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WIND EROSION CONTROL

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Abstract

Wind erosion is a serious problem in many parts of the world. It physically removes from the field the most fertile portion of the soil, pollutes the air, fills road ditches, reduces seedling survival and growth, lowers the marketability of many vegetable crops, and creates new desert landforms and landscapes. It is generally worse in arid and semiarid than in humid and subhumid climates.

A wind erosion equation was developed as the result of many investigations on the factors influencing wind erosion. It is a useful guide to wind erosion control principles. The functional relationship is expressed as $E = f(I, K, C, L, V)$, where E is potential average annual soil loss per unit area, I is a soil erodibility index, K is a soil ridge roughness factor, C is a climatic factor, L is the unsheltered median travel distance of wind across a field, and V is an equivalent quantity of vegetative cover.

Principles suggested by the wind erosion equation for controlling wind include: stabilizing erodible surface soil with various materials; producing a rough, cloddy surface; reducing field width or the distance wind travels in crossing an unprotected field with barriers and strip crops; and establishing and maintaining sufficient vegetative cover. This last item is sometimes referred to as the "cardinal rule" for controlling wind erosion.

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Introduction

Wind erosion is a serious problem in many parts of the world, and extensive aeolian deposits from past geologic eras give evidence that it is not a recent phenomenon.

Wind erosion is worst in arid and semiarid areas where these conditions frequently occur: (1) loose, dry, finely divided soil; (2) smooth soil surface devoid of vegetative cover; (3) large fields; and (4) strong winds (FAO, 1960). Arid and semiarid lands are extensive. Arid lands comprise about one-third of the world's total land area and are the home of one-sixth of the world's population (Dregne, 1976; Gore, 1979). General areas most susceptible to wind erosion on agricultural land are: much of North Africa and the Near East, parts of southern and eastern Asia, Siberian Plain, Australia and southern South America, and the semiarid and arid portions of North America (FAO, 1960).

Lands undergoing desertification become vulnerable to wind erosion (Secretariat, 1977, p. 14). In pastoral rangelands, composition of pastures subject to excessive grazing in dry periods deteriorates, the proportion of edible perennial plants decreases, and the proportion of annuals increases. The thinning and death of vegetation in dry seasons or droughts increase the extent of bare ground, and surface-soil conditions deteriorate, increasing the fraction of erodible aggregates on the soil surface. In rainfed farming, removal of the original vegetation and fallow expose the soil to accelerated wind and water erosion.

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

Wind erosion physically removes from the field the most fertile portion of the soil and therefore lowers productivity of the land (Daniel and Langham, 1936; Lyles, 1975).

Some soil from damaged lands enters suspension and becomes part of the atmospheric dustload. Hagen and Woodruff (1973) estimated that eroding lands of the Great Plains contributed 244 and 77 million tons 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 tons per year. Dust obscures visibility and pollutes the air, causes automobile accidents, fouls machinery, and imperils animal and human health.

Blowing soil fills road ditches, reduces seedling survival and growth, lowers the marketability of vegetable crops like asparagus, green beans, and lettuce, increases the susceptibility of plants to certain types of stress including diseases, and contributes to transmission of some plant pathogens (Hayes, 1965, 1966; Claflin et al., 1973).

Control Principles

Principles for controlling wind erosion include: stabilizing with various materials; producing a rough, cloddy surface; reducing effective field width with barriers; and establishing and maintaining sufficient vegetative cover (Woodruff et al., 1972).

Stabilizers. Various soil stabilizers have been evaluated to find suitable materials and methods to control wind erosion (Armbrust and Dickerson, 1971; Armbrust and Lyles, 1975; Chepil, 1955; Chepil and Woodruff, 1963; Chepil et al., 1963; Lyles et al., 1969; Lyles et al., 1974). Several tested products successfully controlled wind erosion for a short time but many were more expensive than equally effective wheat straw anchored with a rolling disk packer (Chepil et al., 1963). The following are criteria for surface-soil stabilizers: (1) 100 percent

of the soil surface must be covered, (2) the stabilizer must not adversely affect plant growth or emergence, (3) erosion must be prevented initially and reduced for at least 2 months, (4) the stabilizer should apply easily and without special equipment, and (5) cost must be low enough for profitable use (Armbrust and Lyles, 1975). Armbrust and Lyles (1975) found five polymers and one resin-in-water emulsion that met all those requirements. They added, however, that before soil stabilizers can be used on agricultural lands, methods must be developed to apply large volumes rapidly. Also, reliable preemergent weed-control chemicals to use on coarse-textured soils must be developed as well as films resistant to raindrop impact, yet still allow water and plant penetration without adversely affecting the environment.

Rough, Cloddy Surface. Chepil and Milne (1941a), investigating the influence of drifting dune materials and cultivated soils, found that the initial intensity of drifting was always much less over a ridged than a smooth surface. Ridging cultivated soils reduced the severity of drifting, but ridging highly erosive dune materials was less effective because the ridges disappeared rapidly. The rate of flow varied inversely with surface roughness.

Armbrust et al. (1964) studied the effects of ridge roughness equivalent on total quantity of eroded material from three simulated, cultivated soils exposed to different friction velocities. From their data, a curve can be constructed showing the relationship between quantity of eroded material and ridge roughness equivalent. Presumably, that is the origin of the chart by Woodruff and Siddoway (Fig. 4, 1965) showing a soil-ridge roughness factor as a function of soil-ridge roughness. The ridge roughness factor estimates the fractional reduction of erosion caused by ridges of nonerodible aggregates. It is influenced by ridge spacing and ridge height and is defined relative to a 1:4 ridge height to ridge spacing ratio. A soil-ridge roughness equivalent of 6 cm reduces wind erosion 50 percent.

As roughness increases to about 11 cm, the soil-ridge roughness factor remains about constant; then, with additional roughness, the effectiveness of ridges gradually decreases.

When ridges are mostly gone, vegetative cover is depleted, and the threat of wind erosion continues, a rough, cloddy surface resistant to the force of wind can be created on many cohesive soils with appropriate "emergency tillage." Lyles and Tatarko (1982) found that chiseling of growing winter wheat on a silty clay soil increased greatly nonerodible surface aggregates without influencing grain yields. Listers, chisels, cultivators, one-ways with two or three disks removed at intervals, and pitting machines can be used to 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, 1972).

Residue. Living vegetation or residue from harvested crops protects the soil against wind erosion. Standing crop residues provide nonerodible elements that absorb much of the shear stress in the boundary layer. When vegetation and crop residues are sufficiently high and dense to prevent intervening soil-surface drag from exceeding threshold drag, soil will not erode. Rows perpendicular to wind direction control wind erosion more effectively than do rows parallel to wind direction (Englehorn et al., 1952; Skidmore et al., 1966). Flattened stubble, though not so effective as standing, also protects the soil from wind erosion (Chepil et al., 1955).

Soon after the disastrous "dirty thirties" in the U.S. Great Plains, use of stubble-mulch systems was demonstrated to be a feasible method of reducing wind erosion on cultivated land (Duley, 1959). "Stubble mulching" is a crop residue management system using tillage, generally without soil inversion, usually with

blades or V-shaped sweeps (McCalla and Army, 1961; Mannering and Fenster, 1983). The goal is to leave a desirable quantity of plant residue on the surface of the soil at all times. Residue is needed for a period of time even after the crop is planted to protect the soil from erosion and to improve infiltration. The residue used is generally that remaining from a previous crop.

Studies (Chepil, 1944; Chepil et al., 1955; Siddoway et al., 1965) 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 (flat, standing, height).

Efforts have continued to evaluate the protective role of additional crops (Craig and Turelle, 1964; Lyles and Allison, 1981), range grasses (Lyles and Allison, 1980), 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).

Barrier. Reducing the field width or the distance that wind travels in crossing unprotected field strips reduces wind erosion. Chepil and Milne (1941b) reported zero soil movement on the windward side of fields or field strips and soil movement increased with distance downwind. Later, Chepil (1946) found that the cumulative rate of soil movement with distance away from the windward edge of eroding fields was the main cause of increasing abrasion and gradual decrease in surface roughness along the direction of wind. He called the increase in rate of flow with distance downwind "avalanching."

"Rate of soil flow increased with distance downwind across an eroding field until, if the field was large enough, it reached a maximum that a wind of a given velocity can carry. Beyond that point the rate of flow remained essentially constant" (Chepil, 1957).

Use of wind barriers is an effective method of reducing field width. 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 windspeed; a properly oriented barrier, when winds predominate from a single direction, will decrease wind erosion forces by more than 50 percent from the barrier leeward to 20 times its height; 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 (Ferber, 1969; Read, 1964; Woodruff et al., 1976), many other barrier systems are used to control wind erosion. They include annual crops like small grains, corn, sorghum, sudangrass, sunflowers (Carreker, 1966; Fryrear, 1963, 1969; Hagen et al., 1972; Hoag and Geiszler, 1971), tall wheatgrass (Aase et al., 1976; Black and Siddoway, 1971), sugarcane, and rye strips on sands in Florida (Griffin, SCS Agronomist, personal communication, 1975).

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 (Dickerson et al., 1976; Woodruff et al., 1976). Such barriers also compete with the crops for water and plant nutrients (Lyles et al., 1983). Thus, the net effect for many tree-barrier systems is that their use may not benefit crop production. Frank et al., 1977; McMartin et al., 1974; Skidmore et al., 1975; Skidmore et al., 1974; Staple and Lehane, 1955). Perhaps the tree-barrier systems could be designed so that they become a useful crop, furnishing nuts, fruit, and wood.

Strip Cropping. The practice of farming land in narrow strips on which the crop alternates with fallow is an effective aid in controlling wind erosion

(Chepil, 1957). Strips are most effective when they are at right angles to the prevailing wind erosion direction but also provide some protection from winds that are not perpendicular to the field strip.

Strip cropping reduces erosion damage in the following ways: reduces the distance the wind travels across exposed soil, localizes drifting that starts at a focal point, and reduces wind velocity across the strip when adjacent fields are covered with tall stubble or crops.

Although each method to control wind erosion has merit and application, establishing and maintaining vegetative cover, when feasible, remains the best defense against wind erosion. However, that becomes a difficult challenge as pressure increases to use the crop residues for livestock feed and fuel for cooking.

Summary

Those principles for controlling wind erosion just discussed are summarized by the general functional relationship given by Woodruff and Siddoway (1965) as a wind erosion equation in the form $E = f(I, K, C, L, V)$ where E is potential average annual soil loss per unit area, I is a soil erodibility index based on fraction of soil aggregates (particles) in the erodible size range, K is a soil ridge roughness factor, C is a climatic factor, L is the unsheltered median travel distance of wind across a field, and V is equivalent quantity of vegetative cover.

The equation was developed as a result of many years of studying the factors influencing wind erosion. It has been used widely for its intended purposes to determine both the potential erosion from a particular field and the field conditions (soil cloddiness, roughness, vegetative cover, sheltering by barrier, or width and orientation of field) necessary to reduce potential erosion to a tolerable amount.

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