ADVANCES IN WIND EROSION CONTROL IN THE GREAT PLAINS 1/

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W. S. Chepil stated "The basic causes of wind erosion are few and simple. Wherever (a) the soil is loose, finely divided, and dry, (b) the soil surface is smooth and bare, and (c) the wind is strong, erosion may be expected" (5). A. W. Zingg, after analyzing climate in relation to wind erosion problems, concluded that wind erosion is a serious threat in areas with low and variable precipitation, high frequency of drought, high temperatures and evaporation rates, and variable high wind velocities (36). All who live in the Great Plains know that the climate meets the criteria established by Zingg oftener than we would like; consequently, the basic conditions specified by Chepil as causing wind erosion frequently are present.

The Great Plains has a long history of wind erosion, most of it occurring after the virgin lands were broken and planted to cultivated crops, but some before the soil was cultivated (22). Weather records reveal major duststorms in 1854-60, 1864-65, 1874, 1880, 1890-94, 1901, 1910-14, 1917, 1919, 1922-23, 1934-39, and 1954-57. The extent of damage to the land is evidenced by quantitative measurements in the late 1930's (which indicated that many fields lost as much as 12 inches of topsoil) and by measurements of dust concentration in the 1950's indicating that as much as 10,000 tons per hour per vertical square mile of dust was in the air and moving about in western Kansas and eastern Colorado. Estimates made from such data and from analyses of wind records indicate that 48 million acre-feet or 1.2 inches of soil material probably has been removed from about 750,000 square miles in the Great Plains during the 40 years from 1922 to 1961 (7). Quantitative measurements have not been made since 1961, but during 1961-67 the Soil Conservation Service's Report of Wind Erosion Conditions in the Great Plains has indicated an average damage of about 2.7 million acres, with a low of 1 million in 1961-62 and a high of about 4.4 million in 1963-64.

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Despite millions of acres being damaged each year, I believe we have made some progress and advances in controlling wind erosion. It is difficult to find quantitative figures to justify progress because detailed records of duststorms are not kept throughout the Plains. Acreage damaged figures give us some idea of the extent of the problem but they do not necessarily give a measure of the seriousness of erosion. This is evident when one examines the acreage damage charts for the 1936-37 and the 1955-56 blow seasons and compares them with the number of duststorms. In 1936 and 1937 there were about 5 million acres of land damage each year by 120 duststorms. In 1955 about 15 million acres were reported as damaged and in 1956 about 10 million acres damaged by only 40 duststorms during those two years, which were considered to have had more serious droughts than during the 1930's. The conclusion from such data is that perhaps we haven't solved the wind erosion problem but we probably have made some rather substantial progress in reducing its seriousness.

How Advances Have Been Made

Advances in wind erosion control have been made because: (a) Farmers are more knowledgeable and have better attitudes, (b) better farm machinery is available, (c) cost-sharing by government has assisted in establishing conservation practices, and (d) research has contributed knowledge about the mechanics of wind erosion and provided a scientific basis for its control.

Farmers

The farmer today is much more knowledgeable about wind erosion and its control than his predecessor of the 1930's. If he is an older man, he learned some valuable lessons in the 1930's. If he is a younger man, he is probably better educated through formal schooling or through the valuable assistance he receives through the Soil Conservation Service and University Extension Service. Because he is more knowledgeable he has a better attitude and more readily accepts research results and practices recommended by Soil Conservation and Extension Service specialists.

Farm Machinery

Better machinery provided by manufacturers of farm equipment has contributed immeasurably to better wind erosion control. The manufacturers have provided larger and more efficient machines for the farm, many of which have introduced more effective and new kinds of tillage action. Manufacturers' organizations such as the Farm Equipment Institute and the Farm Equipment Manufacturers' Association have promoted a better understanding of equipment requirements through meetings and conferences with federal and state research groups. All of the various companies carry out extensive research programs to improve present lines of equipment and to develop new machines.

Development of subsurface sweep machines, which have advanced the stubble-mulch system of farming, have probably contributed the most to wind erosion control but development and improvement of drills to work in heavy residues, mulch treaders, stubble choppers, and rod-weeders for subsequent cultivation operations also have provided better wind erosion control.

Cost-sharing

Federal programs initiated in the 1930's and 1940's, such as Public Law 46 of the 74th Congress, shelterbelt planting, Water Facilities Act Development, Farm Forestry Act Plantings, and Land Utilization, added considerable impetus to establishing better control of wind erosion (15). Then in 1956, after the drought of the 50's, enactment of the Great Plains Conservation Program provided a means to further minimize the climatic and other hazards of farming and ranching in the Plains. Through this program, landowners receive federal payments for fulfilling contracts to do such things as plant cropland to grass, control brush, develop stock water sources, develop and improve irrigation systems, and spread water for hay crops. The program has also stimulated farmer and rancher use of stubble-mulch tillage and grazing management, though neither practice is cost-shared (15). All of those practices contribute directly or indirectly to controlling wind erosion, and the financial assistance--about 46 percent of total cost of a given practice--has made the farmers' economic situation much more tenable and in many cases has been the difference in applying or not applying a given practice.

Research

Research during the past 20 years has given us a better understanding of the wind erosion process and of methods to control it. Since the last meeting of this group in 1962 where Dr. Chepil reported on wind erosion factors, I think there have been some advances resulting from research. In this section we will point out particular areas where research has contributed to better wind erosion control, mention a few things learned, and provide a rather complete reference list for anyone wanting more detail.

Mechanics of wind erosion.--Continuing studies of the physics or mechanics of the wind erosion processes contribute indirectly to wind erosion control by providing a better understanding of how wind moves soil and of the forces we must deal with to devise control measures. Research to evaluate the turbulence of the wind and the forces exerted as soil particle movement is initiated has indicated (a) a turbulence factor of 2.7 near the soil surface, (b) a lift force equal to about 0.85 of the drag force, and (c) a threshold drag ranging from 0.85 dynes/cm.^{2} to 14.0 dynes/cm.^{2}, depending on size and density of soil particles but equal to that derived from a 13- to 15-mile per hour wind measured at 1-foot height for most field soils (6,10).

Recent studies of dust deposition from the atmosphere have shown that the amount deposited decreases with distance from source, ranges from 10 to 3,600 pounds per acre per month from the Rocky Mountains to the East Coast, and seems large enough to influence soil genesis and soil renewal (28).

Major factors influencing wind erosion.--The delineation of major factors influencing the amount of erosion from a given field and development of a wind erosion equation have perhaps been two of the most important contributions toward advances in wind erosion control that have come from research (35). The equation that is useful in determining the potential amount of erosion from a given field and in designing wind erosion control measures is

$$E = f(I', C', K', L', V) \qquad (1)$$

where E = average annual soil loss in tons per acre, I' = soil erodibility index measured in terms of soil aggregates greater than 0.84 mm. in diameter and land slope percentage, C' = climatic factor measured in terms of wind velocity and surface soil moisture, K' = soil surface roughness, L' = unsheltered field width measured along direction of prevailing wind, and V - vegetative cover.

Recent research that has contributed to the improvement and usefulness of the equation inclues: (a) Determining I values for highly erodible soils in Ohio, thus extending the range of application of the equation, (b) analyzing windflow patterns over hills and knolly terrain and determining a coefficient to account for increased wind forces on tops and windward slopes of hills of different percentage slopes (9), (c) computing a monthly climatic factor C' for all areas in the United States subject to wind erosion, whibh accounts for monthly variations in wind velocity and provides a better short-term index of wind velocity's influence on soil erosion (27), (d) determining the relation between soil roughness and erodibility, indicating that a ridge roughness of from 2 to 5 inches is more effective than roughness less or greater (4), (e) developing a mathematical method for computing magnitude of wind erosion forces, prevailing wind erosion direction, preponderance of wind erosion forces in the prevailing direction, and computing these values for 212 locations in the United States thus providing useful information for evaluating need for wind erosion protection, proper orientation and spacing of a suitable barrier, relative merits of barrier orientation, and field length distances D_f and L in the wind erosion equation (24, 27), (f) determining distances protected from soil erosion by various kinds of field shelterbelts, which is useful in determining the distances D_b and L in the wind erosion equation (34), and (g) studying the effects of different kinds, amounts, and orientation of residues on wind erosion and development of the parameter V in the wind erosion equation (23, 35).

Tillage

Advances in wind erosion control have come from a number of recent research studies to determine the influence of soil variables on tillage, to measure the performance characteristics of stubble-mulch tillage machines, to evaluate longtime effects of delayed fallow, to evaluate farmer tillage practices, and to develop machines and systems to increase soil cloddiness. Investigations of the influence of soil density, moisture, and texture on soil cloddiness showed that there is an optimum moisture level that produces more cloddiness of increased stability, that increasing density by compaction greatly increases clod yield and strength, and that the rate of increase is related to texture (19, 20, 21). Performance of various stubble-mulch tillage machines has been measured in regard to the machines' conserving residues and producing clods for wind erosion control (1, 2, 12, 13, 29, 31, 32, 33). Evaluation of longtime effectiveness of stubble-mulch farming and delayed fallow showed those two practices to maintain good wheat yields and provide adequate soil clods and residue for wind erosion control. Portable wind tunnel testing of practices farmers use to control wind erosion on sandy soils of northwest Ohio showed that delaying tillage to corn planting time, using no-tillage planting, sidewinder or power-disk planting methods are far more effective in controlling wind erosion than the plow-plant method. Other research has determined design criteria and helped to develop and test impact-type tools to increase the cloddiness potential of sandy loam soils (17).

Nonvegetative and processed vegetative soil stabilizers

Research by the Wind Erosion Laboratory, the Big Spring Field Station, Big Spring, Texas, and the International Synthetic Rubber Co. Ltd., Southampton, England, has provided information on effectiveness, amounts required, and costs of a number of nonvegetative and processed vegetative soil stabilizers, which are useful in advancing wind erosion control (11, 14, 30). Stabilizers evaluated include gravel and crushed rock, various surface films such as resin-in-water emulsion (petroleum origin), rapidcuring cutback asphalt, asphalt-in-mineral oil emulsions, wood cellulose fiber, and cotton gin trash. Cutback asphalt is particularly effective. Asphalt and resin emulsions. especially those that remain moist at least 3 months after application, are effective. Latex-in-mineral oil emulsions are very effective and moderate in cost. Starches are not effective. Wood cellulose fiber is reasonably effective if a binder like asphalt is mixed with the fiber. About 1.5 tons per acre of cotton gin trash is required to hold erosion rates on loamy fine sand to a tolerable amount (3 tons per acre per year), and 3 or 5 tons of trash reduced soil losses by 73 and 88 percent, respectively.

Crop row spacing

Recent testing of grain sorghum and wheat row spacing using a portable wind tunnel has provided useful information on the influence of space between rows and on planting parallel or non-parallel with wind directions. Erosion losses on sorghum stubble land can be significantly reduced if high plant populations within recommended limits (240 square inches per plant in southwestern Kansas) are planted in narrow (21-inch) rows perpendicular to the prevailing wind erosion direction (26). Eight-inch row spacing of winter wheat provides a considerably less midwinter erosive condition on sandy lands than does 10- or 12-inch row spacing, and winds blowing parallel to wheat rows eroded nearly 10 times more soil than winds blowing perpendicular to rows (16).

Barriers

Continuing field and laboratory research on wind barriers at Big Spring, Texas, and Manhattan, Kansas, has shown: (a) A barrier of 40 percent porosity is more effective in reducing leeward windspeed than one of 0, 20, or 60 percent porosity, (b) rows of annual crops of kenaf, pearl millet, and the forage sorghum "Cropguard" produce effective barriers in the sandylands of Texas, and (c) trees, shrubs, and grasses like Lombardy poplar, honeylocust, Russian mulberry, caragana, American plum, honeysuckle, tamarisk, pampasgrass, and bamboograss have good drought hardiness and potentials for producing effective wind barriers in central and western Kansas. Present research is examining barrier effects on microclimate and the energy budget.

Plant abrasion

Research at Manhattan, Kansas, on vegetables and at Big Spring, Texas, on cotton has revealed differences in erosion tolerances of those two crops. Cotton yield apparently is not affected by wind erosion unless erosion rates are high enough to completely kill the plants but relatively low rates of sand movement (0.2-ton per rod width per hour) severely damage green bean seedlings and substantially reduce yields (3, 25). Present research is evaluating the tomatoes' tolerance to abrasion under varying conditions of moisture stress.

Wind-rain

Recent research at Manhattan to evaluate effects of wind-driven rain on clod destruction has contributed indirectly to better wind erosion control by giving information useful in connection with other research on optimum size and number of clods needed to control erosion and on methods of producing clods. Resistance of clods to beating and wetting action of rainfall was strongly related to clod size and to intensity and duration of rainfall. Small clods were more readily destroyed by raindrop impact than large clods. Short-duration, high-intensity rains were more destructive than long-duration, low-intensity rains. Up to 66 percent more soil is detached from clods exposed in rain driven by 30-mile-per-hour wind than from clods exposed to rain of equal intensity and duration without wind (18). Present research is evaluating the effect of wind on the path of falling raindrops.

Prediction of erosion hazard

Some research has been done to attempt to devise a method of predicting the wind erosion hazard before it occurs so precautionary measures can be taken. Analyses of precipitation, wind, and temperature data in relation to number of duststorms occurring at Dodge City and Garden City, Kansas, during the 40 years, 1922-61, has produced a prediction equation with only fair reliability (8). The predicted number of duststorms for a given blow season is calculated from an analysis of conditions for a 3-year period prior to May 31 of each year. Values of C_c, the crucial climatic index; C_3, the 3-prior-year index for 1966 and 1967; and N, the number of duststorms predicted for four locations in Kansas are as follows:

Location	C_c	C_3		N	
		1966	1967	1966	1967
Concordia	35	35	37	4	9
Dodge City	94	102	118	20	24
Goodland	83	154	108	33	26
Wichita	34	24	127	2	26

The predictions indicate that the 3-prior-year index for 1967 is above crucial for all locations and that except for Goodland, the potential for duststorms is greater this year than last. The erosion hazard in the Wichita and Goodland areas is particularly high and some precautionary emergency measures might be necessary in those areas if strong winds are experienced in the critical February-April period.

More research is needed to improve predictions. The present prediction provides some indication of the erosion hazard; however, it does not adequately assess the influence of late summer and fall precipitation and soil moisture when wheat is planted. If soil moisture is good at planting time and winter wheat makes substantial growth, the erosion hazard seems to be substantially reduced regardless of prior conditions.

Conclusions

Advances in wind erosion control have been made in the Great Plains because of better attitudes and "know how" on the part of the farmers; because farm machinery companies have improved tillage, planting, and harvesting machinery; because the government cost-sharing programs have helped finance conservation practices; and because research has given us a better understanding of the mechancis of wind erosion and methods of control. While advances have been made, there is room for improvement. We still have more duststorms than we need. Cropping systems and methods of farming are continually changing, e.g., we raise some vegetables in Kansas now and we are talking about leveling and benching more land. We must strive to devise and apply more effective methods of wind erosion control to the changing agricultural systems.

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