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Small-Grain Equivalent of Mixed Vegetation for Wind Erosion Control and Prediction

E.L. Skidmore* and R.G. Nelson

ABSTRACT

Control and prediction of wind erosion require knowledge of the effectiveness of surface vegetative cover. The effectiveness is usually referenced to as small-grain equivalent. The procedure used to convert mixed vegetation to small-grain equivalent was found faulty. Improper weighting of regression coefficients caused the conversion procedure to predict that adding crop residue decreased small-grain equivalent. Therefore, the purpose of this analysis was to improve the conversion of mixed vegetation to a small-grain equivalent. The new expression derived for this purpose gave a logical conversion where the previous procedure failed. It did not predict a decreasing small-grain equivalent with increased soybean [*Glycine max* (L.) Merr.] residue in the 0 to 300 kg/ha range as did the former method. Applied to the same data that were used for testing the previous procedure, the new procedure reduced the error by almost 50%. The new procedure improves the conversion of mixed vegetation to small-grain equivalent.

CONTROL AND PREDICTION of wind erosion requires knowledge of the effectiveness of surface vegetative cover. Scientists realized early the value of crop residue for controlling wind erosion and reported quantitative relationships (Chepil, 1944).

Amounts of wheat (*Triticum aestivum* L.) straw needed to protect most erodible dune sands and less erodible soils against strong winds were determined (Chepil et al., 1960). Standing stubble was much more effective than flattened stubble (Chepil et al., 1955). Standing sorghum [*Sorghum bicolor* (L.) Moench.] stubble controlled wind erosion more effectively with rows perpendicular to wind direction than with rows parallel to wind direction (Englehorn et al., 1952; Skidmore et al., 1966).

Siddoway et al. (1965) quantified the specific properties of vegetative covers influencing soil erodibility and developed regression equations relating soil loss by wind to selected amounts, kinds, and orientation of vegetative covers; wind velocity; and soil cloddiness. They found a complex relationship among the different kinds and orientations of residue in terms of relative effectiveness. The relative value of kinds and orientations of residue in controlling erosion must be quantified by soil, wind velocity, and variable characteristics of the residues. Generally, Siddoway and associates concluded that (i) on a weight basis, fine-textured residues were more effective than coarse-textured residues; (ii) any orientation of residue reduced wind erosion more than flattened; and (iii) fine-leafed crops, such as grasses and cereals, provided a high degree of erosion control per unit weight. Those studies led to the relationship developed by Woodruff and Siddoway (1965) showing the influence of an equivalent vegetative cover of small-grain and sorghum stubble for various orientations (flat, standing) and heights, and relating soil loss to equivalent vegetative cover.

Efforts to evaluate the protective role of more crops have continued. In wind tunnel tests, Lyles and Allison (1980; 1981) determined the equivalent wind erosion protection provided by selected range grasses and crop residues. They found a good correlation between small-grain equivalent and the quantity of residue or grass with use of the following equation:

$$\mathrm{SGE} = aX^b \qquad [1]$$

where SGE is the flat small-grain equivalent, X is the quantity of residue or grass to be converted, and a and b are equation coefficients.

Until recently, all small-grain equivalent data have been limited to dead crop residue or dormant grass. Armbrust and Lyles (1985) reported regression coefficients for Eq. [1] to determine flat small-grain equivalent for five growing crops—corn (*Zea mays* L.), cotton (*Gossypium hirsutum* L.), grain sorghum, peanut (*Arachis hypogaea* L.), and soybean. They found that if only rough estimates of SGE are needed, an average coefficient could be used. An average equation determined from pooling all crop data with rows running perpendicular to wind direction gave values of 8.9 and 0.9, respectively, for a and b.

In conservation tillage systems, residue from the previously harvested crop is still present on the surface as the newly planted crop develops. Also, vegetation on rangeland consists of a mixture of grasses and forbs. The mixture of various vegetative components increases the complexity of determining the small-grain equivalent.

Lyles and Allison (1980) proposed determining the

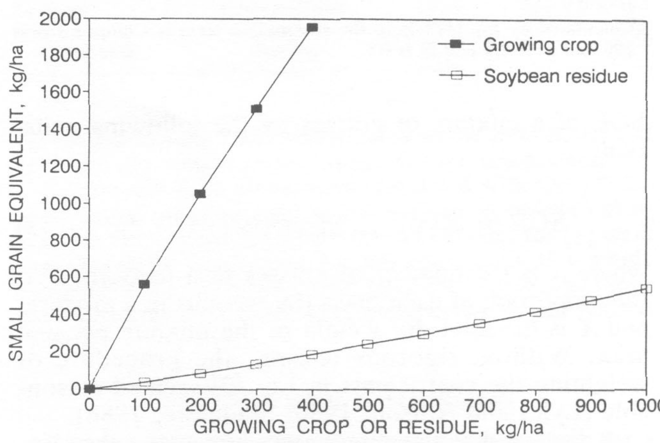

Fig. 1. Small-grain equivalent from various amounts of growing crop (dry weight) and flat-random soybean residue.

Abbreviation: SGE, small-grain equivalent.

E.L. Skidmore, USDA-ARS, Kansas State Univ., Manhattan, KS 66506–4006; and R.G. Nelson, Engineering Extension, Kansas State Univ., Manhattan, KS 66506–2508. Joint contribution of the USDA-ARS and Kansas Agric. Exp. Stn., Contribution no. 91-312-J. Received 5 Feb. 1991. *Corresponding author.

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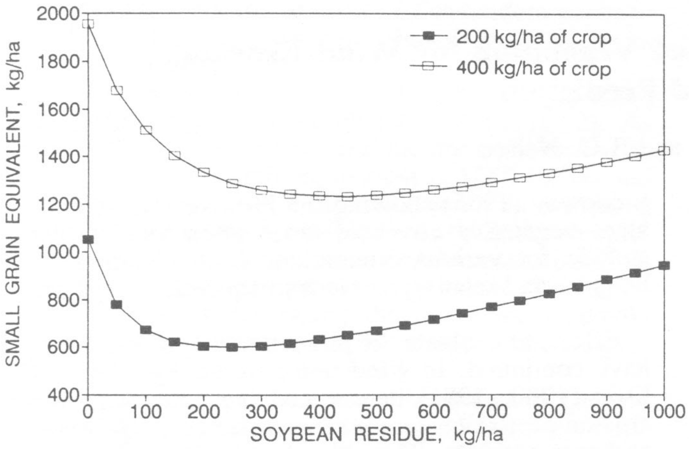

Fig. 2. Illogical decline in small-grain equivalent with added residue calculated from improperly weighted equation.

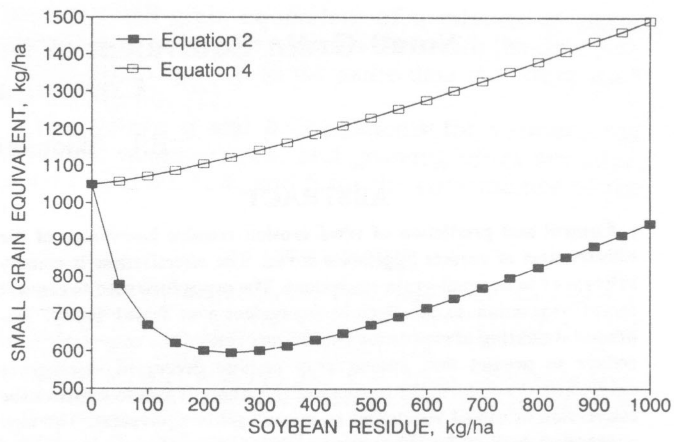

Fig. 3. Comparison of small-grain equivalent calculated from the different procedures for combining 200 kg/ha of growing crop with soybean residue for wind erosion protection.

Table 1. Total small-grain equivalent (SGE) from 200 kg/ha (dry weight) of growing crop and specified amount of flat-random soybean residue.

RESIDUE SOYBEAN	SGE† SOYBEAN	CROP‡ NEEDED	SGE§ TOTAL
kg/ha			
0	0	0	1048
50	16	2	1057
100	37	5	1071
150	59	8	1086
200	82	12	1103
250	107	16	1122
300	132	20	1142
350	158	24	1163
400	185	29	1184
450	212	34	1207
500	240	39	1230
550	268	44	1253
600	297	49	1278
650	326	55	1303
700	365	60	1328
750	386	66	1354
800	416	72	1380
850	447	78	1407
900	478	84	1435
950	509	90	1462
1000	540	96	1490

†Calculated by Eq. [1] from the amount of residue in Column 1 and 0.167 for *a* and 1.17 for b.
‡Calculated by Eq. [3] where SGE is from Column 2 and a' is 8.9 and b' is 0.9.
§Calculated by Eq. [4] where the summation term is Column 3 plus 200 and a' is 8.9 and b' is 0.9.

SGE of a mixture of grasses by the following equation:

$$SGE = a_1^{P_1} a_2^{P_2} \ldots a_n^{P_n} X^{P_1 b_1 + P_2 b_2 + \ldots + P_n b_n} \quad [2]$$

where n is the number of grasses in a mixture, P is the proportion of each grass (by weight) in a mixture, and X is the total dry weight of the mixture per unit area. Without rigorous testing, the procedure of weighting the coefficients in Eq. [2] seemed reasonable (Lyles and Allison, 1980; Skidmore, 1988).

A discrepancy was discovered, however, when Eq. [2] was used to determine the quantity of crop residue that can be removed from fields for bioenergy purposes. Therefore, in response to that discovery, the purpose of this analysis was to examine this discrepancy and derive an improved expression to determine the small-grain equivalent of mixed vegetation.

MATERIALS AND METHODS

The small-grain equivalent was calculated for a growing crop by Eq. [1] using coefficients as determined by Armbrust and Lyles (1985) from pooled data with rows running perpendicular to wind direction ($a = 8.9$, $b = 0.9$). The above-ground dry weight was varied from 0 to 400 kg/ha. The small-grain equivalent was calculated for flat-random soybean residue. The coefficients a and b were 0.167 and 1.17, as determined by Lyles and Allison (1981). The soybean residue was varied from 0 to 1000 kg/ha. Then, these two vegetative components were combined in various ways, and small-grain equivalents were calculated by Eq. [2].

An improved method to estimate the small-grain equivalents from mixed vegetation was developed:

1. Find small-grain equivalent for each component of the mixture by Eq. [1].
2. Select the component with the largest small-grain equivalent and call this the prime component.
3. Find the mass, M_i, of the prime component needed to contribute a small-grain equivalent equal to the small-grain equivalent of each component of the mixture

$$M_i = (SGE_i/a')^{1/b'} \quad [3]$$

where a' and b' are the regression coefficients for the prime component.

4. Sum all of the masses determined by Eq. [3].
5. Use the total mass as determined in Step 4 in Eq. [1] and calculate total small-grain equivalent of the vegetative mixture.

The above procedure written as a single equation becomes:

$$SGE_T = a' \left[\left(\frac{a_1 M_1^{b_1}}{a'}\right)^{1/b'} + \left(\frac{a_2 M_2^{b_2}}{a'}\right)^{1/b'} + \ldots + \left(\frac{a_n M_n^{b_n}}{a'}\right)^{1/b'} \right]^{b'} = a' \left[\sum_{i=1}^{n} (a_i M_i^{b_i}/a')^{1/b'} \right]^{b'} \quad [4]$$

where SGE_T is the total small-grain equivalent summed for n components of the mixture; a_i and b_i are the coefficients

Table 2. Comparison of small-grain equivalents of range grass mixtures using Eq. [2] and [4].

Grass mixture†	Management level	Total dry weight	Small-grain equivalent			Error	
			Eq. [1]	Eq. [2]	Eq. [4]	Eq. [2]	Eq. [4]
		kg/ha				%	
GM_3	Ungrazed	300	1649	2163	2002	+31	+21
GM_3	Properly grazed	300	1363	1232	1420	−10	+ 4
GM_3	Overgrazed	150	1744	1248	1620	−28	− 7
GM_1	Properly grazed	500	1450	1007	1110	−31	−23
GM_1	Overgrazed	500	1089	1387	1229	+27	+13
GM_2	Properly grazed	300	1312	1082	1127	−18	−14
GM_2	Overgrazed	300	1297	1824	1781	+41	+37

†See Lyles and Allison (1980) for mixture composition.

Table 3. Coefficients in prediction equation, SGE = aX^b, for conversion of crop residues to equivalent quantity of flat, small-grain residue both in kg/ha (Lyles and Allison, 1981).

Crop residue	Surface orientation	Height	Length	Row spacing	Row orientation to flow	Prediction equation coefficients a	b	r^2
		cm						
Winter wheat	Standing	25.4	—	25.4	Perpendicular	4.31	0.97	1.00
Rape (Brassica rapa)	Standing	25.4	—	25.4	Perpendicular	0.10	1.40	0.99
Cotton	Standing	34.3	—	76.2	Perpendicular	0.19	1.15	1.00
Sunflower (Helianthus)	Standing	43.2	—	76.2	Perpendicular	0.02	1.34	0.99
Winter wheat	Flat-random	—	25.4	—	—	7.28	0.78	0.99
Soybean	Flat-random	—	25.4	—	—	0.17	1.17	0.99
Rape	Flat-random	—	25.4	—	—	0.06	1.29	1.00
Cotton	Flat-random	—	25.4	—	—	0.08	1.17	1.00
Sunflower	Flat-random	—	43.2	—	—	0.01	1.37	0.99
Forage sorghum	Standing	15.9	—	76.2	Perpendicular	0.35	1.12	1.00
Silage corn	Standing	15.9	—	76.2	Perpendicular	0.23	1.14	1.00
Soybean	1/0 standing 9/10 flat-random	6.4 —	— 25.4	76.2 —	Perpendicular —	0.02	1.55	0.99

Table 4. Coefficients in prediction equation for small grain equivalent, SGE = aX^b, for conversion of range grasses to equivalent quantity of flat, small-grain residue both in kilograms per hectare (Lyles and Allison, 1980)

Grass species	Grazing management	Grass height	Prediction equation coefficients a	b	r^2
		cm			
Blue grama [*Bouteloua gracilis* (H.B.K) Lag.]	Ungrazed	33.0	0.60	1.39	0.98
Buffalograss [*Buchloe dactyloides* (Nutt.)]	Ungrazed	10.2	1.40	1.44	0.97
Big Bluestem (*Andropogon gerardii* Vitm.)	Properly grazed	15.2	0.22	1.34	0.99
Blue grama	Properly grazed	5.1	1.60	1.08	0.99
Buffalograss	Properly grazed	5.1	3.08	1.18	0.99
Little bluestem (*Andropogon scoparius* Michs.)	Properly grazed	10.2	0.19	1.37	0.99
Switchgrass (*Panicum virgatum* L.)	Properly grazed	15.2	0.47	1.40	0.99
Western wheatgrass (*Agropyron smithii* Rydb.)	Properly grazed	10.2	1.54	1.17	0.99
Big bluestem	Overgrazed	2.5	4.12	0.92	0.99
Blue grama	Overgrazed	2.5	3.06	1.14	0.99
Buffalograss	Overgrazed	1.5	2.45	1.40	0.99
Little bluestem	Overgrazed	2.9	0.52	1.26	0.99
Switchgrass	Overgrazed	2.5	1.80	1.12	0.99
Western wheatgrass	Overgrazed	2.5	3.93	1.07	0.99

Table 5. Coefficients in prediction equation SGE = aX^b for conversion of growing crop to an equivalent quantity of flat small-grain residue, both in kg/ha (Armbrust and Lyles, 1985).

Growing crop	Row orientation to flow	Prediction coefficients *a*	*b*	r^2
Corn	Perpendicular	11.17	0.79	0.99
Corn	Parallel	0.07	1.38	0.99
Cotton	Perpendicular	10.58	0.83	0.99
Cotton	Parallel	5.70	0.72	0.99
Grain sorghum	Perpendicular	3.61	1.07	1.00
Peanut	Perpendicular	6.54	0.98	0.99
Soybean	Perpendicular	19.24	0.81	0.99
Soybean	Parallel	8.53	0.77	1.00
AVERAGE	Parallel	8.87	0.89	0.99

for the component contributing most to the total SGE; and M_i is the dry weight mass, kg/ha, of each component.

Small-grain equivalents were calculated with Eq. [4] for mixtures of range grasses and compared to results calculated by Eq. [1] and [2] where the coefficients for [1] were experimentally determined for the mixture as if a single component. The coefficients for the grass species and range grass mixtures were those determined by Lyles and Allison (1980).

RESULTS AND DISCUSSION

The small-grain equivalent was much greater for a generic growing crop than for flat-random soybean residue, as shown in Fig. 1. The small-grain equivalent for 200 kg/ha of growing crop is 1050 kg/ha, whereas for the same amount of flat-random soybean residue, the small-grain equivalent is only 82 kg/ha (TAble 1, Column 2).

But see what happens according to Eq. [2] when the two vegetative materials are added (Fig. 2). As small amounts of soybean residue are combined with 200 kg/ha (small-grain equivalent is 1050 kg/ha) and 400 kg/ha of growing crop (small-grain equivalent is 1950 kg/ha), the small-grain equivalent declines sharply. The slope of the decline gradually decreases until the mixture is 50/50, then gradually increases. This illogical behavior of decreasing the protective value by adding residue demonstrates the inappropriate weighting of the coefficients of Eq. [2].

Intermediate calculations are illustrated in Table 1 for a more appropriate procedure to determine small-grain equivalent. The small-grain equivalent in Column 2 was calculated by Eq. [1] from the amount of residue in Column 1 and the regression coefficients for flat-random soybean residue, 0.167 and 1.17 for a and b, respectively. Values in Column 3 were calculated by Eq. [3], where SGE is from Column 2 and a' and b' are the regression coefficients for a growing crop. Values in Column 4 were calculated by Eq. [4]. The symbols are as previously defined.

The results from Eq. [2] and [4] for calculating small-grain equivalent by adding soybean residue to 200 kg/ha of growing crop are compared in Fig. 3. The increase in small-grain equivalent from adding soybean residue is consistent with expected results.

The reasonableness and accuracy of the procedure represented by Eq. [4] is demonstrated further by data in Table 2. The error (last column, Table 2) in estimating small-grain equivalent of a mixture of range grasses was reduced by almost 50% with the new procedure when applied to the same data that were used for testing Eq. [2].

The known a and b coefficients for various crop residues, range grasses, and growing crops are compiled in Tables 3, 4, and 5 for the convenience of the reader.

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