 the Bureau of Soils of the U.S. Department of Agriculture published a comprehensive bulletin *The Movement of Soil Material by Wind* by E. E. Free and the *Bibliography of Eolian Geology* by S. C. Stuntz and E. E. Free (*26*). But it took the dust bowl disaster to inspire those remaining on the land, and their governments, to begin research on why soils are eroded by wind and what remedies can be used to

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prevent the damage.

Soil surveys of the Great Plains were initiated to aid in stabilizing agriculture. Various state and federal agencies established emergency wind-erosion-control programs, and leading agricultural experts published papers and bulletins about the problem and ways to control wind erosion (*4*, *21*, *22*, *24*, *37*, *53*, *55*).

By the late 1930s, systematic and scientific approaches for wind erosion research were being pioneered by Chepil, Milne, and Doughty in Canada; von Karman and Malina in California; Joy in South Dakota; Whitfield in Texas; and Bagnold in England (*42*). The experimental methods used natural wind in the field and a suitably-directed, artificially-produced airstream. Special wind tunnels were developed and constructed in California and South Dakota in the U.S.; in Swift Current, Saskatchewan; and in London, England. Research produced information on the mechanics of soil transport by wind, the influence of cultural treatment on rates of movement, and the influence of windbreaks on windflow patterns.

### *Present Research Programs*

When World War II broke out, much of the research on wind erosion was discontinued. After the War, interest was renewed and research programs in England and Canada were reestablished. Bagnold published a highly important book, *The Physics of Blown Sand and Desert Dunes* (*3*), which established theory for much of the wind erosion mechanics work that has followed. Chepil also published an important series of basic papers dealing with the dynamics of wind erosion (*7*, *8*, *9*, *10*, *11*, *12*).

In the United States an intensive research program on wind erosion was started at Manhattan, Kansas, in 1947 by the U.S. Department of Agriculture in cooperation with Kansas State University. That research program, the only one of its kind, was started under the able leadership of two highly competent agricultural research scientists, Austin W. Zingg and W. S. Chepil, the pioneer in wind erosion research in Canada. The research project's primary purposes at the beginning, and continuing during the intervening years, were to study the mechanics of erosion of soil by wind, delineate factors with major influences on erosion, and devise and develop methods to control wind erosion.

In addition to the program at Manhattan, some wind erosion research has been conducted at Big Spring and Bushland, Texas; Wooster, Ohio; Madison, Wisconsin; Sidney, Montana; Morris, Minnesota; and Boulder, Colorado, in the U.S.; in Swift Current, Saskatchewan and Lethbridge, Alberta, Canada; and in Deniliquin, New South Wales, Australia. A book on eolian erosion that refers extensively to United States and Canadian research was published in Madrid, Spain, in 1967 (*44*).

Recent visits of U.S. scientists to the Soviet Union indicate that they have wind erosion research programs at Leningrad, Stavropol, Alma Ata, and Shortandi. Research at several U.S. State Experiment Stations, although generally not classified as wind erosion research, also has contributed indirectly to wind erosion control. Stubble mulching work at the Nebraska and Kansas stations is an example.

Research since the 1940s has contributed a volume of information leading to a better understanding of the mechanics of wind erosion, has identified factors influencing the amount of erosion, developed a wind erosion equation useful in designing control practices, evaluated the consequences or damage of wind erosion, and recognized the principles of wind erosion control.

Space limitations here permit only brief comments and a partial list of references for each of those areas. I hope the references will expand information for interested readers and lead to additional references and more complete information about wind erosion and its control.

Erosion-mechanics research has included analyses of windspeed and associated climatic data which have provided basic information on wind distribution and shear stress (*16*, *35*, *50*, *61*). The forces of both lift and drag have been discovered and their role recognized in the initiation and transport of soil particles, and the role and importance of turbulence in increasing erosion forces have been delineated (*5*, *15*, *38*). Surface creep, saltation, and suspension transport of soil particles have been quantified and characterized mathematically (*19*, *62*). Basic theory for, and practical application of, aerodynamic roughness elements in controlling wind erosion have been developed (*39*, *40*, *43*).

Extensive research has been carried out to delineate major factors influencing the amount of erosion that will occur from given agricultural surfaces and conditions. This work has included laboratory wind tunnel evaluations of soil conditions that influence wind erosion, the role of the kind, amount, and placement of residue, studies of the effect of field length, and portable wind tunnel evaluations of many farmers' fields (*13*, *14*, *20*, *47*). Such research, with analyses of climatic data, was used as a basis for developing the wind erosion equation, $E = f(I',K',C',L',V)$, now widely used to design wind erosion control practices (*25*, *49*, *50*, *59*).

The duststorms of the 1950s and recent intermittent wind erosion events in the Plains have provided an outdoor laboratory to obtain measurements on air pollution, a consequence of wind erosion. Measurements of concentrations of dust particulates during severe storms gave quantitative information on the air pollution load and provided data to establish relationships between dust concentration, visibility, and windspeed (*18*, *30*, *33*). Operation of a dust deposition network across parts of the U.S. in the early 1960s also provided information on recent eolian activity (*51*). There has been some effort, also, over the years to predict numbers of duststorms ahead of the blow season--to encourage precautionary measures (*17*, *29*). Plant damage, another consequence of wind erosion, has been evaluated in several research studies (*2*, *28*, *48*, *56*).

Five principles of wind erosion control can be established from analyses of wind erosion phenomena. They include establishing and maintaining vegetative or nonvegetative land cover, reducing field lengths along the prevailing wind direction, producing stable clods or aggregates, roughening the land, and leveling or benching land to reduce effective field widths and erosion rates on slopes and hilltops where wind shear stress maximizes. Research to develop practical methods of applying these principles has included studies with wind barriers, stripcrops, tillage, soil adhesives, and mulching. Publications from this research and on general wind erosion control practices are numerous (*1*, *23*, *27*, *31*, *32*, *41*, *45*, *46*, *57*, *58*, *60*).

## *Future Research Programs*

Where do we stand today? Has research and its application, more knowledgeable farmers, irrigation, better farm machinery, and government conservation programs brought us to the point where the dust bowl need be only a sad memory? Or, do we face the possibility of a recurrence, resulting in an economic disaster and a badly polluted environment? No one knows what would happen if the Plains area should have a drought worse than any previous one, but indications are that the dust bowl days will not be repeated.

There is evidence that control practices developed by researchers and applied to the land by SCS extension service technicians and farmers, utilizing better farm machinery and support from government conservation programs, have provided improved wind erosion control. During the 1936-37 blow season, there were 120 duststorms at Dodge City, Kansas. But, during the drought of the 1950s, which was more severe, only 40 duststorms occurred during the 1955-56 blow season. Records also show that incidence of wind erosion during the decade of the 1960s was relatively low despite the fact that severe drought occurred in some parts of the Plains. However, several incidents show that we have not completely solved the problem and cannot relax our research and erosion control efforts. The incidents include the drought and 36 sandstorms in west-central Texas during the 1970-71 blow season, the wind erosion on about 70 million acres of land in the United States, and the average of 5 million acres of land damaged each year by wind erosion over the past 30 years.

Research in the past has dealt mostly with the mechanics and prevention of mass soil removal from agricultural land in the surface creep and saltation processes. Future wind erosion research must continue in those areas and must also deal with short-term wind erosion events and with soil particles less than 100 microns in diameter that pollute our environment while traveling in suspended flow. Models must be developed that can use weather probabilities and provide a means of assessing land damage and food production. Future wind erosion research must also deal with wind erosion problems brought about by new technology and shortages of farm machinery, center pivot irrigation, reduced availability of energy, greater production of high economic investment and return crops, and diminishing water supplies.

A recently prepared, 10-year research program[1] to improve wind-erosion control, to protect crops and soils, and to reduce air pollution identified more than 20 research problems and approaches. Ten of the 20 are presented as examples of needs and direction for future wind erosion research:

1. To assess the impact of wind erosion on long-term soil productivity and crop yields: obtain information from bench mark soils relating crop yield to soil depth or topsoil removed, and determine specific soil physical or chemical properties that need to be measured to objectively monitor land damage from wind erosion.

2. To improve the accuracy of the wind erosion equation and facilitate its use in forecasting wind erosion activity and assessing land in condition to blow: further evaluate and define the climatic factor by examining soil drying rates and dryness of particles as functions of hydraulic soil properties and climatic variables; incorporate probability functions for the dynamic variables, especially the climatic factor, into the equation, converting it from a deterministic to a stochastic model; and determine seasonal variation of soil erodibility as influenced by climate and soil properties.

3. To quantify erosion, develop standards for reporting severity of soil blowing for individual windstorms, and assess environmental impact: develop a generally applicable flux equation to predict rates of soil erosion during windstorms; and determine the percentages of eroding soil suspended and the residence time and fate of various sizes of soil particles.

4. To determine large-scale regional assessments of land damage and land in condition to blow using the wind erosion equation: develop a data bank and techniques for using remote sensing (supplemented with ground truth) of climatic data, statistical sampling of bench mark soils at specified times, and probabilities of precipitation, wind, and soil drying.

5. To better quantify erosion and land

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1 USDA-ARS Research Program "Prevention of wind and water erosion" 20710, Technological objective 2 "Improved wind erosion control to protect crops and soils and reduce air pollution."

damage: develop measuring devices and samplers which can monitor surface creep, saltation, and suspended soil flow in remote locations without constant human attention.

6. To preserve and extend wind erosion protection and conservation of diminishing water supplies by crop residues: study basic microbial activity; evaluate possible negative (phytotoxic) effects of residues on crop yield and economics; screen and test various commerical products with potential for residue preservation; and develop economical methods for using the technology.

7. To provide a better understanding of the wind erosion process: conduct wind tunnel research on critical barrier ratio concept of erosion control as applied to crop stubble, soil clods, and surface roughness.

8. To improve wind erosion control using tillage operations and to conserve energy expended in tillage: conduct research on the optimum orientation of residues, the development of improved herbicide-tillage techniques, the role of sequence and frequency of operations, and the improvements of drilling and planting procedures.

9. To improve wind erosion control using wind barriers: continue simulation, wind tunnel, and field research to determine optimum porosity, shape, and spacing of wind barriers required to reduce soil blowing.

10. To improve farmer acceptance of wind erosion control technology: initiate research in the economic-psychological-human behavioral area using variations of thematic apperception tests to determine how the farmer perceives wind erosion, why he resists application of proven wind-erosion-control practices, and why he is willing to gamble on the probability of a serious wind erosion occurrence rather than routinely apply short-term or permanent control systems.

Wind erosion research has been discontinued at several locations. About 6.5 scientific man year's were devoted to wind erosion research in the United States in 1975. The probability of success in the research outlined in the next 10 years is estimated at 70 percent. However, the probability of achieving that level of success by 1985 with present levels of research input is probably not more than 50 percent. Funding for wind erosion research should be increased sufficiently to provide four to six additional scientists and for modest increases in existing programs.

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