LEON LYLES

PREDICTING AND CONTROLLING WIND EROSION

"The wind blows where it wills" is a biblical statement reflecting man's lack of control over winds' occurrence, speed, direction, duration, and distribution.[1] Wind, of course, is the force behind all soil blowing, and knowledge about its characteristics is essential in assessing the need for wind erosion protection on agricultural lands. Equally essential is knowledge of precipitation and drought.

Although there is little documentation concerning the extent and frequency of dust storms (sometimes called dirt storms) in the Great Plains before 1860, a few personal reports indicate they did occur.[2] Based on current knowledge of soil and surface conditions that are conducive to wind erosion, I believe they were local in origin and from coarse-textured (sandy) soils lacking vegetative cover. Possible reasons why vegetative cover was sparse or absent include drought, concentrated animal or human activity, sandy stream channels, fire, and perhaps insects.

Fire, of course, would destroy the surface vegetation, but not the root system that would largely protect the soil against wind erosion (except possibly on very sandy soils with sparse stands) until regrowth of perennial grass species. However, ash, because of its low weight per unit volume, could be easily picked up and transported by the wind and could account for reported dust storms (really ash or soot storms), in the eastern edge of the Plains where the wind erosion hazard is relatively low.

In the 1930s, the simultaneous occurrence of the most severe drought and the worst economic depression in U.S. history focused public attention on the fundamental importance of our land resources in general and on wind erosion in particular. Much has been written about those

LEON LYLES is Research Leader, U.S. Department of Agriculture, Agricultural Research Service, Kansas State University, Manhattan, Kansas.

[1]John 3:8 (NEB).

[2]R. Douglas Hurt, *The Dust Bowl* (Chicago: Nelson-Hall, 1981), 4; Paul Bonnifield, *The Dust Bowl* (Albuquerque: University of New Mexico Press, 1979), 13.

twin catastrophes. Various writers have identified factors they thought contributed to the cause(s) of the Dust Bowl. These include properties of the Plains soils, climate (especially precipitation and wind), plowing of the sod, one-crop farming (wheat), the rapid increase in farm tractors and other machinery, use of eastern farming methods, and inflated crop/land prices. All those factors were involved.

Wind erosion is caused by strong winds over bare, erodible soil. Coarser (sandy) soil textures are more susceptible to wind erosion than soils having a finer texture (more silt and clay), but for a given texture, erosion will be closely related to drought, crop, and tillage practices. Although there may be a weak link between droughty periods and average windspeed, which is slightly higher during those periods, erosive winds occur every year in the Plains, with the higher winds more likely to occur during February through May, peaking in April. Because it is unlikely that average winds during the 1930s were significantly different than other periods of equal length, wind cannot be considered the primary cause of the Dust Bowl. Of the other three factors—crops, tillage, and drought—the most important is drought. Why do I think that? Because the Dust Bowl period ended at the close of 1939, when average or above-average precipitation returned to the Plains. Annual precipitation at Dodge City, Kansas, averaged 15.71 inches in the 1930s compared to 23.98 inches in the 1940s. Except for the early 1950s, consecutive years of drought have not occurred since.

Before we turn our attention to wind erosion control principles and practices, I will briefly describe wind erosion. Wind erosion occurs in three distinct transport modes based on particle size: suspension, saltation, and surface creep.[3] Very small soil particles less than 100 micrometers (one-thousandth of a millimeter) in diameter are lifted from the surface and may be carried in suspension for some distance before ending up on the neighbor's farm or a couple of states to the east (downwind). These particles are the showy part of wind erosion, seen by the observer as dust storms, which have been called black blizzards, black rollers, bread-basket dust, and "Kansas Grit." Generally, however, less than 10 percent by weight of an eroding soil is carried in suspension.

In saltation, a wind blown sand grain or soil aggregate 100 to 500 micrometers in diameter, lifted from the surface but too large to be suspended, returns to the surface to hammer away at weak clods (aggregates) until they are whittled (abraded) into particles which also join the parade (avalanching). These particles hopping along close to the ground make up roughly 50 to 80 percent of an eroding soil. They usually end up in a fence row or ditch or edge of a vegetated area downwind.

[3]W. S. Chepil and N. P. Woodruff, "The Physics of Wind Erosion and Its Control," in *Advances in Agronomy* 15 (1963): 215–16.

Sand-sized soil particles or aggregates 500 to 1,000 micrometers in diameter, too large to leave the surface in ordinary erosive winds, are pushed, rolled, and driven by the spinning particles in saltation. In high winds, the whole surface appears to be creeping slowly forward. Surface creep makes up 7 to 25 percent of an eroding soil. Creep particles seldom move far from their points of origin.

Efforts to control wind erosion began very early in U.S. agriculture. Samuel Deane, a New England minister and farmer, in about 1790 was the first person in the United States to attempt to control wind erosion.[4] To prevent the blowing and drifting of sand, Deane recommended hedge fences, as well as plantations (planting) of locust trees. Thus wind barriers (also known as windbreaks and shelterbelts) such as trees, shrubs, grasses, crops, and inert materials have a long history as a wind erosion control practice. They provide a sheltered zone 10 to 15 times their height and reduce the length over which winds flow uninterrupted — both helping to reduce wind erosion.

F. H. King, after visual observations of thirty-five sites in Wisconsin in 1894, suggested ways to prevent "the destructive effects of winds." His main suggestions were: cultivating crops in long, narrow strips perpendicular to the prevailing winds and not wider than 15 to 20 rods (1 rod equals 16.5 feet); alternating with similar strips of grass or legumes (largely clover); green manuring (the practice of plowing under a growing crop) to increase water-holding power; leaving the ground uneven after seeding to lower the windspeed near the surface; and planting windbreaks on the section and quarter-section lines, i.e., one-half mile apart.[5] The first practice, called wind stripcropping, is still used on some soils today. Leaving the ground uneven is also still used. Because of deficient rainfall, however, green manuring is not practical in the semiarid parts of the Plains. Windbreaks at the spacing King recommended would fully protect only about 15 percent of the land, even if properly oriented to prevailing winds.

A 1910 USDA Farmers' Bulletin listed actions to control soil blowing, as follows:[6]

Increase the water content of the soil.
Increase the amount of humus (organic matter).
Provide a cover of growing vegetation.
Leave the stubble of the last crop still standing on the land.

[4] J. H. Stallings, *Soil Conservation* (New Jersey: Prentice-Hall, Inc., 1957), 13.

[5] F. H. King, *Destructive Effects of Winds on Sandy Soils and Light Sandy Loam With Methods of Protection*, Wisconsin Agricultural Experiment Station Bulletin 42 (Madison, Wisconsin, 1894), 19–29.

[6] E. E. Free and J. M. Westgate, *The Control of Blowing Soils*, U.S. Department of Agriculture, *Farmers' Bulletin* 421 (1910), 1–23.

Provide an artificial cover of straw and brush lines.
Plant windbreaks to protect fields.
Leave the soil surface in small clods instead of in a finely pulverized condition.
Roughen the surface by proper cultivation at right angles to the direction of dangerous winds.

Perhaps there was too much emphasis on the importance of the moisture and organic matter content of the surface soil for arid areas, but this is an excellent listing of wind erosion control methods and would fit well in a 1980s publication. The statement "a cover of vegetation is a nearly perfect protection against blowing," was and still is the cardinal principle of wind erosion control. The four principles of wind erosion control can be extracted from the above list.[7] They are:

Establish and maintain vegetation or vegetative residues.
Produce or bring to the surface nonerodible aggregates or clods.
Reduce field width along the prevailing wind direction.
Roughen the soil surface.

The "what" of erosion control principles and practices was available to the public at least 20 years before the Dust Bowl. I do not know, however, whether it was feasible for most farmers to apply control practices. The use of moldboard plow or lister made maintenance of crop residue impossible; the one-way plow (disk) was better but not effective after several operations, especially in a crop-fallow system. The rodweeder, as a secondary tillage tool, would have been a good choice to conserve crop residues but was not owned by many farmers. Although windbreaks to reduce field width are effective if correctly spaced and oriented, they are difficult to establish in the drier parts of the Plains and years pass before they grow sufficiently tall to give protection. Therefore, they would not have met immediate, short-term needs of the Dust Bowl years. Despite the credit the Prairie States Forestry Project has received in ending the Dust Bowl, windbreak plantings under the Project did not begin on a large scale until 1936.[8] The main practices available for use by farmers in the 1930s were production of nonerodible clods and roughening the land surface. Used alone, these practices are commonly called "emergency tillage" today. They may provide temporary control but seldom are dependable as the only control measure. Unfortunately, they fail more often under droughty conditions and, most frequently, on the more susceptible sandy soils. Consequently,

[7]L. Lyles, L. J. Hagen, and E. L. Skidmore, "Soil Conservation: Principles of Erosion by Wind," in *Dryland Agriculture,* Agronomy Monograph 23 (1983): 177–88.

[8]Ralph A. Read, *The Great Plains Shelterbelt in 1954,* Great Plains Agricultural Council Publication 16 (1958), 4.

Plains farmers did not apply adequate control methods and were almost overwhelmed by the drought, depression, and dust.

Although the "what" might have been known during the 1930s, the "how to" or "how much" of control principles and practices for the widely diverse soils, crops, and climate of the West were largely unknown. The goal of erosion researchers has been quantification of the need for protection and means to provide it, given those variables of soils, crops, and climate.

Because the cardinal principle of wind erosion control is maintaining vegetative materials on the soil surface, researchers and farmers tried to develop ways to apply this principle on cropland. L. S. Carter and G. R. McDole trace the practice of using crop residues as a stubble mulch as far back as 1910 when somebody began "gopher plowing" (by removing the moldboard from the plow) summer-fallowed land; only a small acreage, however, was managed in the stubble-mulch system by 1941.[9] Since that time, this practice of conserving or maintaining vegetation on the surface has evolved into various forms of tillage management, which currently go under the generic name of conservation tillage and have become a major technique for erosion control today. F. L. Duley and J. C. Russel began scientific studies for managing crop residues to control runoff and erosion near the end of the Dust Bowl.[10] World War II interrupted most soil conservation research just as the British Physicist, R. A. Bagnold's *The Physics of Blown Sand and Desert Dunes* (1941) became available. Later researchers were greatly influenced by Bagnold as they applied the lessons from his desert studies to research on agricultural lands.[11]

After the war, agricultural research was boosted by the Flannagan-Hope Bill, officially designated as the Research and Marketing Act of 1946. Section 10 of the bill read in part "... to provide further research into basic laws and principles relating to agriculture. . . ." That act was the source of funds to establish a USDA wind erosion project at Manhattan, Kansas, in late 1947. The project was under the administrative supervision of the Research Division of the Soil Conservation Service (SCS) until November 1953, when all soil conservation research except that related to the National Cooperative Soil Survey was transferred from the SCS to the Agricultural Research Service (ARS).[12] The project,

[9] L. S. Carter and G. R. McDole, *Stubble-Mulch Farming for Soil Defense,* U.S. Department of Agriculture, *Farmers' Bulletin* 1917 (1942), 1.

[10] F. L. Duley and J. C. Russel, "Crop Residues for Protecting Row-Crop Land Against Runoff and Erosion," *Soil Science Society of America Proceedings* 6 (1941): 484–87.

[11] R. A. Bagnold, *The Physics of Blown Sand and Desert Dunes* (London: Chapman and Hall, 1941).

[12] Robert L. Geiger, Jr., "A Chronological History of the Soil Conservation Service and Related Events," U.S. Department of Agriculture, Soil Conservation Service SCS-CI-1 (December 1955), 23.

officially called the High Plains Wind Erosion Laboratory, was associated with the Agronomy Department at Kansas State University. The name Wind Erosion Laboratory stuck, even though the official name today is Wind Erosion Research Unit. The number of scientists assigned to the Lab during any given year has ranged from one in 1947 to ten in 1967. Since 1967 the number has gradually decreased to five by 1980. This small unit, since its inception, has been a major focus of USDA wind erosion research.

Wind erosion research in the late 1940s and 1950s was concerned with development of suitable equipment and methods for studying wind erosion, including the processes by which soil materials are moved and transported by wind; the physical and chemical properties that affect soil erodibility; and the effects of plant cover/residue, surface barriers, topography, surface roughness, and mechanical and land use on soil drifting. Erosion control research was directed toward refining existing methods to make them economically feasible and more effective. Much was learned about how the principal soil properties—mechanical composition (percentage of sand, silt, and clay), organic matter content, calcium carbonate content, water-stable aggregates, dry aggregate size distribution, soil water, aggregate-particle density, and dry-aggregate stability—influenced the rate of wind erosion.[13]

Extended drought returned to the Plains during 1952–1956. Three consecutive years of drought (1952–1954) occurred at Dodge City, Kansas. The SCS estimated that wind erosion damaged about 15 million acres in the ten Great Plains states during the 1954–1955 "blow" season (November-May). The average area damage annually over the last fifty years was about 5 million acres. The drought was not as long as the one in the "dirty thirties" and received much less public attention. However, some journalists dubbed the decade the "filthy fifties."

ARS wind erosion research was initiated at Big Spring, Texas in 1954 and has continued with a two-person team mainly concerned with erosion control practices on large areas of sandy soils in west Texas where cotton is still king. ARS has conducted intermittent wind erosion studies at Mandan, North Dakota; Sidney, Montana; Prosser, Washington; Las Cruces, New Mexico; and Brookings, South Dakota.

General aspects of wind erosion control that have been studied during the 1960s and 1970s include wind climatology, influence of wind barriers, aerodynamic forces, effects of surface roughness, residue con-

[13]W. S. Chepil, "Properties of Soil Which Influence Wind Erosion: I-V," *Soil Science* 69 (1950) 1: 149–62, 2: 403–14; 71 (1951) 3: 141–53; 72 (1951) 4: 387–401, 5: 465–78. W. S. Chepil, "Factors that Influence Clod Structure and Erodibility of Soil by Wind: I-V," *Soil Science* 75 (1953) 1: 463–83; 76 (1953) 2: 389–99; 77 (1954) 3: 473–80; 80 (1955) 4: 155–62, 5: 413–21.

servation (tillage), soil stabilizers, plant tolerance, abrasion, surface soil aggregation, and erosion tolerance and soil renewal.

Wind erosion prediction rests largely on our ability to outguess nature. Variations in soil conditions and wind velocities combined with uncertainties of future wind and rain distribution make precise prediction impossible. I hasten to add, however, that fact has not prevented erosion researchers from trying! Such predictions assume that the climate of the past will, on the average, given a sufficiently long time, repeat itself. Based on that premise and previous studies, W. S. Chepil and colleagues at the Wind Erosion Research Unit, Manhattan, Kansas set out in the mid-1950s to develop a wind erosion equation that would parallel the water erosion equation (USLE) developed slightly earlier. The framework of the equation was established before Chepil's death, but it was not officially published until 1965 by N. P. Woodruff and F. H. Siddoway.[14] Taking the four principles of erosion control (discussed earlier) and adding a fifth for climate, the equation is expressed in this functional form:

$$E = f(I, K, C, L, V)$$

where E is the potential average annual soil loss in tons per acre, I is the soil erodibility index, K is the soil ridge roughness factor, C is the climatic factor, L is the unsheltered, weighted travel distance of the wind across a field, and V is the equivalent vegetative cover.

The soil erodibility index is the potential average soil loss in tons per acre per year from a wide, unsheltered, isolated field with a bare, smooth, noncrusted surface, based on climatic conditions near Garden City, Kansas. It is related to the percentage of soil clods or aggregates in the surface layer that are greater than about 1 millimeter—too large to be moved by ordinary erosive winds. The larger the percentage of these nonerodible aggregates, the smaller the expected amount of soil moved by wind. Sandy soils normally contain small amounts of nonerodible aggregates.

The ridge-roughness factor (K) is a measure of the effect of ridges on erosion rates compared to a smooth (nonridged) surface. It is determined from the height and spacing of ridges created by tillage implements.

The climatic factor (C) characterizes the erosive potential of climate (windspeed, precipitation, and air temperature) at a particular location compared to that at Garden City, Kansas, which is assigned an annual value of 100 percent, based on long-term data.

The L factor recognizes that more wind erosion occurs on large fields

[14] N. P. Woodruff and F. H. Siddoway, "A Wind Erosion Equation," *Soil Science Society of America Proceedings* 29 (September-October 1965) : 602–8.

than on small fields. It also considers that winds at a given site usually have a prevailing direction and that more winds blow in the prevailing direction in some places than in others.

The vegetative cover factor (*V*) is based on the quantity, kind, and orientation of vegetation or vegetative residues. Generally, the *V* factor recognizes that, on a weight basis, plants with small stalks are more effective in controlling erosion than plants with larger stalks, that standing plants' residues are more effective than flattened, and that fine-leafed crops like grasses and wheat provide a high degree of erosion control per unit weight.

The equation is used either to estimate potential erosion from a particular field or to determine the field conditions necessary to reduce potential erosion to "tolerable" amounts. It illustrates that simple questions about wind erosion control, expressed in terms of only one factor, cannot be answered directly (unconditionally). For example, a logical question—how much wheat stubble (the *V* factor) should I leave on my field to control wind erosion—cannot be answered without answering the other questions: how erodible is my soil (*I*), how rough is the surface (*K*), what is the climate here (*C*), and how large is the field (*L*)?

Erosion prediction researchers have responded to changes in society's perceptions of national resource problems. When preserving environmental quality became a public goal, wind erosion researchers focused on estimating the atmospheric dustload because suspension of particulates often causes poor visibility and health hazards and deposition causes chemical and sediment pollution. Research results suggested that particulate suspension from wind erosion exceeded that from all other sources—both natural and those generated by man.[15]

As a result of USDA's natural resource assessment required by the Resource Conservation Act of 1977, conservationists, researchers, and the general public have expressed a renewed concern about effects of erosion on long-term soil productivity. The RCA analyses revealed that only gross estimates were possible for assessing the effects of erosion on intrinsic soil productivity. That stimulated ARS, SCS, and the Economic Research Service (ERS) to develop a model that projects the long-term effects of erosion on soil productivity.[16] The wind erosion equation was incorporated as one component of that model.

Before I conclude, it seems appropriate to peek into the future. Not long after the beginning of any dry period in the Plains, the news media

[15]L. J. Hagen and N. P. Woodruff, "Particulate Loads Caused by Wind Erosion in the Great Plains," *APCA Journal* 25 (August 1975): 861.

[16]J. R. Williams, C. A. Jones, and P. T. Dyke, "A Modeling Approach to Determining the Relationship Between Erosion and Soil Productivity," *Transactions of the American Society of Agricultural Engineers* 27 (January–February 1984): 129–44.

call me about its expected effects or extent. A question that almost invariably arises is: Is this the beginning of another Dust Bowl? J. D. Schwein and his colleagues think that we don't need to worry.[17] They state "with farmers now applying the results of extensive research, chances of another Dust Bowl seem very small" and again, "with continued innovation by farmers and ranchers, and support for research and action programs, the demise of the Dust Bowl should be fact rather than fancy." They argue that it will not happen again because there are numerous government programs related to conservation and farmers are using improved technology, such as conservation tillage, improved crop varieties, improved farming equipment and farm chemicals (fertilizers and herbicides) and are working hard to be good stewards of their soil and water.

Those are sound reasons, but one does not need to look far to find other opinions. D. Worster raised ecological questions involving both ethics and science and concluded, "until these issues are considered and resolved, the future of the Great Plains will not be entirely secure against another dust bowl."[18] There are two reasons I am uneasy about future wind erosion in the United States.[19] First is the rapid expansion of irrigation (especially center-pivot systems) over the dust bowl region where the Ogallala Aquifer is the water source. Studies indicate that declining water tables and increasing costs of pumping may make irrigated agriculture economically unfeasible in parts of the Great Plains and the desert Southwest by 2000.[20] When pumping in the area becomes unprofitable, erosion-prone sandy soils now under center-pivot systems may be abandoned, leaving conditions ripe for accelerated wind erosion.

Second is the probability of a long drought. Droughts intensify the erosion control problem. One year of severe drought seldom has any great effect on control strategies, but two or more consecutive years can be disastrous because there is little or no crop residue and soil structure is so degraded that emergency tillage becomes ineffective. Why am I worried about an extended drought? After looking over the precipitation record for Dodge City, Kansas, for the last 109 years, I note: (1) there have been thirty drought years during that period (I define a drought year to be any year when precipitation is less than 80 percent of

[17] J. D. Schwein, W. O. Willis, and A. R. Grable, "Specter of Another Dust Bowl Seems Laid to Rest," in U.S. Department of Agriculture, *Using Our Natural Resources, Yearbook of Agriculture* (Washington: GPO, 1983), 422–29.

[18] Donald Worster, "Grass to Dust," *Environmental Review* 3 (1977): 9.

[19] L. Lyles, "The U.S. Wind Erosion Problem," in *Crop Production With Conservation in the 80's,* American Society of Agricultural Engineers Publication 7–81 (1981), 22–23.

[20] U.S. Department of Agriculture, *Soil and Water Resources Conservation Act, 1980 Appraisal Part II: Soil, Water, and Related Resources in the United States: Analysis of Resource Trends* (August 1981), 25.

the long-term average), (2) in the last quarter century, the time between drought years has been more than twice the 109-year average, (3) the longest period between drought years to date has been thirteen years (1970–1983), and (4) there have been no *consecutive* years of drought since 1956 (twenty-seven years). My conclusions are: Dodge City is definitely in a wet cycle, the longest since records began in 1875, and it is overdue for both individual and consecutive years of drought (assuming that the past climate will repeat in the future). To put these data in perspective, to a 27-year-old Dodge City native driving his stepside pickup with roll bars along Front Street (near Boot Hill) with a little "skoal" between his cheek and gum, consecutive years of drought are not even a memory. Depression, dust, and drought are something old-timers speak about when they want to impress the grandkids with how tough things were when they were younger. However, based on historical data, a long drought is due in the Central Great Plains, perhaps in the 1980s. Along with the dirty thirties and the filthy fifties, we may remember the hazy eighties.