Proc. Intl. Conf. Dryland Farming Aug. 15-19, 1988, Texas AES Amarillo, TX

88-561-A

File Copy

27 Coping with the Wind

E. L. Skidmore

U.S. Department of Agriculture, Agricultural Research Service, Wind Erosion Research Unit, Kansas State Universsity, Room 105-B, East Waters Hall, Manhattan, Kansas 66506

Introduction

High Potential Evaporation

Wind in low humidity environments increases the potential evaporation rate and, thus, increases water use and plant water stress in a dryland farming environment. Aristotle (cited by Penman, 1956) believed that wind is a more important factor than sun for causing evaporation. Skidmore et al. (1969) characterized the contribution of wind to potential evapotranspiration for a climate typical of the Great Plains and found that on consecutive "nonwindy" and "windy" days, the wind-dominant term of the model for computing potential evaporation contributed 33 and 113%, respectively, more than the radiation-dominant term to the total calculated potential evaporation.

Wind Erosion

Extensive soil erosion in the U.S. Great Plains during the last half of the 19th century and in the prairie region of western Canada during the 1920s warned of impending disaster. In the 1930s, a prolonged dry spell culminated in dust storms and soil destruction of disastrous proportions in the prairie regions of both western Canada and the Great Plains (Anderson, 1975; Svobida, 1940; Malin, 1946abc; Johnson, 1947; Hurt, 1981).

Wind erosion physically removes the most fertile portion of the soil from fields and, therefore, lowers productivity of the land. Some soil from damaged lands enters suspension and becomes part of the atmospheric dust load. Hagen and Woodruff (1973) estimated that eroding lands of the Great Plains contributed 244 and 77 million Mg of dust per year to the atmosphere in the 1950s and 1960s, respectively. Jaenicke (1979) estimated the source strength of mineral dust from the Sahara at 260 million Mg per year. Dust obscures visibility and pollutes the air, causes automobile accidents, fouls machinery, and imperils animal and human health. Blowing soil also fills road ditches; reduces seedling survival and growth; lowers the marketability of vegetable crops like asparagus (*Asparagus officinalis*), green beans (*Phaseolus vulgaris*), and lettuce (*Lactuca sativa*); increases the susceptibility of plants to certain types of stress including diseases; and contributes to transmission of some plant pathogens.

Wind erosion continues as a national problem, with the greatest potential for occurrence centered in the Great Plains—80% of susceptible cropland and 42% of susceptible rangeland. The 10 Great Plains states contain 71% of the total wheat (*Triticum aestivum* L.) area in the U.S. About 2 million ha are moderately to severely damaged by wind erosion in those states each year. Other susceptible areas include the coarse-textured soils of the arid West, the muck and sandy soil areas around the Great Lakes, the Columbia River Basin, and the Gulf and Atlantic seaboards. A recent national erosion inventory showed that the potential for wind erosion in amounts greater than 11 Mg/ha annually exists on 66 million ha (163 million acres) of land in the United States—22.5 million ha of cropland, 43 million ha of rangeland, and 0.5 million ha of forest land.

Reducing Potential Evaporation

The high potential evaporation induced by wind is combated by reducing wind speed at the evaporating surfaces and conserving the soil water. Since four sessions of this conference treat water conservation, I shall only discuss water conservation as it relates to use of wind barriers.

Barrier reduction of wind speed reduces evaporation and is frequently the main purpose of windbreaks (Staple, 1961; Skidmore and Hagen, 1970, 1973). A characterization of the contribution of wind to potential evaporation for a climate typical of the Great Plains demonstrated that for high temperature/low humidity environments, a decrease in wind speed also profoundly decreased evaporation from freely evaporating surfaces (Skidmore and Hagen, 1970, 1973; Skidmore et al., 1969). Calculations (Skidmore and Hagen, 1973) using climatological data (May through September 1960-1969) showed a 31 and 26% average-potential-evaporation reduction from 0 to 10*H* (barrier height) distances north of east-west oriented barriers near Dodge City, Kansas, and Bismark, North Dakota, respectively. When the area was extended to 30*H* distances, the average evaporation decrease was 14 and 7% for Dodge City and Bismark, respectively.

Reducing Wind Erosion

Barriers

In addition to reducing evaporation, barriers have long been recognized as valuable for controlling wind erosion (Bates, 1911). Hagen (1976) and Skidmore and

Hagen (1977) developed a model that, when used with local wind data, shows wind barrier effectiveness in reducing wind erosion forces. Barriers will reduce wind forces more than they will wind speed (surface wind shear stress is proportional to wind speed squared). A properly oriented barrier, when winds predominate from a single direction, will decrease wind erosion forces by more than 50% from the barrier leeward to 20 times its height; and the decrease will be greater for shorter distances from the barrier.

Different combinations of trees, shrubs, tall-growing crops, and grasses can reduce wind erosion. Besides the more conventional tree windbreak, many other barrier systems are used to control wind erosion. They include annual crops like small grains, corn (*Zea mays* L.), sorghums (*Sorghum* sp.), sunflowers (*Helianthus annuus* L.), tall wheatgrass (*Agropyron* sp.), sugarcane (*Saccharum* sp.), and rye (*Secale cereale*) strips on sands in Florida.

Most barrier systems for controlling wind erosion, however, occupy space that could otherwise be used to produce crops. Perennial barriers grow slowly and are often established with difficulty. Such barriers also compete with the crops for water and plant nutrients. Thus, the net effect for many tree-barrier systems is that their use may not benefit crop production. Perhaps the tree-barrier systems could be designed so that they become a useful crop, furnishing nuts, fruits, or wood.

Stabilizers

Another method that has been used to control wind erosion is use of soil stabilizers. Periodically, symposia (DeBoodt and Gabriels, 1976; Armbrust and Lyles, 1975) are held on soil conditioning, including papers on some aspect of using soil conditioners for controlling wind erosion. Chepil et al. (1963) found several products that successfully controlled wind erosion for a short time, but were relatively expensive. Armbrust and Lyles (1975) found five surface-soil stabilizers that met their criteria for successful use, including low cost. However, they added that before soil stabilizers can be used on agricultural lands, methods must be developed to apply large volumes rapidly. Also, reliable pre-emergent weed-control chemicals for use on coarse-textured soils must be developed, as well as films that resist raindrop impact, yet still allow water and plant penetration without adversely affecting the environment. Activating neutral sand surfaces with iron sulfate and stabilizing the surface with ureaformaldehyde has much promise as an inexpensive and effective method from controlling wind erosion on sandy soils (M. DeBoodt, personal communication, Ghent, Belgium).

Clods and ridges

Ridge roughness and soil cloddiness are two principal factors affecting wind erosion (Woodruff and Siddoway, 1965). Soil erodibility by wind decreases rapidly as fraction of soil aggregates > 0.84 mm increases. Ridges were found to reduce wind erosion by 50% (Armbrust et al., 1964) or more (Fryrear, 1984). A rough, cloddy surface resistant to the force of wind can be created on many cohesive soils with appropriate "emergency tillage." Listers, chisels, cultivators, one-way disks with two or three disks removed at intervals, and pitting machines can be used to roughen the surface and bring compact clods to the surface. Emergency tillage is most effective when done at right angles to the prevailing wind direction. Because clods eventually disintegrate (sometimes rapidly), emergency tillage offers at best only temporary wind erosion control (Woodruff et al., 1957).

Crop residue

Establishing and maintaining sufficient vegetative cover is referred to as the "cardinal rule" for controlling wind erosion. Studies to quantify specific properties of vegetative covers influencing wind erosion led to the relationship presented by Woodruff and Siddoway (1965), showing the influence of an equivalent vegetative cover of small grain and sorghum stubble for various orientations. Efforts have continued to evaluate the protective role of additional crops (Lyles and Allison, 1981; Armbrust and Lyles, 1985), range grasses (Lyles and Allison, 1980), desert shrubs (Hagen and Lyles, in press) and feedlot manure (Woodruff et al., 1974), and the protective requirements of equivalent residue needed to control wind erosion (Lyles et al., 1973; Skidmore and Siddoway, 1978; Skidmore et al., 1979).

Research Needs

Past research has contributed significantly to understanding the mechanics of wind erosion, delineated those factors having major influence on wind erosion, and developed methods for control. One of the major accomplishments was the development of an empirical wind erosion model. This model has been used extensively to predict potential wind erosion and determine field conditions necessary to control erosion.

While this past research has been reasonably accepted and implemented, significant gaps exist in our understanding and technology. We need to improve our technology for measuring wind erosion and monitoring windblown soil transport; better understand the soil aggregation process as influenced by inherent soil properties, soil management, cropping sequence, climate, and the changes in aggregate status seasonally and during a wind erosion event; determine probabilities and establish confidence limits for predicting duration and intensity of meteorologic conditions conducive to wind erosion; develop a physically based flux equation for predicting wind erosion during individual wind storms; and develop soil-, climate-, and crop-specific conservation tillage and residue management systems that are most cost-effective for sustaining agricultural productivity and protecting the environment. Research is in progress to better cope with wind erosion problems in dryland agriculture (Hagen, 1988; Gregory, 1988; Fryrear and Stout, 1988).

References

Anderson, C. H. 1975. A history of soil erosion by wind in the Palliser Triangle of Western Canada. Historical Series No. 8, Research Branch, Canada Department of Agriculture. 25 pp.

Armbrust, D. V., W. S. Chepil, and F. H. Siddoway. 1964. Effects of ridges on erosion of soil by wind. Soil Science Society of America Proceedings 28:557-560.

Armbrust, D. V. and L. Lyles. 1975. Soil stabilizers to control wind erosion. Soil Conditioners 7:77-82.

Armbrust, D. V. and L. Lyles. 1985. Equivalent wind erosion protection from selected growing crops. Agronomy Journal 77:703-707.

Bates, C. G. 1911. Windbreaks: Their influence and value. United States Department of Agriculture, Forest Service Bulletin 86. 100 pp.

Chepil, W. S., N. P. Woodruff, F. H. Siddoway, D. W. Fryrear, and D. V. Armbrust. 1963. Vegetative and nonvegetative materials to control wind and water erosion. Soil Science Society of America Proceedings 27:86-89.

DeBoodt, M. and D. Gabriels (eds). 1976. Third international symposium on soil conditioning. Belgium: State University of Ghent.

Fryrear, D. W. 1984. Soil ridges-clods and wind erosion. Transactions of the American Society of Agricultural Engineers 27:445-448.

Fryrear, D. W. and J. E. Stout. 1988. Instrumentation for evaluating wind erosion. *In* Wind erosion conference proceedings. Lubbock: Texas Tech University.

Gregory, J. 1988. Formulation of the Texas Tech wind erosion model. *In* Wind erosion conference proceedings. Lubbock: Texas Tech University.

Hagen, L. J. 1976. Windbreak design for optimum wind erosion control. p. 31-36. *In* Shelterbelts on the Great Plains - Proceedings of the symposium. Great Plains Agricultural Council Publication Number 78.

Hagen, L. J. 1988. New wind erosion model developments in the USDA. *In* Wind erosion conference proceedings. Lubbock: Texas Tech University.

Hagen, L. J. and L. Lyles. (In press) Estimating small grain equivalents of shrub-dominated rangelands for wind erosion control. Transactions of the American Society of Agricultural Engineers.

Hagen, L. J. and N. P. Woodruff. 1973. Air pollution from dust storms in the Great Plains. Atmosphere Environment 7:323-332.

Hurt, R. D. 1981. The dust bowl: An agricultural and social history. Chicago: Nelson-Hall. 214 pp.

Jaenicke, R. 1979. Monitoring and critical review of the estimated source strength of mineral dust from the Sahara. p. 155-157. *In* Christer Morales (ed.) Saharan dust. Mobilization, transport, deposition. Scope 14. New York: John Wiley & Sons.

Johnson, V. 1947. Heaven's tableland - The dust bowl story. p. 155-157. New York: Farrar-Straus.

Lyles, L. and B. E. Allison. 1980. Range grasses and their small grain equivalents for wind erosion control. Journal Range Management 33:143-146.

Lyles, L. and B. E. Allison. 1981. Equivalent wind-erosion protection from selected crop residues. Transactions of the American Society of Agricultural Engineers 24:405-408.

Lyles, L., N. F. Schmeidler, and N. P. Woodruff. 1973. Stubble requirements in field strips to trap windblown soil. Kansas Agricultural Experiment Station Research Publication 164. 22 pp.

Malin J. C. 1946abc. Dust storms - part one, two, and three, 1850-1860, 1861-1880, 1881-1900, respectively. The Kansas Historical Quarterly 14:129-144, 265-296, 391-413.

Penman, H. L. 1956. Evaporation: An introductory survey. Netherlands Journal Agricultural Science 4:9-29.

Skidmore, E. L. and L. J. Hagen, 1970. Evaporation in sheltered area as influenced by wind break porosity. Agriculture Meteorology 7:363-374.

Skidmore, E. L. and L. J. Hagen. 1973. Potential evaporation as influenced by barrier-induced microclimate. Ecological Studies 4:237-244. New York: Springer Verlag.

Skidmore, E. L. and L. J. Hagen. 1977. Reducing wind erosion with barriers. Transactions of the American Society of Agricultural Engineers 20:911-915.

Skidmore, E. L., H. S. Jacobs, and W. L. Powers. 1969. Potential evaporation as influenced by wind. Agronomy Journal 61:543-546.

Skidmore, E. L., M. Kumar, and W. E. Larson. 1979. Crop residue management for wind erosion control in the Great Plains. Journal of Soil and Water Conservation 34:90-96.

Skidmore, E. L. and F. H. Siddoway. 1978. Crop residue requirements to control wind erosion. p. 17-33. *In* W. R. Oschwald (ed.) Crop residue management systems. ASA Special Publication Number 31. Madison, Wisconsin: American Society of Agronomy.

Staple, W. J. 1961. Vegetative management and shelterbelts in evaporation control. Proceedings of Hydrology Symposium 2:214-232.

Svobida, L. 1940. An empire of dust. Caldwell, Idaho: Caxton Printers, Ltd. 203 pp.

Woodruff, N. P., W. S. Chepil, and R. D. Lynch. 1957. Emergency chiseling to control wind erosion. Kansas Agricultural Experiment Station Technical Bulletin 90.

Woodruff, N. P. and F. H. Siddoway. 1965. A wind erosion equation. Soil Science Society of America Proceedings 29:602-608.

Woodruff, N. P., L. Lyles, J. D. Dickerson, and D. V. Armbrust. 1974. Using cattle feedlot manure to control wind erosion. Journal of Soil and Water Conservation 29:127-129.