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Wind erosion calculator: Revision of residue table

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ABSTRACT: A wind erosion calculator was examined for discrepancies between its results and computer solution of the wind erosion equation. Results obtained from the wind erosion calculator were compared with results obtained from the computer for several values of potential erosion at each of 11 different levels of equivalent flat small grain residue. Generally, agreement between the two methods was good. In some cases, however, the calculator overestimated erosion. The calculator scales were redesigned to give near perfect agreement between the two methods. The r-squared value, after revision, was 0.9999 with an intercept and slope of −0.003 and 1.000, respectively.

A wind erosion equation (*14*) that expresses potential average annual erosion from a given agricultural field has proven to be an important, widely used conservation tool. Because of the cumbersomeness of the many tables and figures required to solve the functional relationships of the equation, a computer solution was developed (*4, 11*).

Later, a slide rule-type wind erosion calculator[1] was developed through the cooperative efforts of the Agricultural Research Service, Soil Conservation Service (SCS), and Graphic Calculator Company. The calculator was used extensively by SCS field personnel for estimating wind erosion and designing wind erosion control systems. SCS personnel detected discrepancies between calculator and computer solutions of the wind erosion equation for some combinations of flat small grain residue and IKCL, where IKCL, sometimes referred to as E4 (*12, 14*), is an intermediate step in solving the wind erosion equation. It is the step just prior to the final one of determining the influence of crop residue on wind erosion. Here, I present redesigned calculator scales for improving the agreement between results obtained by computer and calculator and show an example of using the wind erosion calculator.

Study methods

I determined equivalent vegetative cover, V, as a function of flat small grain residue, FSG, from Woodruff and Siddoway (*14, figure 7*) for each level of FSG on the calculator. Those values for FSG were 0, 250, 500, 750, 1,000, 1,250, 1,500, 1,750, 2,500, and 3,000 pounds per acre. I then used subroutine FIN of WEROS (*4*) to determine E5 = IKCLV for a range of values for E4 = IKCL at each level of FSG.

I also determined E5 with the wind erosion calculator for the same combinations of FSG and E4 as used by the computer.

Results obtained by wind erosion calculator for finding E5 from E4 at each level of FSG were compared.

The scales for finding E5 from E4 at each level of FSG were redesigned according to the computer solutions.

Two corresponding points between E4 and E5 were obtained near the extremes for the ranges of E4 and E5 for each level of FSG; for FSG = 250 pounds per acre and E4 = 1.0 ton per acre per year, E5 = 0.76 ton per acre per year, and when E4 = 300 tons per acre per year, E5 = 276.6 tons per acre per year. The E5 scale is logarithmic to the base 10 with values ranging from 0.5 to 300. That covers two full cycles with an additional approximate half cycle on each end. The E4 scales also are logarithmic but have a longer cycle length than E5.

I obtained intermediate values for the E4 scale using the equation:

$$DF = (\log X - \log X_1)/(\log X_2 - \log X_1) \quad [1]$$

where X is the value of E4 corresponding to the sought value of E5; X_1 and X_2 are the near extreme values for E4 (1.0 and 300 in the above example); and DF is the fraction of the total distance between X_1 and X_2 where E5 corresponds to E4.

For example, to find the value E5 corresponding to E4 = 5 tons per acre per year with 250 pounds per acre of FSG, first from equation 1

$$DF = (\log 5 - \log 1)/(\log 300 - \log 1) = 0.282 \quad [2]$$

Now, multiply the measured distance between X and X_1 by 0.282 to find the position on E4 that corresponds to an E5 of 4 tons per acre per year for that combination of variables. I repeated this procedure several times for each level of FSG.

A plotter routine for the CALCOMP plotter for plotting logarithmic scales was used to plot the scales for each level of FSG.

Results

I found the relationship between flat small grain residue, FSG, and equivalent vegetative cover, V, both in 1,000 pounds per acre, to be

$$V = -0.0967 + 1.9119FSG + 1.8240FSG^2 - 0.2865FSG^3 \quad [3]$$

with an r^2 of 0.9998.

Figures 1 and 2 compare the results obtained for calculating E5 with WEROS and the wind erosion calculator before revision. Figures 3 and 4 show this comparison after revision. Figures 1 and 2 show discrepancies between the two different computational procedures for some combinations of variables. The lines are relatively well aligned, but not perfect. If one were to plot differences in data values between the results for the two computational procedures versus E4 for the apparent worst case (FSG = 1,500 lbs/acre), large values would result at high erosion rates. On the average, the calculator estimated 25 percent more erosion than the computer for FSG of 1,500 pounds per acre and E4 between 200 and 400 tons per acre per year for this apparent worst case. In perspective with other possible errors, a judgment between rough and semi-rough for ridge roughness factor causes a 50-percent increase in E5. Also, the difference in soil erodibility, I, between placing a soil in wind erodibility group 1 instead of group 2 results in a 64-percent increase in soil erodibility (*6*).

In general, the agreement between the wind erosion calculator and the computer was not bad. The E5 calculated with WEROS regressed against E5 calculated with the wind erosion calculator before revision in a general linear model gave a coefficient of determination of 0.9972, with slope and intercept of 0.961 and 0.030, respectively.

Revision of the wind erosion calculator improved agreement between calculator and computer. Figures 3 and 4 show almost perfect agreement beteen computational procedures. The E5 calculated with WEROS regressed against E5 calculated with the wind erosion calculator after revision gave a coefficient of determination of 0.999, with slope and intercept of −0.003 and 1.000, respectively. Figure 5 shows the

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[1] Skidmore, E.L. 1977. "Wind Erosion Calculator: Examples of Use," paper presented at Soil Conservation Service Western Regional Agronomy Workshop, Salt Lake City, Utah.

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revised wind erosion calculator scales for finding E5, given E4 at 11 levels of flat small grain residue. These scales are the ones that are now on the calculator and produced the results in figures 3 and 4.

Use of calculator

The front side of the calculator lists step-by-step instructions for using the calculator. Variables are defined on the slide. When using the calculator, it is helpful if the user is familiar with the wind erosion equation.

The first instruction is to determine I, K, C, field width, V, and the wind erosion direction factor. I is soil erodibility, K is the ridge roughness factor, C is a climatic factor, and V is equivalent vegetative cover.

Information to accomplish the first instruction is obtained from various sources. Soil erodibility, I, is best obtained from standard dry sieving to determine the percentage of dry soil aggregates greater than 0.84 millimeter (*2*). In practice, to avoid sampling in the field and sieving, soil erodibility is often estimated by grouping soils according to predominant soil textural class, WEG (*6*).

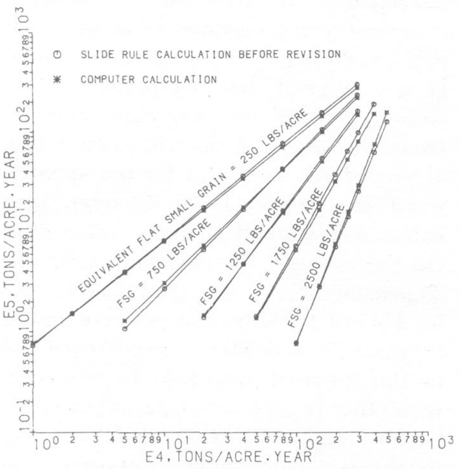

Figure 1. Wind erosion calculator and computer solutions of wind erosion equation for various combinations of E4 and equivalent flat small grain residue before revision of calculator scale.

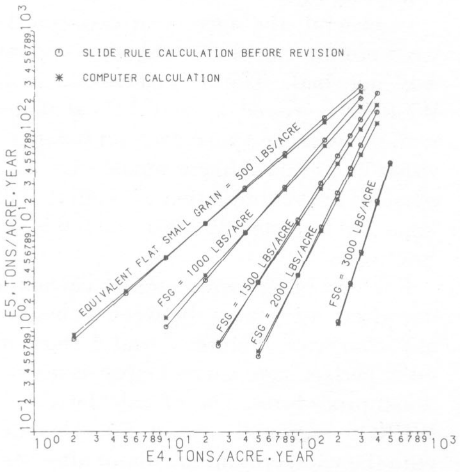

Figure 2. Wind erosion calculator and computer solutions of wind erosion equation for various combinations of E4 and equivalent flat small grain residue before revision of calculator scale.

The ridge roughness factor K estimates the fractional reduction of erosion caused by the ridges of nonerodible aggregates formed. It is influenced by ridge spacing and ridge height and is defined relative to a 1:4 ridge height to spacing ratio. Table 1 gives the K values for various combinations of ridge height and ridge spacing. Ridge spacing combinations that yield soil ridge roughness factors of 0.5 to 0.6 approximate ridged surfaces; 0.7 and 0.8, semiridged surfaces; and 0.9 and 1.0, smooth surfaces. SCS has evaluated fields as smooth, semiridged, or ridged and then assigned 1.0, 0.75, and 0.5, respectively, as the soil ridge roughness factor (*5*).

The climatic factor C determines soil loss for climatic conditions other than those occurring when the relationship between wind tunnel and field erodibility were obtained (*3*). Monthly C values and wind energy distributions have been determined for calculating erosion when plant damage or certain periods of the year are the major interest (*1, 7, 12, 13*). Climatic factor maps have been prepared for major wind erosion areas of the United States (*7, 12*).

Field width is the shorter dimension of a rectangular field and is multiplied by the wind erosion direction factor to obtain equivalent field length, L, that is needed for solving the wind erosion equation. The wind erosion direction factor is a dimensionless number that depends upon the preponderance of prevailing wind erosion forces in prevailing direction, angle of deviation of prevailing wind erosion direction from perpendicular to field length, and length/width ratios for rectangular fields. Wind erosion direction factors for many combinations of variables are available in a manuscript on wind erosion direction factors that I am preparing for publication. Prevailing wind erosion directions are available for many locations in Agriculture Handbook 346 (*12*).

Equivalent vegetative cover originally was designated as V by Woodruff and Siddoway (*13*). They also gave the relationship between equivalent vegetative cover and equivalent flat small grain residue and other residues, then used equivalent vegetative cover in the equation. More recently, effectiveness of crop residues usually is expressed as equivalent flat small grain residue (*8, 9*). Effectiveness of residues in terms of equivalence to flat small grain is needed to solve the wind erosion equation with the wind erosion calculator. The relationship between flat small grain and amount of residues of selected crops and range grasses is given by Lyles and Allison (*8, 9*). I (*10*) adapted the data of Woodruff and Siddoway (*14*) to give equivalent flat small grain for standing small grain and sorghum stubble. This information, which is available from various sources in the literature and is needed for solving the wind erosion equation, will be combined and presented in the revision of Agriculture Handbook 346 now in progress.

Once values for the variables in the first instruction have been determined, one just follows the remaining instructions to predict potential average annual soil loss.

Also, suppose the calculated soil loss is 10 tons per acre per year and you want to know the amount of flat small grain need-

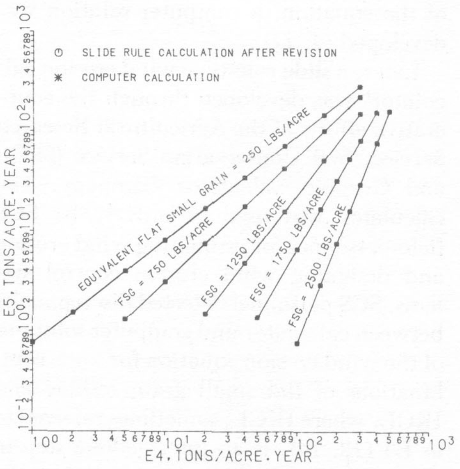

Figure 3. Wind erosion calculator and computer solution of wind erosion equation compared for various combinations of E4 and equivalent flat small grain residue after revision of calculator scale.

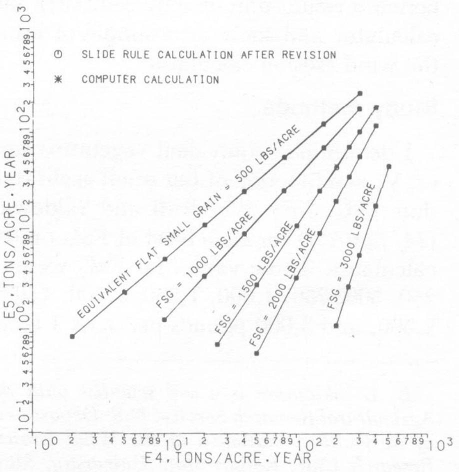

Figure 4. Wind erosion calculator and computer solution of wind erosion equation compared for various combinations of E4 and equivalent flat small grain residue after revision of calculator scale.

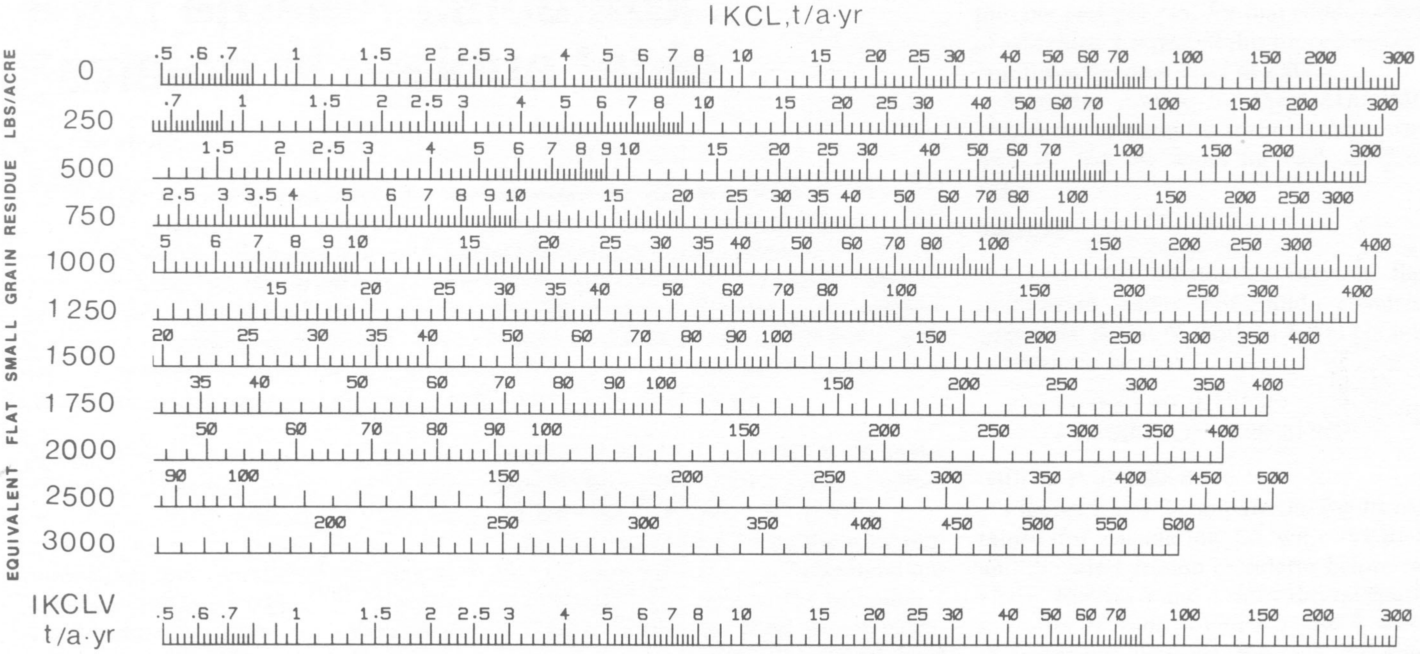

Figure 5. Revised wind erosion calculator scale for finding E5 = IKCLV as a function of E4 at indicated levels of equivalent flat small grain residue.

ed to reduce wind erosion to 5 tons per acre per year. For IKCLV = 10 tons per acre per year and FSG = 1,000 pounds per acre. Then from figure 5, IKCL is 40 tons per acre per year. When FSG = 1,250 pounds per acre and IKCL = 40 tons per acre per year, IKCLV is about 5 tons per acre per year. In other words, an additional 250 pounds of flat small grain residue per acre would reduce potential soil loss from 10 to 5 tons per acre per year. This procedure of working backwards through the solution allows one to determine other conditions, such as field length and roughness, necessary to control potential wind erosion to some predetermined amount.

The wind erosion calculator is a convenient conservation tool that can be used in solving the wind erosion equation to predict potential wind erosion and to design erosion control practices. Its accuracy is within the limits of uncertainties of the functional relationships of the equation.

Table 1. Soil ridge roughness factor K.

Ridge Spacing (in)	Ridge Roughness Factor K by Ridge Height (in)											
	1	2	3	4	5	6	7	8	9	10	11	12
1	0.5	0.8										
2	0.5	0.6	0.8									
4	0.6	0.5	0.7	0.8								
6	0.7	0.5	0.6	0.8								
8	0.8	0.5	0.5	0.6	0.8							
10	0.8	0.6	0.5	0.6	0.8							
12	0.9	0.6	0.5	0.5	0.7	0.8						
14	0.9	0.6	0.5	0.5	0.6	0.8						
16	0.9	0.6	0.5	0.5	0.6	0.7	0.8					
18	0.9	0.7	0.5	0.5	0.5	0.6	0.8					
20	0.9	0.7	0.5	0.5	0.5	0.6	0.8					
22	0.9	0.7	0.6	0.5	0.5	0.6	0.7	0.8				
24	0.9	0.7	0.6	0.5	0.5	0.6	0.7	0.8				
26	0.9	0.8	0.6	0.5	0.5	0.5	0.6	0.8				
28	0.9	0.8	0.6	0.5	0.5	0.5	0.6	0.7	0.8			
30	0.9	0.8	0.6	0.5	0.5	0.5	0.6	0.7	0.8			
32	1.0	0.8	0.6	0.5	0.5	0.5	0.6	0.6	0.8			
34	1.0	0.8	0.6	0.5	0.5	0.5	0.5	0.6	0.7	0.8		
36	1.0	0.8	0.6	0.5	0.5	0.5	0.5	0.6	0.7	0.8		
38	1.0	0.8	0.6	0.6	0.5	0.5	0.5	0.6	0.7	0.8		
40	1.0	0.8	0.7	0.6	0.5	0.5	0.5	0.6	0.7	0.8		
42	1.0	0.9	0.7	0.6	0.5	0.5	0.5	0.6	0.6	0.7	0.8	
44	1.0	0.9	0.7	0.6	0.5	0.5	0.5	0.5	0.6	0.7	0.8	
46	1.0	0.9	0.7	0.6	0.5	0.5	0.5	0.5	0.6	0.7	0.8	
48	1.0	0.9	0.7	0.6	0.5	0.5	0.5	0.5	0.6	0.7	0.8	

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