Effect of Kind, Amount, and Placement of Residue on Wind Erosion Control

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SINCE depletion of vegetation almost invariably leads to accelerated wind erosion, present-day wind-erosion control practices use vegetation in one manner or another to reduce the incidence of wind erosion. Examples are field windbreaks, cover crops, strip crops, permanent revegetation of submarginal cultivated areas, and the management of postharvest residues to maintain maximum ground cover. The latter example includes stubble mulching of small grains and sorghums, which is perhaps the most universally applied erosion control practice in the Great Plains.

Early work on the use of crop residues for wind-erosion control dealt mainly with the mechanics of accomplishing the stubble-mulch condition, and in comparing productivity of the stubble-mulch system with conventional systems of farming. Quantitative relations between soil losses by wind and vegetative properties were first published (10)* in 1943 and reported more completely in 1944 (2). Among other conclusions, it stated that total soil loss varied exponentially with residue quantity. This relation appeared valid for all soil, vegetative, and wind-velocity variables studied. Subsequent studies measured soil losses from field surfaces with a portable wind tunnel (11, 12, 14, 16) and related erodibility to surface roughness, soil cloddiness, and wind drag parameters, as well as to residue quantity. From these and additional studies, empirical equations were developed to estimate the erodibility of field surfaces (6, 7). Two studies, in which vegetative and nonvegetative mulches were applied to the surface, established quantities of cover needed to control wind erosion under extremely high winds (8, 9).

Because of the complexity of the vegetative cover-soil loss relationship, which is largely due to the variable vegetative structural characteristics and the variable spatial distribution of the vegetation with respect to the soil surface, development of equations by other than empirical methods is difficult, if not impossible. To date, the specific properties of vegetative covers that influence soil erodibility have only been partially quantified. This study attempted to (a) develop regression equations relating soil loss by wind to selected amounts, kinds and orientations of vegetative covers, wind velocity, and soil cloddiness, and (b) develop and evaluate research techniques that may be useful in future experiments.

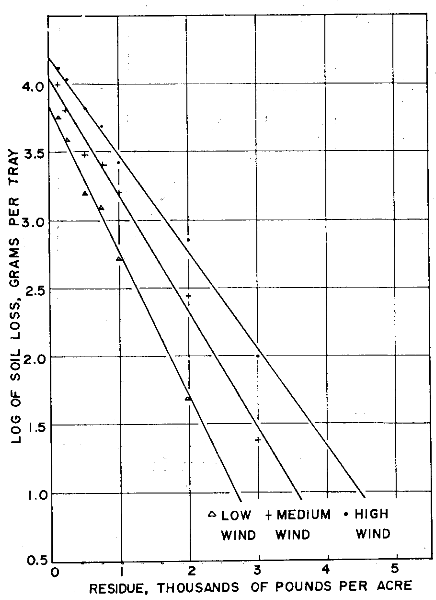

FIG. 1 Effect of wind on soil erosion under a flattened wheat-stubble cover. (A = 3.1 percent clods > 0.84 mm in diameter.)

Experimental Methods

One dependent variable, total soil loss, and five independent variables – kind of vegetation, orientation of vegetation, quantity of vegetation, wind velocity, and soil cloddiness – were included in a nonorthogonal factorial arrangement of treatments. An explanation of these independent variables, their test levels, and the test procedure follows:

Four Kinds of Vegetation, S Growing winter wheat and three crop residues – wheat stubble and fine- and coarse-textured sorghum stubble – were selected. Ten-inch stalks of the residues were stripped of leaves to achieve uniformity and were differentiated quantitatively by their respective average stalk diameters of 2.7, 12.6, and 23.9 mm. Growing winter wheat could not be assigned an equivalent quantitative measurement and was, therefore, excluded from certain analyses.

Three Orientations of Vegetation, K_m The residues were arranged in rows 10 in. apart and normal to wind direction. Residues within the rows were oriented in either a flat, leaning, or standing position. The flattened stalks were parallel with wind direction, and the leaning stalks were inclined at a 45 deg angle with the wind. Winter wheat was grown in rows 9 in. apart and was exposed to winds both normal and parallel to wind direction. The maximum ridge roughness equivalent (15), in inches, measured for a particular kind and orientation of residue, quantitatively characterized the orientations.

n* Quantities of Vegetation, *R The amount of vegetation required to control erosion depended on the other independent variables; therefore, fixed quantities of all the kinds of vegetation could not be standardized, making the factorial arrangement of treatments nonorthogonal. Test quantities of vegetative materials were: 125, 250, 500, 750, 1,000, 2,000, and 3,000 lb per acre of wheat stubble; 410, 810, 1,630, 2,440, 3,250, 4,880, and 6,500 lb of fine sorghum; 500, 1,000, 2,000, 4,000, 6,000, 8,000, 10,000, and 12,000 lb per acre of coarse sorghum; and 10, 37, 130, and 252 lb per acre of growing winter wheat. To attain uniformity, weights of residues were expressed in terms of stalk bulk density of wheat, which was 0.13 gram per cubic centimeter.

Three Wind Velocities, *V* More specifically, wind velocity was expressed in terms of the drag velocities (1) 94.7, 105.6, and 116.5 cm per second, which are equivalent to wind velocities of 39, 43, and 48 mph (miles per hour) when measured at a height of 5 ft over a smooth ground surface under neutral atmospheric conditions.

Two Soil Cloddiness Levels, *A* Soil cloddiness is defined as the percent clods greater than 0.84 mm in diameter (6). Two synthetic soils, equivalent to natural soils containing 3.1 and 11.0 percent clods, were prepared by mixing dune sand, screened to less than 0.84 mm in diameter, with gravel ranging from 1.2 to 6.4 mm in diameter. These synthetic soils gave reproduci-

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* Numbers in parentheses refer to the appended references.

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ble results by eliminating variation due to abrasion. Only the most erodible soil was included in the growing winter-wheat portion of the experiment.

Test Procedure The windward 38-ft section of a previously described 56-ft laboratory wind tunnel (13) was used to test soil erodibility under various combinations of vegetative cover. Crop residue was placed in rows in the 38-ft length of tunnel by fastening the stalks to frames made from ¼-in.-steel rod and wire. The three orientations — flat, leaning, and standing — were obtained by positioning the frames.

The test soil was placed in open-end trays 60 in. long by 8 in. wide (3.33-ft square surface area) by 1.5 in. deep, and after the soil surface was uniformly smoothed, the trays were countersunk parallel with the tunnel floor, so the soil surface was flush and approximately continuous with the adjacent gravel floor of the tunnel. Two trays were placed side by side in the 30 to 35-ft section of the tunnel. Only one tray, 16 in. wide, was used in testing erodibility of the winter wheat in rows parallel with the wind.

The soil, under a given vegetative cover condition, if any, was exposed to a given wind for ten minutes. Total soil loss, which was measured gravimetrically, ceased or approached zero prior to the end of the ten-minute period. Tests, with a few exceptions, were repeated once for a total of four measurements per treatment for all vegetation except the growing winter wheat that was in rows parallel with the wind.

The first vegetation, fine-textured sorghum, was tested over a wide range of drag velocities to determine the fixed levels of drag velocity that were used in subsequent experiments. Soil losses from the fine-textured sorghum tests were then adjusted to the foregoing three drag-velocity levels by extrapolation from log E-log V curves or by interpolation from polynomial regression equations. This adjustment reduced degrees of freedom in subsequent regression analyses involving fine sorghum.

Methods of simple and multiple curvilinear regression were employed to analyze and interpret the data.

Results and Discussion

Soil Loss from Bare Surface Rate of soil loss varies as a power of drag velocity (1, 3), and relative soil erodibility as a power of soil cloddiness within the range of soil cloddiness levels included in this experiment (4). Using these relationships for the regression model, the following equation estimates total soil loss E_o from a bare soil as a function of drag velocity V and soil cloddiness A:

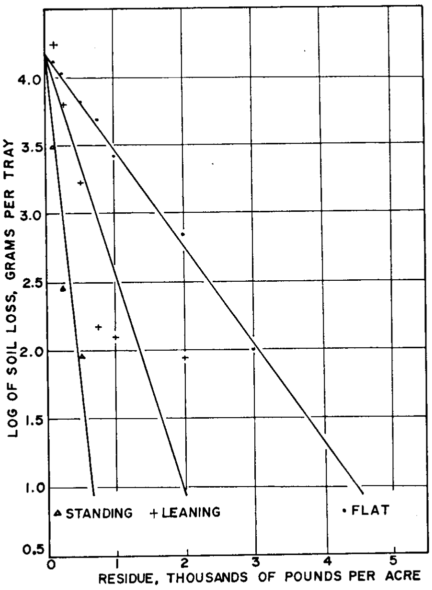

FIG. 2 Effect of wheat-stubble orientation on soil erosion by wind. (A = 3.1 percent clods > 0.84 mm in diameter; V = 116.5 cm per second.)

$$\log \hat{E}_o = -3.52074 + 3.96328 \log V -0.99774 \log A \; . \; . \; . \; . \; . \; . \; . \; . \; . \; [A]$$

where the constants were determined by regression analysis. Regression accounted for 98.4 percent of the variation in log E_o. The sample standard deviation from regression for this analysis is 0.04139. On the basis of standard coefficients, log V had approximately twice as much influence on log E_o variation as did log A.

Influence of Treatment on Soil Loss Soil loss E_f measured under residue cover, in addition to depending on the experimental variables, also depended on the frames that supported and anchored the residue. The frame influence confounded the effect of wheat and sorghum residues on soil loss with the magnitude of influence increasing from flat to leaning to standing orientations. The original soil loss measurements, therefore, included not only residue-quantity effect but also frame effect.

For each residue orientation and kind of residue, each soil, and each wind variable, E_f was best expressed as an exponential function of residue quantity R. The log form of the equation is

$$\log E_f = \log a - R \log b \; . \; . \; . \; [B]$$

where log a is the log of soil loss when residue, but not frames, equaled zero and log b is the rate of change in log E_f per unit change in R.

The effect of frames (which did not change in position or magnitude for a given orientation) on log E_f was assumed constant for a particular kind and orientation of residue, a particular soil, and a particular wind. Under this assumption, the slope of the individual log E-R curves was not changed by the frames; only the magnitude of soil loss or elevation of the curves was changed. The logarithms of the original soil loss measurements were adjusted upward to estimate what the soil loss would have been without frames as follows:

$$\log E = \log E_f + (\log \hat{E}_o - \log a) \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; [C]$$

where log E is a single soil-loss measurement adjusted to eliminate frame effect.

After adjustment, the estimating equation for soil loss (exclusive of frame effect) for a given kind and orientation of residue, and a given combination of wind and soil, can now be expressed by

$$\log \hat{E} = \log \hat{E}_o - R \log b \; . \; . \; . \; [D]$$

A similar adjustment was also made for the measured soil loss data from the growing winter wheat tests. Here the boxes in which the winter wheat was grown, rather than the frames, were the confounding, though relatively minor, influence.

The quantity of residue R_o necessary to reduce soil loss to an insignificant quantity for a given wind and soil condition is extremely important in practical erosion control. This loss has been described as the amount eroded from a field when no distinct visible effects of soil movement are apparent (5). This same criterion was used to establish an insignificant quantity of soil loss from the test trays — approximately equivalent to 10 grams per tray. No evidence of sorting of the surface soil grains was discernible for a loss of this magnitude, and, furthermore, it is a convenient value to use with equation [D]. This loss in terms of adjusted values is obtained by projection and, therefore, assumes that equation [D] is a continuous function through soil loss values of this magnitude. The amount of residue $R_{0.5}$ required to reduce the relative soil loss value E to one half of what it was under bare conditions was arbitrarily chosen as the second basis for comparing soil loss under a given set of independent variables with another given set.

The results of the regression analysis, when all independent variables except R were held constant, and the estimated quantities of R_o and $R_{0.5}$ computed from equation [D] are given in Table 1. The relatively high r^2 values strongly indicate that total soil loss from a vegetatively covered surface varies exponentially with the quantity of residue. This relationship appears valid whether the vegetation is: crop residues left standing after harvest; crop residues whose natural orientation with respect to the soil surface has been altered by tillage or other activity (leaning or flattened); or vegetation grown in rows parallel or normal with wind direction. On an average, regression

TABLE 1. STATISTICS RELEVANT TO REGRESSION ANALYSIS AND ESTIMATED VALUES OF R_o AND $R_{0.5}$ WITH ALL VARIABLES EXCEPT R HELD CONSTANT

Combination of independent variables				df	−log b	r^2	$s_{\log E \cdot R}$	Residue quantities	
Vegetation	Orientation	Drag velocity, cm/sec	Soil cloddiness, percent					R_o	$R_{0.5}$
								Pounds per acre × 10^{-3}	
Wheat stubble	flat	94.7	3.1	26	1.05872	0.951	0.15786	2.665	0.284
Wheat stubble	leaning	94.7	3.1	13	5.31440	0.700	0.65781	0.520	0.056
Wheat stubble	standing	94.7	3.1	10	9.70438	0.876	0.40753	0.291	0.031
Wheat stubble	flat	105.6	3.1	30	0.84798	0.985	0.12389	3.553	0.355
Wheat stubble	leaning	105.6	3.1	21	2.73855	0.934	0.26853	1.100	0.110
Wheat stubble	standing	105.6	3.1	13	5.35555	0.692	0.67433	0.562	0.056
Wheat stubble	flat	116.5	3.1	30	0.70944	0.987	0.08161	4.480	0.424
Wheat stubble	leaning	116.5	3.1	22	1.61925	0.765	0.52241	1.963	0.185
Wheat stubble	standing	116.5	3.1	14	4.94320	0.881	0.35856	0.643	0.061
Wheat stubble	flat	94.7	11.0	26	0.86199	0.981	0.07981	2.640	0.349
Wheat stubble	leaning	94.7	11.0	13	4.85528	0.900	0.30518	0.468	0.062
Wheat stubble	standing	94.7	11.0	9	9.67259	0.913	0.35211	0.235	0.031
Wheat stubble	flat	105.6	11.0	28	0.76787	0.943	0.16556	3.209	0.392
Wheat stubble	leaning	105.6	11.0	22	2.26970	0.919	0.24686	1.086	0.133
Wheat stubble	standing	105.6	11.0	14	3.86712	0.774	0.41297	0.637	0.078
Wheat stubble	flat	116.5	11.0	28	0.61080	0.974	0.08374	4.305	0.493
Wheat stubble	leaning	116.5	11.0	24	1.20706	0.858	0.27391	2.179	0.249
Wheat stubble	standing	116.5	11.0	14	3.63643	0.875	0.27205	0.723	0.083
Fine sorghum stubble	flat	94.7	3.1	4	0.45827	0.978	0.14588	6.158	0.657
Fine sorghum stubble	leaning	94.7	3.1	2	1.34125	0.976	0.17852	2.104	0.224
Fine sorghum stubble	standing	94.7	3.1	1	2.25891*	0.962	0.25823	1.249	0.133
Fine sorghum stubble	flat	105.6	3.1	6	0.36184	0.993	0.07694	8.326	0.832
Fine sorghum stubble	leaning	105.6	3.1	4	0.75313	0.994	0.08124	4.000	0.400
Fine sorghum stubble	standing	105.6	3.1	2	1.38155	0.989	0.12617	2.181	0.218
Fine sorghum stubble	flat	116.5	3.1	6	0.31282	0.993	0.06527	10.161	1.282
Fine sorghum stubble	leaning	116.5	3.1	4	0.55743	0.985	0.09721	5.702	0.540
Fine sorghum stubble	standing	116.5	3.1	4	0.81716	0.941	0.28787	3.890	0.368
Fine sorghum stubble	flat	94.7	11.0	5	0.38899	0.977	0.11463	5.843	0.774
Fine sorghum stubble	leaning	94.7	11.0	2	1.03965	0.993	0.07341	2.186	0.289
Fine sorghum stubble	standing	94.7	11.0	1	1.87328*	0.944	0.26310	1.213	0.161
Fine sorghum stubble	flat	105.6	11.0	5	0.29194	0.992	0.04929	8.440	1.031
Fine sorghum stubble	leaning	105.6	11.0	3	0.66440	0.999	0.04290	3.708	0.453
Fine sorghum stubble	standing	105.6	11.0	3	0.78230	0.915	0.26964	3.149	0.385
Fine sorghum stubble	flat	116.5	11.0	6	0.26518	0.987	0.07503	9.917	1.135
Fine sorghum stubble	leaning	116.5	11.0	4	0.47978	0.992	0.05950	5.481	0.627
Fine sorghum stubble	standing	116.5	11.0	3	0.66034	0.926	0.21140	3.982	0.456
Coarse sorghum stubble	flat	94.7	3.1	34	0.20612	0.921	0.25856	13.690	1.460
Coarse sorghum stubble	leaning	94.7	3.1	25	0.25257	0.931	0.19310	11.172	1.192
Coarse sorghum stubble	standing	94.7	3.1	18	0.45209	0.845	0.23058	6.241	0.666
Coarse sorghum stubble	flat	105.6	3.1	34	0.16810	0.910	0.23293	17.922	1.791
Coarse sorghum stubble	leaning	105.6	3.1	30	0.22284	0.952	0.17970	13.519	1.351
Coarse sorghum stubble	standing	105.6	3.1	22	0.32774	0.936	0.18913	9.192	0.919
Coarse sorghum stubble	flat	116.5	3.1	34	0.13887	0.925	0.16861	22.888	2.168
Coarse sorghum stubble	leaning	116.5	3.1	30	0.19659	0.938	0.18268	16.168	1.531
Coarse sorghum stubble	standing	116.5	3.1	24	0.30357	0.963	0.15681	10.470	0.992
Coarse sorghum stubble	flat	94.7	11.0	32	0.17217	0.931	0.19887	13.202	1.748
Coarse sorghum stubble	leaning	94.7	11.0	26	0.23832	0.917	0.20861	9.538	1.263
Coarse sorghum stubble	standing	94.7	11.0	18	0.41444	0.832	0.27777	5.485	0.726
Coarse sorghum stubble	flat	105.6	11.0	32	0.14950	0.926	0.18011	16.481	2.014
Coarse sorghum stubble	leaning	105.6	11.0	30	0.19557	0.936	0.18415	12.598	1.539
Coarse sorghum stubble	standing	105.6	11.0	20	0.31803	0.944	0.15142	7.747	0.947
Coarse sorghum stubble	flat	116.5	11.0	32	0.11988	0.928	0.14223	21.936	2.511
Coarse sorghum stubble	leaning	116.5	11.0	30	0.15959	0.946	0.13733	16.478	1.886
Coarse sorghum stubble	standing	116.5	11.0	20	0.26559	0.966	0.09695	9.901	1.133
Growing winter wheat	normal	94.7	3.1	14	6.93522	0.919	0.20796	0.407	0.043
Growing winter wheat	parallel	94.7	3.1	6	5.46351	0.965	0.11389	0.516	0.055
Growing winter wheat	normal	105.6	3.1	14	5.88832	0.959	0.12280	0.539	0.052
Growing winter wheat	parallel	105.6	3.1	6	4.19329	0.979	0.06745	0.718	0.072
Growing winter wheat	normal	116.5	3.1	14	5.12428	0.959	0.10742	0.620	0.059
Growing winter wheat	parallel	116.5	3.1	6	3.21318	0.978	0.05282	0.989	0.093

* All other regression coefficients significantly different from zero ($P = 0.01$).

accounted for 88.4, 97.4, 92.5, and 96.0 percent of the variation in log E for the wheat, fine sorghum, coarse sorghum, and growing winter wheat, respectively. Regression accounted for 96.0, 92.4, and 89.9 percent of the variation in log E for the respective flat, leaning, and standing crop residue orientations. The corresponding percentages for winter wheat in rows parallel and normal to wind direction were 97.4 and 94.6. All regression coefficients except two were significantly different from zero, and the exceptions were attributed to insufficient degrees of freedom rather than to deviation from the assumed regression equation.

Flat residues differ from leaning or standing residues in the mechanism whereby they reduce erosion losses. Flat residues reduce erosion primarily by forming a protective barrier between the soil surface and the force of the wind, and secondarily by reducing wind velocity near the soil surface. Leaning and standing residues, on the other hand, reduce wind erosion primarily by decreasing wind velocity at the soil surface, and secondarily by forming a surface barrier. If the protective barrier effect were the only mechanism involved in soil loss reduction for flattened crop residues, the soil would have to be completely covered before soil loss would approach zero under the force of an erosive wind. In this experiment, soil loss under flattened residue was controlled short of complete soil coverage by the residue. Because the exponential relation fits all three residue orientations about equally, the net effect of the nature of the mechanisms involved in reducing erosion appears to be similar for all orientations of residue. Only the magnitude of the effect varied from one orientation to another.

Aside from the possibility of the assumed relation differing from the true one, if any, there are several experimental errors that could account for the deviations from regression. Variations in soil cloddiness within a cloddiness level, slight variations in wind velocity, weighing inaccuracies, and variation in the elevation of the surface of the test soil with respect to the tunnel floor — all contributed to experimental error. There were also some other unavoidable sources of variation. To achieve a level, smooth surface from one test to another, the soil in the trays was prepared by drawing a metal bar over the soil. This tended to concentrate the fine or erodible portion in the surface and narrowed the erodibility characteristics of the two soils. For large soil losses, this condition was inconsequential, but for small losses, the percentage was relatively large. An attempt was made to simulate field conditions in arranging the residue stalks within a row in neither a systematic nor a randomized arrangement. As a result, the arrangement of stalks in the rows immediately windward of the soil trays sometimes caused variations in soil loss from one increment of residue to the other different from those expected from the effect of the increment alone.

Relation of the Slope of the Log *E-R* Curves to *V*, *A*, K_m, and *S*. The slopes of the log *E-R* curves, designated by log *b* in Table 1, varied with all independent variables. Figs. 1 through 4 illustrate the direction of variation when all but one of the independent variables were held constant. Log *b* decreased numerically with: increasing wind velocity (Fig 1); an increase in coarseness of residue (Fig. 3); and soil cloddiness (Fig. 4). Log *b* increased numerically from flat to leaning to standing residue orientations (Fig. 2). Retaining the exponential equation [*D*], this relationship may be functionally expressed by

$$\log E = f_1\ (V,A) + Rf_2\ (V,A,K_m,S) \quad \ldots\ldots\ldots\ldots\ldots \text{[E]}$$

where f_1 (*V*, *A*) determines the log *E* intercept when *R* equals zero and f_2 (*V*, *A*, K_m, *S*) determines the slope of the log *E-R* curves of Table 1. When R equals zero, equation [A] expresses the relationship between log *E* and the independent variables *V* and *A* and can be substituted for f_1 in equation [E] where the respective constants are assigned the symbols a_1, b_1, and b_2.

By alternately taking the average of the log *b* values across all independent variables except one, and by plotting these averages against the values of the omitted variable, log *b* was functionally related to *V*, *A*, K_m, and *S*. To arrive at a relatively simple final regression model, the relationships between log *b* and the independent variables were chosen for their simplicity, provided, of course, that the relationships appeared graphically reasonable. The derivative form of the developed regression equation is

$$\log \left\{ \frac{d \log E}{d\, R} \right\} = a_2 + b_3 \log V + b_4\, A + b_5 \log K_m + b_6\, S^{0.5} \quad \ldots \text{[F]}$$

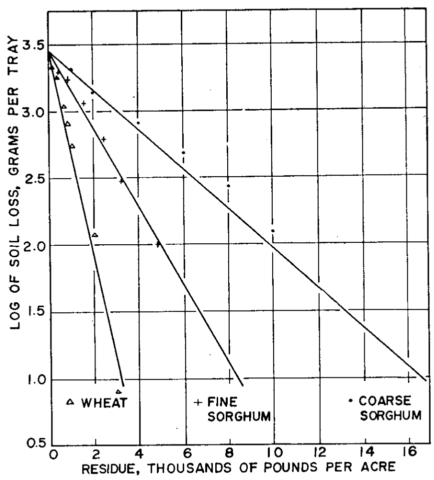

FIG. 3 Effect of kind of residue on soil erosion by wind (orientation = flat, A = 11 percent clods > 0.84 mm in diameter, V = 105.6 cm per second).

where the constants a_2 and b_i were determined by regression analysis. Equation [F] may now be substituted for f_2 in equation [E], and the equation can be rewritten in exponential form to express *E* as a function of all independent variables by

$$E = a_1\ V^{b_1}\ A^{b_2} \cdot 10^{(a_2\ V^{b_3}\ b_4^{A}\ K_m^{b_5}\ b_6^{S^{0.5}})\ R} \quad \ldots \text{[G]}$$

The results of the regression analysis, assuming equation [F], are given in Table 2. The symbol *s* designates sample standard deviation and the *t*-distribution was used to test the hypothesis that b_i equals zero.

Judging from the standard regression coefficients *b'*s the relative influence of the independent variables on the slope of the log E-R curves was in the descending order: kind of residue, orientation of residue, wind velocity, and soil cloddiness. Regression accounted for a significant proportion of the total variation. The regression coefficients b_i's for log V, log K_m, and $S^{0.5}$ were highly significant (0.01 level), and the soil cloddiness coefficient was significant (0.05 level). Partial correlation coefficients also were highly significant. None of the possible paired combinations of independent variables was correlated.

The R_o values of Table 1 were compared with the R'_o values computed from equation [G], assuming that the most reliable estimate of insignificant erosion is represented by Table 1 values. This is analogous to the usual "measured *vs* computed" comparison. A regression analysis was made assuming the equation

$$b = \frac{\Sigma(R'_o/R_o)}{n} \quad \ldots\ldots\ldots\ldots \text{[H]}$$

when *n* is 54 and *b* is the slope of the R'_o - R_o curve. The computed *b* value of 1.046 was not significantly different from the theoretical value of unity. The sample standard deviation of the ratio $s_{R'o/Ro}$ was 0.29. Other comparisons of R'_o and R_o were made by omitting, one at a time, each level of the independent variables, S and log K_m, assuming the regression model of equation [F]. The sample standard deviations of R'_o/R_o for these analyses of the kinds of residues and orientations were: wheat, 0.18; fine sorghum, 0.14, coarse sorghum, 0.09; standing residue, 0.18; leaning residue, 0.20; and flattened residue, 0.06. Omitting an independent level decreased the sample standard deviation of the R'_o/R_o ratio. Whether the deviations are within the realm of practicality for estimating erodibility depends on the tolerances one would be willing to accept.

CONCLUSIONS

The results of this study suggest that wind erosion varies exponentially with the quantity of residue on the soil surface and agrees with the first quantitative research carried out on this phase of wind erosion (2). Within the limits of the number of independent variables that were evaluated in this wind-tunnel experiment, the elevation of the soil loss-vegetation quantity curves above the abscissa varied with wind velocity and soil cloddiness. All independent variables influenced the slope of the curves, although the influence of soil cloddiness was relatively minor. The relation between the relative effectiveness of different kinds and orientations of residue is not simple. One cannot,

TABLE 2. STATISTICAL VALUES FOR THE REGRESSION OF THE LOG E-R SLOPE ON LOG V, A, LOG K_m, AND $S^{0.5}$

Variable	df	b_i	b'_i	s_{b_i}	t_{b_i}
log V	52	−3.16680	−0.231	0.48444	−6.537†
A	51	−0.00977	−0.077	0.00450	−2.171*
log K_m	50	0.52908	0.461	0.04050	13.064†
$S^{0.5}$	49	−0.30388	−0.807	0.01330	−22.852†

Constant a_2	=	7.06117
s for equation	=	0.13061
F for equation	=	188.35†
r^2	=	0.939

Partial correlation coefficients of the log of the log E-R slope with:

log V	=	−0.683†
A	=	−0.296†
log K_m	=	0.881†
$S^{0.5}$	=	−0.956†

* Denotes significance at 5 percent level.
† Denotes significance at 1 percent level.

for example, generalize that wheat stubble is a given number of times as effective as sorghum stubble, or that standing residue is a given number of times as effective as flattened crop residue. The relative value of kinds and orientations of residue for erosion control must be qualified by the soil, wind velocity, and the many other variable characteristics of the residues involved. One can, however, generalize to the extent that: fine-textured residues on a weight basis are much more effective than coarse-textured residues; any orientation of residue with respect to the soil surface decreases wind erosion more than the flattened position; and, growing fine-leafed crops, like grasses and cereals, affords a high degree of erosion control per unit weight.

From the nature of equation [D], it can be seen that relatively small quantities of even the coarsest residues result in sizable reductions in erodibility compared with the erodibility of bare soil. This phenomenon, if combined with other wind-erosion-control measures, should be taken into account in applying wind-erosion-control practices. Amounts of residue that look inconsequential may in fact make a significant contribution and diminish the degree of intensity required of other practices, like strip cropping, shelterbelts, and emergency tillage.

Growing winter wheat oriented in rows normal to the wind was about 1.4 times as effective as winter wheat oriented in rows parallel to wind direction under the imposed variables of this experiment. This relative advantage would probably increase with wider row-width spacings.

Although the independent variables accounted for the major portion (94 percent) of the variation in the log of the log E-R slopes, there was evidence that had interactions been included in the regression model, even more variation could have been accounted for. The fewer the variables involved, the more accurate were the erosion estimates.

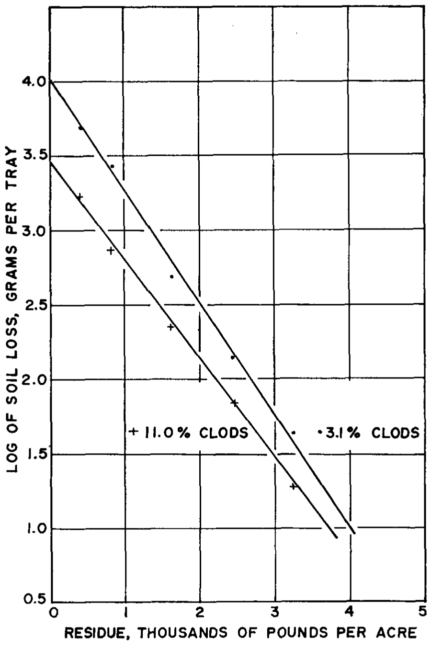

FIG. 4 Effect of soil cloddiness on soil erosion under a leaning, fine-textured sorghum cover (V = 105.6 cm per second).

If one is willing to accept the validity of the relation between soil loss and quantity of residue expressed by equation [D] in this study and in previous work (2), the testing procedure used in this experiment should prove quite useful for routine testing of soil and residue conditions. By maintaining soil cloddiness and wind velocity constant, a curve could be established by measuring soil loss at only two residue levels – preferably zero and some intermediate quantity with respect to the magnitude of soil loss. At zero, residue variation due to bias in positioning the vegetation would be eliminated. An intermediate quantity of residue with respect to magnitude of soil loss would insure that the quantity of residue was below the amount where the threshold velocity would be skirted and would eliminate errors due to that cause. If at all possible, mechanical means of supporting and anchoring the residue, which projects into the airflow, should be avoided. There is no simple way to determine if the adjustments made to separate effects of vegetation from mechanical devices are truly accurate. If the soil trays could be weighed in place in the wind tunnel, accuracy would undoubtedly be improved and much time could be saved. Some method of placing and leveling the soil in the test tray that would retain the structural characteristics of the soil at the soil surface-wind interface would eliminate some of the error encountered in this experiment.

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