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677 South Segoe Rd., Madison, WI 53711 USA

Comment on Chain Method for Measuring Soil Roughness

It is common knowledge among those who study wind erosion and develop plans for controlling it that soil ridges and surface random roughness have a major influence on wind erosion. My colleague, Saleh (1993, 1994), has proposed a chain method to measure both random and oriented roughness. A roughness R is calculated from

$$R = (1 - \mathrm{L2}/\mathrm{L1})100 \qquad [1]$$

where L1 is the length of chain required to span roughness element(s) for a horizontal distance L2.

At first glance, the procedure has appeal. It is simple to use and inexpensive and appears to give reasonable results. As ridge height increases without changing ridge spacing (L2), the length of chain needed to span the ridge will increase; thus, it it can be seen from Eq. [1] that the calculated roughness also will increase. Similarly, if ridge height is held constant and ridge spacing is increased, roughness as calculated by Eq. [1] will decrease. However, a problem occurs when ridge height and ridge spacing vary together. When L2 and L1 vary but the ratio remains constant, Eq. [1] produces unrealistic results.

For well-defined ridges, like the constructed wooden isosceles triangular ridges used by Saleh (1994), L1 can be computed directly based on the geometry of the ridges. Thus, to estimate the length of chain required to span one ridge cycle, let s be ridge spacing, which is equal to L2 for one ridge, and h be ridge height for isosceles triangular ridges (Fig. 1), then

$$\mathrm{L1} = s/\cos[\arctan(2h/s)] \qquad [2]$$

Substitution of Eq. [2] into Eq. [1] for L1 gives:

$$R = \{1 - \cos[\arctan(2h/s)]\}100 \qquad [3]$$

Table 1 shows the results of the calculated roughness R from Eq. [3] for four ridges (1, 2, 3, and 4) under column heading R2. Column R1 of Table 1 is from Saleh's (1994, Table 1) chain method measurement. The agreement between measured and calculated values is as good as would be expected. However, when other ridge configurations (5, 6, and 7 of Table 1) with the same L2/L1 ratio are considered, Saleh's (1994) chain method, Eq. [1], would give each of them the same roughness (Table 1, heading R2). Obviously, these three ridges, depicted in Fig. 1, are not the same.

Consider the different effects that the ridges of Fig. 1 have on the wind speed profile parameters. The familiar logarithmic law for wind speed profile is given by

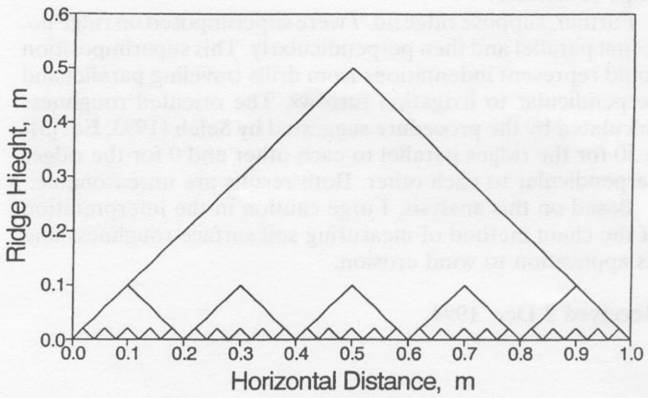

Fig. 1. Three different isosceles triangular ridges that all have the same height/spacing ratio and roughness as calculated by the chain method.

$$u = u_*/k \ln[(z - d)/z_0] \qquad [4]$$

where u is the wind speed at height z, u_* is friction velocity, k is the von Karman constant (0.4), d is the displacement height, and z_0 is the aerodynamic roughness parameter. The displacement height was estimated by multiplying the ridge height by 0.5, and the roughness parameter was estimated by multiplying the ridge height by 0.065 (Abtew et al., 1989). Then the friction velocity was calculated with Eq. [3] for a wind speed of 10 m/s at 10-m height. The results (Table 1) show that aerodynamically the ridges are very different.

A ridge-roughness factor (K_r) based on height and spacing of ridges has been used in the wind erosion equation (WEQ) to estimate the reduction of wind erosion caused by nonerodible ridges. The traditional equation (Saleh, 1993, Eq. [5])

$$K_r = 4h^2/s \qquad [5]$$

and the equation proposed by Saleh (1993, Eq. [6])

$$K_r = C_{or}0.02118/N \qquad [6]$$

where N is the number of ridges covered under L2 length, were used to calculate ridge roughness for the ridges in Table 1. The results of these calculations (Table 1) show that the ridges depicted in Fig. 1 all have the same ridge roughness (0.62 m) as calculated by Eq. [6] (Saleh, 1993). However, the ridge roughness calculated by the traditional method varies from 0.04 to 1.0 m. Saleh's (1993) Eq. [6] has a term N for the number of ridges covered under L2 length. In my examples, N was always one. Suppose I had let N be the number of

Table 1. Ridge specifications and various results.

Ridge no.	Ridge spacing	Ridge height	L1	L2	Saleh R1	Eq. [3] R2	Eq. [5] K_r	Eq. [6] K_r	z_0	d	u_*
	m					m				m/s	
1	1.0	0.25	1.11	1.0	9.9	10.6	0.25	0.21	–	–	–
2	1.0	0.25	1.11	1.0	9.3	10.6	0.25	0.20	–	–	–
3	1.0	0.33	1.18	1.0	15.4	16.5	0.44	0.33	–	–	–
4	1.0	0.50	1.42	1.0	29.8	29.3	1.0	0.63	–	–	–
5	1.0	0.50	1.41	1.0	–	29.3	1.0	0.62	0.0325	0.25	0.70
6	0.2	0.10	0.283	0.2	–	29.3	0.2	0.62 (0.12)	0.0065	0.05	0.55
7	0.04	0.02	0.0566	0.04	–	29.3	0.04	0.62 (0.025)	0.0013	0.01	0.45

ridges covered for a horizontal distance of 1 m (this may be the intended definition), then the ridge roughness is sensitive to ridge height (values in parentheses, Table 1). The agreement is still not good between the two methods of calculation for ridge roughness.

Further, suppose ridge no. 7 were superimposed on ridge no. 5, first parallel and then perpendicularly. This superimposition could represent indentations from drills traveling parallel and perpendicular to irrigation furrows. The oriented roughness calculated by the procedure suggested by Saleh (1993, Eq. [3]) is 50 for the ridges parallel to each other and 0 for the ridges perpendicular to each other. Both results are unreasonable.

Based on this analysis, I urge caution in the interpretation of the chain method of measuring soil surface roughness and its application to wind erosion.

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USDA-ARS
Throckmorton Hall
Kansas State Univ.
Manhattan, KS 66506
skidmore@weru.ksu.edu

E.L. Skidmore

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