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Stubble Requirements in Field Strips to Trap Windblown Soil

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INTRODUCTION

Because of current interest in environmental quality, public service agencies are increasingly concerned about soil erosion by wind. The ideal —though practically unattainable—goal of soil- and crop-management practices is to prevent initial movement of soil particles (100-percent control) by wind. A realistic objective is to reduce soil loss or movement to a tolerable limit. One approach is to use erosion-resistant strips of vegetation to trap soil particles (moving in saltation and creep) originating in erosion-susceptible field strips (3).

Current procedures for determining spacing of trap strips is to use this wind erosion equation in obtaining L (6, 9, 10):

$$E = f(I, K, C, L, V) \quad [1]$$

where E is the potential annual soil-loss rate; I the soil erodibility; K the soil ridge roughness factor; C the climatic factor; L the unsheltered distance across a field along the prevailing wind direction; and V the equivalent vegetative cover. If the prevailing wind direction deviates from perpendicular to the field border, L is converted to the perpendicular distance across a field to obtain the permissible width of erosion-susceptible strips. That width also is used as trap strip width in an alternate crop-fallow system (2-year rotation). The Soil Conservation Service also uses a chart (based on preliminary data they believe are inadequate to meet their needs) to determine the minimum number of rows required in protective strips (4, 6). That chart (in its present form) has four sources of error: (a) it does not consider that volume of soil to be trapped increases with L even when tolerable erosion rate (E_T) remains constant; (b) no row spacing is designated, thus saltating (jumping) particles could be carried across narrow trap strips and trapping efficiency would be less than 100 percent; (c) the chart apparently assumes that increasing number of rows continues to be effective, while number of stalks per 10-foot row length (N) decreases to low values (an assumption that cannot,

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in general, be true because adding more rows of low N may not increase a strip's ability to trap moving soil); and (d) no restrictions on stubble height (a very important parameter) are indicated.

In recent research (8) we calculated the wind-erosion protection provided by various crop residues (stubble), depending on their physical dimensions, amount, and orientation. From information in that study, we developed tables to use to design or evaluate trap strips (or both) for various wind-erodibility soil groups (table 1) used by the Soil Conservation Service in applying equation [1]. The form of the regression equation used to determine the degree of wind erosion protection is:

$$P = f[(\frac{H}{L_x})^a, (\frac{NA_p}{A_T})^b] \quad [2]$$

where P is the protection parameter; H, average stubble height (standing); L_x, distance between stalks in direction of wind; N, number of stalks in total area A_T; A_p, average plan view area of single stalks; and a and b, constants. This report contains the tables, data, and assumptions used in developing them, and examples of their use.

Input Data: Assumptions and Procedures

Wind Velocity

The design mean windspeeds chosen ($\bar{u}_z$) are 35 and 39 m.p.h. at Z = 20 feet over 1.0- and 0.5-foot stubble, respectively. Those velocities are expected to occur on the High Plains every 1 to 3 years, on the average, for a 6-hour period during March, April, or May when soil is most susceptible to wind erosion (12). In less windy parts of the country, the recurrence interval may be 50 years. In windy areas (7) such as western Oklahoma and Kansas, Texas Panhandle, eastern New Mexico, northeastern Colorado, southeastern Wyoming, and north-central Montana, one should adhere strictly to or exceed the plant populations and height requirements found in the tables (3 through 28).

The roughness parameter (Z_o) is taken as 1/25 of stubble height. Using the indicated values of $\bar{u}_z$ and Z_o, we calculated the friction or drag velocity (u_*) of the wind from this equation:

$$u_* = \frac{k\,\bar{u}_z}{\ln(\frac{Z}{Z_o})} \quad [3]$$

where k is von Karman's constant (0.4); the other terms have been defined previously.

Soils

The erodible soil to be trapped is assumed to be 0.15 to 0.42 mm in diameter.

We placed the wind-erodibility soil groups in three categories, based on these particle densities (2):

Wind-erodibility group (WEG)	Average particle density	Threshold friction velocity (u_{*t})
	gm/cm³	cm/sec
1, 2	2.63	21.64
3	2.24	18.74
4, 4L, 5, 6, 7	1.80	16.80

The threshold friction velocity (u_{*t}) for WEG 1 and 2

was determined experimentally (8). Those for WEG 3 and WEG 4 through 7 were calculated from this equation:

$$u_{*t} = A(\alpha\, gd)^{1/2} \qquad [4]$$

where α is the apparent density ratio ρ'/ρ (ρ' is immersed particle density and ρ is air density); g, the gravitational constant; d, the minimum particle diameter; and $A \simeq 0.11$ for particles greater than 0.1 mm diameter (13).

The tolerable soil-erosion rate was selected as 5 tons per acre per year, a value commonly accepted in designing for wind-erosion control of field crops. Note that crop tolerances to blowing soil (especially horticultural crops) may be lower than 5 tons per acre per year. In that case the trap strip widths, which exceed 12 feet (tables 5 to 28), will be larger than required. If other tolerable erosion rates (for example, 1, 2, 3, or 4 tons per acre per year) are desired, trap strip widths exceeding 12 feet would be multiplied by 1/5, 2/5, 3/5, or 4/5, respectively, to determine the appropriate strip width (remembering the 12-foot minimum, to be discussed in a succeeding section).

Plants (Stubble)

The most serious wind erosion is associated with finely granulated soils and high winds, which (generally) occur during late winter or early spring in most parts of the United States. Except for winter-hardy crops, residues remaining after harvest constitute the available plant material in strips to trap windblown soil. Consequently, our tables were developed from after-harvest plant data.

Selected plant data are: (a) height (standing) of 0.5 and 1.0 foot; (b) stalk diameters of 0.1, 0.5, and 1.0 inch; (c) row spacings of 10 to 70 inches in increments of 10 (10-inch spacing is omitted for 1.0-inch stalk diameter); (d) plants per 10-foot row (N) of 5 to 50 in increments of 5; and (e) flat stubble lengths 1 and 1.5 feet for 0.5-inch stalk diameters and 3 and 4 feet for 1-inch stalk diameters.

Those stalk diameters could represent small grains, sorghums, and corn, respectively. Soybean and cotton stalk diameters fall between 0.1 and 0.5 inch. However, soybeans are clipped so close to the soil surface at harvest that the residues remaining are not effective in trap strips. Tables involving 0.5-inch stalk diameters (5 through 16) probably can be used for cotton, although failure for cotton probably is greater than for sorghums.

If standing stubble height is greater than 1 foot, a margin of safety exists but is somewhat offset by less flat stubble available at the soil surface.

Trap Strips

We assumed a minimum trap strip width of 12 feet to insure that most particles in saltation will be retained in the strip; i.e., trapping efficiency will be near 100 percent (5). Another consideration is strip capacity (its ability to hold trapped soil). Flat stubble is effective in trap strips only if not completely covered by soil enter-

ing the strip. Consequently, we restricted the trapped soil depth to 1/2 of stalk diameter for 0.5 and 1.0 inch stalks. Hence, the trap strip width depends on eroding strip width (L), tolerable erosion rate (E_T), and stubble quantity (primarily flat stubble).

We recognize that barriers less than 12 feet wide can be effective in controlling wind erosion (1, 11). However, such barriers generally are small grains or grass whose design depends on the "sheltered zone" concept. They protect by reducing windspeed leeward of the barrier in a sheltered zone whose extent depends primarily on barrier height, width, and porosity. Barrier spacing is some multiple of barrier height (H), usually 8 to 12H, so that the sheltered zone from one barrier extends to or overlaps and next downwind barrier. Our design depends on the ability of stubble to prevent soil movement **within** the trap strip and to hold the soil entering from eroding (cultivated) strips.

Commonly, N for small-grain stubble (standing) greatly exceeds the N values noted in tables 3 and 4, so standing stubble does not need the aid of flat stubble to provide protection; therefore, trap-strip width need not exceed the 12-foot minimum. However, if the erosion rate is greater than 5 tons per acre per year, L is large, and stubble is short (6 inches or less), a 12-foot strip may fail because the effective stubble height is reduced from soil deposition in the strip.

Procedures for determining eroding strip width (L) from equation [1] are available in other publications (6, 9, 10).

Trap Strip Design and Evaluation Information

Tables 3 to 28 were developed from the established soil, plant, and wind velocity criteria given in the "Input Data" section of this report. Those tables can be used to evaluate existing crop and soil conditions in terms of their adequacy as trap strips or to design trap strips. Wind direction is assumed normal to row direction (trap strips) and all the preponderance in the prevailing direction. If wind direction and preponderance deviate from normal, trap-strip effectiveness is reduced because the effective row spacing as "seen" by the wind (RS_Θ) is increased. That increased row spacing (RS_Θ) can be determined from this equation:

$$RS_\Theta = RS(A_f) \qquad [5]$$

where RS is row spacing given in the tables; and A_f, the adjustment factors (table 2). The angle of wind deviation (Θ) from the normal and preponderance can be determined from data given in reference 6 or 9. For example, let $\Theta = 20$; preponderance = 2.0, and existing row spacing (RS) = 30 inches; then $RS_\Theta = 30\ (1.35) = 40.5$ inches. Therefore, when evaluating or designing a trap strip, the 40-inch row spacing tables (instead of the 30-inch) should be consulted. If RS_Θ exceeds 70 inches (the maximum available), indicating a small preponderance, large Θ, or both, trap-strip di-

rection should be oriented more nearly perpendicular to prevailing wind direction, which would reduce ⊛ and hence RS_{Θ}.

Also, if the wind direction deviates from normal, additional protective strips are needed along outer perimeters of eroding strips.

Small Grains (Tables 3 and 4)

Tables 3 or 4 can be used to design or evaluate small grain trap strips. The number 0-0 indicates that N for given row spacing does not meet design conditions and cannot be used for any wind-erodibility groups (WEG); 1-2 indicates that only WEG 1 and 2 of table 1 are suitable for the stated conditions; 1-3, that WEG 1, 2, and 3 are suitable; and 1-7, that the plant data are adequate for trap strips on all WEG in table 1.

N for closely drilled small grains commonly ranges from 100 to 600, which is more than adequate for all WEG if stubble height is 6 inches or more and row spacing does not exceed 10 inches. Consequently, tables 3 and 4 need be consulted only if plant populations are low and associated with wide row spacings. Reference 5 gives further guidance on dense, small-grain trap strips.

Other Crops (Tables 5-28)

Tables 5 to 28 can be used to design or evaluate trap strips composed of crops with larger stalk diameters. Values of N above a horizontal dashed line in the tables are too low for a trap strip to meet design criteria.

The WEG in column 2 of the tables is used if all the stubble is standing (interrow area is bare). In that case, the "width of trap strip" portion of the table is not used, and minimum trap strip width is 12 feet. If **both** standing and flat stubble are present, column 3 of the tables is used to determine what WEG are applicable and the trap strip width needed for the eroding strip width (L) in question.

If row spacings encountered are different from those available in the tables, use the next row spacing in the table that exceeds the row spacing in question. If stubble height is between 0.5 and 1.0 foot, use the 0.5-foot height tables. If stubble height exceeds 1 foot, use the 1-foot tables. All of those procedures will provide a margin of safety in the trap strips.

Examples

Consider a large field of corn stubble after harvest. A farmer wants to fall plow a maximum amount of the field yet leave unplowed trap strips to collect windblown soil particles. This information is available: tolerable erosion rate of 4 tons per acre per year; row spacing of 30 inches; standing stubble height of 14 inches; flat stubble length of 3 feet; WEG of 3; N of 11; ⊛ of 10; and preponderance of 1.8. Is there enough stubble present for trap strips and, if so, what width of trap strip is required?

From references 6 or 10, eroding strip width (L) is determined as 350 feet (fictitious number). $RS_{\Theta} = 30\ (1.33) = 39.9$ inches; table 25 indicates sufficient stubble is available

for WEG 3, and a trap strip width of 4/5 (26) = 21 feet is required. Therefore, the farmer would alternately plow 140 rows, leaving 9 rows in trap strips across the field.

Consider a similar problem with sorghum stubble and this available information: tolerable erosion rate of 5 tons per acre per year; row spacing of 40 inches; standing stubble height of 1 foot; flat stubble length of 1 foot; WEG of 7; N of 25; ⊙ of 20; preponderance of 1.5.

Table 15, column 3, indicates N is not sufficient for WEG 7. Therefore, this field cannot be placed in trap strips; the entire field should be left in stubble. However, if windspeeds reach design levels, erosion would occur on this field even though left in stubble.

A farmer wants to design a trap-strip system for corn that he plans to cut for silage. His soil is in WEG 5; ⊙ of 30; and preponderance of 2.5. He plans to use 30-inch row spacing at high plant population of 60,000 per acre (N = 35) and a tolerable erosion rate of 3 tons per acre per year. In this case, the only stubble remaining after harvest will be standing and will be 6 inches high. Effective row spacing, RS_O is 30 (1.4) = 42 inches.

Table 19, column 2, indicates N is too low for any WEG! Consequently, his present plans are not permissible and alternative decisions are required. One solution is to determine L (e.g., 300 feet) and leave a trap-strip width of 3/5 (25) = 15 feet (6 rows), which is harvested for grain with a standing stubble height of 1 foot and flat stubble length of 3 feet (see table 26).

Finally, a grower wants to seed small-grain trap strips on a soil in WEG 3. The deviation angle is 30 degrees and preponderance is 1.2. What plant populations will be required if he uses a 10-inch row spacing drill? The effective row spacing RS_Θ is 10 (1.77) = 17.7 inches; therefore, use the 20-inch row spacing of table 4. If the stubble is left 1 foot high, 20 stalks per 10-foot row ($\simeq$ 105,000 stalks per acre) are needed. Trap-strip width would be $\geq$ 12 feet, and eroding strip width (L) would be determined from procedures given in references 6 and 10.

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Stalk diameter	Standing stubble height	Flat stubble length	Row spacing	Table no.
inches	feet	feet	inches	
0.1 (small grains	0.5	....	10-40	3
0.1 (small grains)	1.0	....	10-40	4
0.5 (sorghums)	0.5	1.5	10	5
0.5 (sorghums)	0.5	1.5	20	6
0.5 (sorghums)	0.5	1.5	30	7
0.5 (sorghums)	0.5	1.5	40	8
0.5 (sorghums)	0.5	1.5	50	9
0.5 (sorghums)	1.0	1.0	10	10
0.5 (sorghums)	1.0	1.0	20	11
0.5 (sorghums)	1.0	1.0	30	12
0.5 (sorghums)	1.0	1.0	40	13
0.5 (sorghums)	1.0	1.0	50	14
0.5 (sroghums)	1.0	1.0	60	15
0.5 (sorghums)	1.0	1.0	70	16
1.0 (corn)	0.5	4.0	20	17
1.0 (corn)	0.5	4.0	30	18
1.0 (corn)	0.5	4.0	40	19
1.0 (corn)	0.5	4.0	50	20
1.0 (corn)	0.5	4.0	60	21
1.0 (corn)	0.5	4.0	70	22
1.0 (corn)	1.0	3.0	20	23
1.0 (corn)	1.0	3.0	30	24
1.0 (corn)	1.0	3.0	40	25
1.0 (corn)	1.0	3.0	50	26
1.0 (corn)	1.0	3.0	60	27
1.0 (corn)	1.0	3.0	70	28

Table 1.—Descriptions of wind erodibility groups (WEG).†

WEG	Predominant soil textural class	Dry soil aggregates > 0.84 mm	Soil erodibility "I"
		Percent	Tons/acre/year
1	Very fine, fine, and medium sands; dune sands.	1	310
2	Loamy sands; loamy fine sands.	10	134
3	Very fine sandy loams; fine sandy loams; sandy loams.	25	86
4	Clays; silty clays; noncalcareous clay loams and silty clay loams with more than 35 percent clay content.	25	86
4L	Calcareous loams and silt loams; calcareous clay loams and silty clay loams with less than 35 percent clay content.	25	86
5	Noncalcareous loams and silty loams with less than 20 percent clay content; sandy clay loams; sandy clay.	40	56
6	Noncalcareous loams and silt loams with more than 20 percent clay content; noncalcareous clay loams with less than 35 percent clay content.	45	48
7	Silts; noncalcareous silty clay loams with less than 35 percent clay content.	50	38

† Data from Hayes (6).

Table 2.—Row spacing adjustment factors (A_f) for prevailing wind direction and preponderance.† (Multiply row spacing in tables 3-28 times the appropriate value to obtain row spacing (RS_θ) as seen by the wind along the prevailing wind direction. See reference 9 for prevailing wind directions and preponderance.)

Preponderance	θ-degrees of deviation of prevailing wind direction from perpendicular to the trap strips										
	0	5	10	15	20	25	30	35	40	45	50
1.0	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90
1.1	1.69	1.71	1.74	1.76	1.79	1.81	1.84	1.85	1.87	1.89	1.92
1.2	1.55	1.58	1.62	1.65	1.69	1.73	1.77	1.80	1.84	1.88	1.93
1.3	1.46	1.49	1.53	1.57	1.62	1.66	1.70	1.76	1.83	1.88	1.94
1.4	1.39	1.43	1.47	1.51	1.55	1.59	1.64	1.71	1.79	1.87	1.95
1.5	1.33	1.37	1.42	1.46	1.50	1.55	1.60	1.68	1.77	1.86	1.96
1.6	1.29	1.34	1.39	1.43	1.46	1.51	1.56	1.65	1.75	1.86	1.97
1.7	1.25	1.30	1.36	1.39	1.43	1.47	1.52	1.62	1.73	1.86	1.99
1.8	1.22	1.28	1.33	1.37	1.40	1.44	1.49	1.60	1.71	1.86	2.01
1.9	1.20	1.25	1.31	1.34	1.37	1.41	1.46	1.57	1.69	1.86	2.03
2.0	1.18	1.24	1.29	1.32	1.35	1.40	1.44	1.56	1.68	1.86	2.04
2.1	1.17	1.22	1.27	1.30	1.34	1.38	1.43	1.55	1.67	1.86	2.06
2.2	1.16	1.21	1.26	1.29	1.33	1.37	1.41	1.54	1.67	1.87	2.07
2.3	1.14	1.19	1.25	1.28	1.32	1.36	1.40	1.53	1.66	1.87	2.09
2.4	1.13	1.19	1.24	1.28	1.31	1.36	1.40	1.53	1.66	1.89	2.11
2.5	1.13	1.18	1.23	1.27	1.31	1.35	1.40	1.53	1.67	1.90	2.13
2.6	1.12	1.17	1.22	1.26	1.30	1.35	1.40	1.54	1.68	1.92	2.16
2.7	1.12	1.17	1.22	1.26	1.30	1.35	1.41	1.55	1.70	1.94	2.19
2.8	1.11	1.16	1.21	1.25	1.30	1.36	1.42	1.57	1.72	1.97	2.22
2.9	1.10	1.15	1.20	1.25	1.30	1.36	1.43	1.59	1.74	2.00	2.26
3.0	1.10	1.14	1.19	1.24	1.30	1.37	1.44	1.60	1.77	2.03	2.30
3.1	1.09	1.14	1.18	1.24	1.30	1.37	1.45	1.62	1.80	2.07	2.33
3.2	1.08	1.13	1.18	1.24	1.30	1.38	1.46	1.64	1.83	2.10	2.37
3.3	1.07	1.13	1.18	1.24	1.31	1.39	1.47	1.67	1.86	2.14	2.41
3.4	1.07	1.12	1.18	1.25	1.32	1.40	1.49	1.69	1.90	2.17	2.45
3.5	1.06	1.12	1.17	1.25	1.32	1.42	1.51	1.73	1.95	2.22	2.49
3.6	1.06	1.11	1.17	1.25	1.33	1.43	1.53	1.76	2.00	2.27	2.54
3.7	1.05	1.11	1.16	1.25	1.33	1.44	1.55	1.80	2.05	2.32	2.58
3.8	1.05	1.10	1.16	1.25	1.34	1.45	1.57	1.83	2.10	2.36	2.63
3.9	1.04	1.10	1.16	1.25	1.35	1.47	1.60	1.88	2.16	2.42	2.68
4.0	1.04	1.10	1.16	1.26	1.36	1.49	1.63	1.93	2.23	2.48	2.73

† Data from Hayes (6).

Table 3.—Tolerable erosion 1 to 5 tons per acre; stalk diameter 0.1 inch (small grains); standing stubble height 0.5 foot; trap strip width ≥ 12 feet.

Row spacing	N-average number of stalks per 10-foot row									
	5	10	15	20	25	30	35	40	45	50
Inches	Wind erodibility groups									
10					0-0	1-2	1-2	1-3	1-3	1-7
20						0-0	0-0	0-0	0-0	0-0
30										
40										

Table 4.—Tolerable erosion 1 to 5 tons per acre; stalk diameter 0.1 inch (small grains); standng stubble height 1.0 foot; trap strip width ≥ 12 feet.

Row spacing	N-average number of stalks per 10-foot row									
	5	10	15	20	25	30	35	40	45	50
Inches	Wind erodibility groups									
10	0-0	1-3	1-7	1-7	1-7	1-7	1-7	1-7	1-7	1-7
20		0-0	1-2	1-3	1-3	1-7	1-7	1-7	1-7	1-7
30			0-0	0-0	1-2	1-3	1-3	1-7	1-7	1-7
40					0-0	1-2	1-2	1-3	1-3	1-3

Table 5.—Tolerable erosion 5 tons per acre; row spacing 10 inches; stalk diameter 0.5 inch (grain sorghum); standing stubble height 0.5 foot; flat stubble length 1.5 feet.

N-stalks per 10-foot row	WEG*	WEG**	L-eroding strip width, feet									
			20	60	120	180	240	300	360	420	480	540
			Width of trap strip, feet									
5	0-0	0-0										
10	0-0	1-2			17	26	35	43	52	61	69	78
15	0-0	1-2			18	27	36	45	54	63	72	81
20	0-0	1-3			19	28	37	46	56	65	74	83
25	0-0	1-3			19	29	38	48	58	67	77	86
30	1-2	1-7	≧	12	20	30	40	50	60	70	80	90
35	1-3	1-7			21	31	41	52	62	72	83	93
40	1-3	1-7			21	32	43	54	64	75	86	97
45	1-7	1-7			22	34	45	56	67	78	90	101
50	1-7	1-7			23	35	47	58	70	82	93	105

* Standing stubble only.
** Standing and flat stubble combined.

Table 6.—Tolerable erosion 5 tons per acre; row spacing 20 inches; stalk diameter 0.5 inch (grain sorghum); standing stubble height 0.5 foot; flat stubble length 1.5 feet.

N-stalks per 10-foot row	WEG*	WEG**	L-eroding strip width, feet									
			20	60	120	180	240	300	360	420	480	540
			Width of trap strip, feet									
5	0-0	0-0										
10	0-0	0-0										
15	0-0	0-0										
20	0-0	1-2			17	26	35	43	52	61	69	78
25	0-0	1-2			18	26	35	44	53	62	70	79
30	0-0	1-2			18	27	36	45	54	63	72	81
35	0-0	1-2	≧	12	18	27	36	46	55	64	73	82
40	0-0	1-3			19	28	37	46	56	65	74	83
45	0-0	1-3			19	28	38	47	57	66	75	85
50	1-2	1-3			19	29	38	48	58	67	77	86

* Standing stubble only.
** Standing and flat stubble combined.

Table 7.—Tolerable erosion 5 tons per acre; row spacing 30 inches; stalk diameter 0.5 inch (grain sorghum); standing stubble height 0.5 foot; flat stubble length 1.5 feet.

N-stalks per 10-foot row	WEG*	WEG**	L-eroding strip width, feet									
			20	60	120	180	240	300	360	420	480	540
			Width of trap strip, feet									
0	0-0	0-0										
10	0-0	0-0										
15	0-0	0-0										
20	0-0	0-0										
25	0-0	0-0										
30	0-0	1-2			17	26	35	43	52	61	69	78
35	0-0	1-2			18	26	35	44	53	61	70	79
40	0-0	1-2	≧	12	18	27	35	44	53	62	71	80
45	0-0	1-2			18	27	36	45	54	63	72	81
50	0-0	1-2			18	27	36	45	54	63	72	81

* Standing stubble only.
** Standing and flat stubble combined.

Table 8.—Tolerable erosion 5 tons per acre; row spacing 40 inches; stalk diameter 0.5 inch (grain sorghum); standing stubble height 0.5 foot; flat stubble length 1.5 feet.

N-stalks per 10-foot row	WEG*	WEG**	L-eroding strip width, feet									
			20	60	120	180	240	300	360	420	480	540
			Width of trap strip, feet									
5	0-0	0-0										
10	0-0	0-0										
15	0-0	0-0										
20	0-0	0-0										
25	0-0	0-0										
30	0-0	0-0										
35	0-0	1-2			17	26	34	43	52	60	69	77
40	0-0	1-2			17	26	35	43	52	61	69	78
45	0-0	1-2	≧	12	17	26	35	44	52	61	70	79
50	0-0	1-2			18	26	35	44	53	62	70	79

* Standing stubble only.
** Standing and flat stubble combined.

Table 9.—Tolerable erosion 5 tons per acre; row spacing 50 inches; stalk diameter 0.5 inch (grain sorghum); standing stubble height 0.5 foot; flat stubble length 1.5 feet.

N-stalks per 10-foot row	WEG*	WEG**	L-eroding strip width, feet									
			20	60	120	180	240	300	360	420	480	540
			Width of trap strip, feet									
5	0-0	0-0										
10	0-0	0-0										
15	0-0	0-0										
20	0-0	0-0										
25	0-0	0-0										
30	0-0	0-0										
35	0-0	0-0										
40	0-0	0-0										
45	0-0	1-2	≧ 12		17	26	34	43	52	60	69	77
50	0-0	1-2			17	26	35	43	52	61	69	78

* Standing stubble only.
** Standing and flat stubble combined.

Table 10.—Tolerable erosion 5 tons per acre; row spacing 10 inches; stalk diameter 0.5 inch (grain sorghum); standing stubble height 1.0 foot; flat stubble length 1.0 foot.

N-stalks per 10-foot row	WEG*	WEG**	L-eroding strip width, feet									
			20	60	120	180	240	300	360	420	480	540
			Width of trap strip, feet									
5	0-0	1-3			17	25	33	42	50	58	66	75
10	1-3	1-7			17	25	34	42	51	59	68	76
15	1-7	1-7			17	26	35	43	52	61	69	78
20	1-7	1-7			18	27	35	44	53	62	71	80
25	1-7	1-7	≧ 12		18	27	36	45	54	63	73	82
30	1-7	1-7			19	28	37	46	56	65	74	84
35	1-7	1-7			19	29	38	48	57	67	76	86
40	1-7	1-7			19	29	39	49	58	68	78	88
45	1-7	1-7			20	30	40	50	60	70	80	90
50	1-7	1-7			20	31	41	51	61	72	82	92

* Standing stubble only.
** Standing and flat stubble combined.

Table 11.—Tolerable erosion 5 tons per acre; row spacing 20 inches; stalk diameter 0.5 inch (grain sorghum); standing stubble height 1.0 foot; flat stubble length 1.0 foot.

N-stalks per 10-foot row	WEG*	WEG**	L-eroding strip width, feet									
			20	60	120	180	240	300	360	420	480	540
			Width of trap strip, feet									
5	0-0	0-0										
10	0-0	1-3			17	25	33	42	50	58	66	75
15	0-0	1-7			17	25	34	42	50	59	67	76
20	1-3	1-7			17	25	34	42	51	59	68	76
25	1-7	1-7			17	26	34	43	51	60	69	77
30	1-7	1-7	≥	12	17	26	35	43	52	61	69	78
35	1-7	1-7			18	26	35	44	53	61	70	79
40	1-7	1-7			18	27	35	44	53	62	71	80
45	1-7	1-7			18	27	36	45	54	63	72	81
50	1-7	1-7			18	27	36	45	54	63	73	82

* Standing stubble only.
** Standing and flat stubble combined.

Table 12.—Tolerable erosion 5 tons per acre; row spacing 30 inches; stalk diameter 0.5 inch (grain sorghum); standing stubble height 1.0 foot; flat stubble length 1.0 foot.

N-stalks per 10-foot row	WEG*	WEG**	L-eroding strip width, feet									
			20	60	120	180	240	300	360	420	480	540
			Width of trap strip, feet									
5	0-0	0-0										
10	0-0	1-2			17	25	33	41	50	58	66	74
15	0-0	1-3			17	25	33	42	50	58	66	75
20	1-2	1-7			17	25	33	42	50	59	67	75
25	1-2	1-7			17	25	34	42	51	59	67	76
30	1-3	1-7	≥	12	17	25	34	42	51	59	68	76
35	1-7	1-7			17	26	34	43	51	60	68	77
40	1-7	1-7			17	26	34	43	52	60	69	77
45	1-7	1-7			17	26	35	43	52	61	69	78
50	1-7	1-7			17	26	35	44	52	61	70	79

* Standing stubble only.
** Standing and flat stubble combined.

Table 13.—Tolerable erosion 5 tons per acre; row spacing 40 inches; stalk diameter 0.5 inch (grain sorghum); standing stubble height 1.0 foot; flat stubble length 1.0 foot.

N-stalks per 10-foot row	WEG*	WEG**	L-eroding strip width, feet									
			20	60	120	180	240	300	360	420	480	540
			Width of trap strip, feet									
5	0-0	0-0										
10	0-0	0-0										
15	0-0	1-2			17	25	33	41	50	58	66	74
20	0-0	1-3			17	25	33	42	50	58	66	75
25	0-0	1-7			17	25	33	42	50	58	67	75
30	1-2	1-7		≧ 12	17	25	34	42	50	59	67	76
35	1-2	1-7			17	25	34	42	51	59	68	76
40	1-3	1-7			17	25	34	42	51	59	68	76
45	1-3	1-7			17	26	34	43	51	60	68	77
50	1-7	1-7			17	26	34	43	51	60	69	77

* Standing stubble only.
** Standing and flat stubble combined.

Table 14.—Tolerable erosion 5 tons per acre; row spacing 50 inches; stalk diameter 0.5 inch (grain sorghum); standing stubble height 1.0 foot; flat stubble length 0.1 foot.

N-stalks per 10-foot row	WEG*	WEG**	L-eroding strip width, feet									
			20	60	120	180	240	300	360	420	480	540
			Width of trap strip, feet									
5	0-0	0-0										
10	0-0	0-0										
15	0-0	1-2			16	25	33	41	49	58	66	74
20	0-0	1-2			17	25	33	41	50	58	66	74
25	0-0	1-3			17	25	33	42	50	58	66	75
30	0-0	1-3		≧ 12	17	25	33	42	50	58	67	75
35	1-2	1-7			17	25	34	42	50	59	67	75
40	1-2	1-7			17	25	34	42	50	59	67	76
45	1-3	1-7			17	25	34	42	51	59	68	76
50	1-3	1-7			17	25	34	42	51	59	68	76

* Standing stubble only.
** Standing and flat stubble combined.

Table 15.—Tolerable erosion 5 tons per acre; row spacing 60 inches; stalk diameter 0.5 inch (grain sorghum); standing stubble height 1.0 foot; flat stubble length 1.0 foot.

N-stalks per 10-foot row	WEG*	WEG**	L-eroding strip width, feet									
			20	60	120	180	240	300	360	420	480	540
			Width of trap strip, feet									
5	0-0	0-0										
10	0-0	0-0										
15	0-0	0-0										
20	0-0	1-2			17	25	33	41	50	58	66	74
25	0-0	1-2			17	25	33	41	50	58	66	75
30	0-0	1-3			17	25	33	42	50	58	66	75
35	0-0	1-3		≧ 12	17	25	33	42	50	58	67	75
40	1-2	1-7			17	25	33	42	50	59	67	75
45	1-2	1-7			17	25	34	42	50	59	67	76
50	1-2	1-7			17	25	34	42	51	59	67	76

* Standing stubble only.
** Standing and flat stubble combined.

Table 16.—Tolerable erosion 5 tons per acre; row spacing 70 inches; stalk diameter 0.5 inch (grain sorghum); standing stubble height 1.0 foot; flat stubble length 1.0 foot.

N-stalks per 10-foot row	WEG*	WEG**	L-eroding strip width, feet									
			20	60	120	180	240	300	360	420	480	540
			Width of trap strip, feet									
5	0-0	0-0										
10	0-0	0-0										
15	0-0	0-0										
20	0-0	1-2			16	25	33	41	49	58	66	74
25	0-0	1-2			17	25	33	41	50	58	66	74
30	0-0	1-2			17	25	33	41	50	58	66	75
35	0-0	1-3		≧ 12	17	25	33	42	50	58	66	75
40	0-0	1-3			17	25	33	42	50	58	67	75
45	1-2	1-7			17	25	33	42	50	59	67	75
50	1-2	1-7			17	25	34	42	50	59	67	75

* Standing stubble only.
** Standing and flat stubble combined.

Table 17.—Tolerable erosion 5 tons per acre; row spacing 20 inches; stalk diameter 1.0 inch (corn); standing stubble height 0.5 foot; flat stubble length 4.0 feet.

N-stalks per 10-foot row	WEG*	WEG**	L-eroding strip width, feet									
			20	60	120	180	240	300	360	420	480	540
			Width of trap strip, feet									
5	0-0	0-0										
10	0-0	0-0										
15	0-0	1-7				16	21	27	32	38	43	48
20	0-0	1-7	≧ 12			18	24	30	36	42	48	54
25	0-0	1-7			14	20	27	34	41	48	54	61
30	0-0	1-7			16	24	31	39	47	55	63	71
35	0-0	1-7			19	28	37	46	56	65	74	83
40	1-2	1-7			23	34	45	57	68	79	91	102
45	1-2	1-7		15	29	44	58	73	88	102	117	132
50	1-2	1-7		21	41	62	82	103	123	144	164	185

* Standing stubble only.
** Standing and flat stubble combined.

Table 18.—Tolerable erosion 5 tons per acre; row spacing 30 inches; stalk diameter 1.0 inch (corn); standing stubble height 0.5 foot; flat stubble length 4.0 feet.

N-stalks per 10-foot row	WEG*	WEG**	L-eroding strip width, feet									
			20	60	120	180	240	300	360	420	480	540
			Width of trap strip, feet									
5	0-0	0-0										
10	0-0	0-0										
15	0-0	0-0										
20	0-0	1-7				16	21	26	31	36	41	47
25	0-0	1-7	≧ 12			17	22	28	33	39	44	50
30	0-0	1-7				18	24	30	36	42	48	54
35	0-0	1-7			13	20	26	33	39	46	52	59
40	0-0	1-7			14	21	28	36	43	50	57	64
45	0-0	1-7			16	24	31	39	47	55	63	71
50	0-0	1-7			17	26	35	44	52	61	70	79

* Standing stubble only.
** Standing and flat stubble combined.

Table 19.—Tolerable erosion 5 tons per acre; row spacing 40 inches; stalk diameter 1.0 inch (corn); standing stubble height 0.5 foot; flat stubble length 4.0 feet.

N-stalks per 10-foot row	WEG*	WEG**	L-eroding strip width, feet									
			20	60	120	180	240	300	360	420	480	540
			Width of trap strip, feet									
5	0-0	0-0										
10	0-0	0-0										
15	0-0	0-0										
20	0-0	0-0										
25	0-0	1-3				15	20	25	31	36	41	46
30	0-0	1-7				16	21	27	32	38	43	48
35	0-0	1-7		≧ 12		17	23	28	34	40	45	51
40	0-0	1-7				18	24	30	36	42	48	54
45	0-0	1-7			13	19	25	32	38	45	51	57
50	0-0	1-7			14	20	27	34	41	48	54	61

* Standing stubble only.
** Standing and flat stubble combined.

Table 20.—Tolerable erosion 5 tons per acre; row spacing 50 inches; stalk diameter 1.0 inch (corn); standing stubble height 0.5 foot; flat stubble length 4.0 feet.

N-stalks per 10-foot row	WEG*	WEG**	L-eroding strip width, feet									
			20	60	120	180	240	300	360	420	480	540
			Width of trap strip, feet									
5	0-0	0-0										
10	0-0	0-0										
15	0-0	0-0										
20	0-0	0-0										
25	0-0	0-0										
30	0-0	1-2				15	20	25	30	35	40	45
35	0-0	1-7				16	21	26	31	37	42	47
40	0-0	1-7		≧ 12		16	22	27	33	38	44	49
45	0-0	1-7				17	23	29	34	40	46	51
50	0-0	1-7				18	24	30	36	42	48	54

* Standing stubble only.
** Standing and flat stubble combined.

Table 21.—Tolerable erosion 5 tons per acre; row spacing 60 inches; stalk diameter 1.0 inch (corn); standing stubble height 0.5 foot; flat stubble length 4.0 feet.

N-stalks per 10-foot row	WEG*	WEG**	L-eroding strip width, feet								
			20	60	120	180	240	300	360	420	480	540
			Width of trap strip, feet									
5	0-0	0-0										
10	0-0	0-0										
15	0-0	0-0										
20	0-0	0-0										
25	0-0	0-0										
30	0-0	0-0										
35	0-0	1-2				15	20	25	30	35	40	45
40	0-0	1-7	≧ 12			16	21	26	31	36	41	47
45	0-0	1-7				16	21	27	32	38	43	48
50	0-0	1-7				17	22	28	33	39	44	50

* Standing stubble only.
** Standing and flat stubble combined.

Table 22.—Tolerable erosion 5 tons per acre; row spacing 70 inches; stalk diameter 1.0 inch (corn); standing stubble height 0.5 foot; flat stubble length 4.0 feet.

N-stalks per 10-foot row	WEG*	WEG**	L-eroding strip width, feet								
			20	60	120	180	240	300	360	420	480	540
			Width of trap strip, feet									
5	0-0	0-0										
10	0-0	0-0										
15	0-0	0-0										
20	0-0	0-0										
25	0-0	0-0										
30	0-0	0-0										
35	0-0	0-0										
40	0-0	1-2				15	20	25	30	35	40	45
45	0-0	1-3	≧ 12			15	21	26	31	36	41	46
50	0-0	1-7				16	21	26	32	37	42	48

* Standing stubble only.
** Standing and flat stubble combined.

Table 23.—Tolerable erosion 5 tons per acre; row spacing 20 inches; stalk diameter 1.0 inch (corn); standing stubble height 1.0 foot; flat stubble length 3.0 feet.

N-stalks per 10-foot row	WEG*	WEG**	L-eroding strip width, feet									
			20	60	120	180	240	300	360	420	480	540
			Width of trap strip, feet									
5	0-0	1-3				13	17	22	26	30	35	39
10	0-0	1-7				14	19	23	28	32	37	42
15	1-2	1-7	≧ 12			15	20	25	30	35	40	45
20	1-3	1-7				16	21	27	32	38	43	48
25	1-7	1-7				18	23	29	35	41	47	53
30	1-7	1-7			13	19	26	32	38	45	51	58
35	1-7	1-7			14	21	28	35	42	49	57	64
40	1-7	1-7			16	24	32	39	47	55	63	71
45	1-7	1-7			18	27	36	45	54	63	72	80
50	1-7	1-7			21	31	41	52	62	72	83	93

* Standing stubble only.
** Standing and flat stubble combined.

Table 24.—Tolerable erosion 5 tons per acre; row spacing 30 inches; stalk diameter 1.0 inch (corn); standing stubble height 1.0 foot; flat stubble length 3.0 feet.

N-stalks per 10-foot row	WEG*	WEG**	L-eroding strip width, feet									
			20	60	120	180	240	300	360	420	480	540
			Width of trap strip, feet									
5	0-0	1-2				13	17	21	25	30	34	38
10	0-0	1-7				13	18	22	27	31	35	40
15	0-0	1-7				14	19	23	28	32	37	42
20	1-2	1-7	≧ 12			15	19	24	29	34	39	44
25	1-3	1-7				15	20	25	31	36	41	46
30	1-3	1-7				16	21	27	32	38	43	48
35	1-7	1-7				17	23	28	34	40	45	51
40	1-7	1-7				18	24	30	36	42	48	54
45	1-7	1-7			13	19	26	32	38	45	51	58
50	1-7	1-7			14	20	27	34	41	48	55	61

* Standing stubble only.
** Standing and flat stubble combined.

Table 25.—Tolerable erosion 5 tons per acre; row spacing 40 inches; stalk diameter 1.0 inch (corn); standing stubble height 1.0 foot; flat stubble length 3.0 feet.

N-stalks per 10-foot row	WEG*	WEG**	L-eroding strip width, feet									
			20	60	120	180	240	300	360	420	480	540
			Width of trap strip, feet									
5	0-0	1-2				13	17	21	25	29	34	38
10	0-0	1-3				13	17	22	26	30	35	39
15	0-0	1-7				13	18	22	27	31	36	40
20	0-0	1-7				14	19	23	28	32	37	42
25	0-0	1-7				14	19	24	29	34	38	43
30	1-2	1-7	≥ 12			15	20	25	30	35	40	45
35	1-3	1-7				15	21	26	31	36	41	46
40	1-3	1-7				16	21	27	32	38	43	48
45	1-7	1-7				17	22	28	34	39	45	50
50	1-7	1-7				18	23	29	35	41	47	53

* Standing stubble only.
** Standing and flat stubble combined.

Table 26—Tolerable erosion 5 tons per acre; row spacing 50 inches; stalk diameter 1.0 inch (corn); standing stubble height 1.0 foot; flat stubble length 3.0 feet.

N-stalks per 10-foot row	WEG*	WEG**	L-eroding strip width, feet									
			20	60	120	180	240	300	360	420	480	540
			Width of trap strip, feet									
5	0-0	0-0										
10	0-0	1-3				13	17	21	26	30	34	38
15	0-0	1-7				13	18	22	26	31	35	40
20	0-0	1-7				14	18	23	27	32	36	41
25	0-0	1-7				14	19	23	28	32	37	42
30	1-2	1-7	≥ 12			14	19	24	29	33	38	43
35	1-2	1-7				15	20	25	29	34	39	44
40	1-2	1-7				15	20	25	30	35	40	45
45	1-3	1-7				16	21	26	31	36	42	47
50	1-3	1-7				16	21	27	32	38	43	48

*Standing stubble only.
** Standing and flat stubble combined.

Table 27.—Tolerance erosion 5 tons per acre; row spacing 60 inches; stalk diameter 1.0 inch (corn); standing stubble height 1.0 foot; flat stubble lenth 3.0 feet.

N-stalks per 10-foot row	WEG*	WEG**	L-eroding strip width, feet									
			20	60	120	180	240	300	360	420	480	540
			Width of trap strip, feet									
5	0-0	0-0										
10	0-0	1-2				13	17	21	25	30	34	38
15	0-0	1-3				13	17	22	26	30	35	39
20	0-0	1-7				13	18	22	27	31	35	40
25	0-0	1-7				14	18	23	27	32	36	41
30	0-0	1-7	≧ 12			14	19	23	28	32	37	42
35	1-2	1-7				14	19	24	28	33	38	43
40	1-2	1-7				15	19	24	29	34	39	44
45	1-2	1-7				15	20	25	30	35	40	45
50	1-3	1-7				15	20	25	31	36	41	46

* Standing stubble only.
** Standing and flat stubble combined.

Table 28.—Tolerable erosion 5 tons per acre, row spacing 70 inches; stalk diameter 1.0 inch (corn); standing stubble height 1.0 foot; flat stubble length 3.0 feet.

N-stalks per 10-foot row	WEG*	WEG**	L-eroding strip width, feet									
			20	60	120	180	240	300	360	420	480	540
			Width of trap strip, feet									
5	0-0	0-0										
10	0-0	1-2				13	17	21	25	30	34	38
15	0-0	1-3				13	17	21	26	30	34	39
20	0-0	1-7				13	17	22	26	31	35	39
25	0-0	1-7				13	18	22	27	31	36	40
30	0-0	1-7	≧ 12			14	18	23	27	32	36	41
35	0-0	1-7				14	19	23	28	32	37	42
40	0-0	1-7				14	19	24	28	33	38	43
45	1-2	1-7				14	19	24	29	34	39	43
50	1-2	1-7				15	20	25	30	34	39	44

* Standing stubble only.
** Standing and flat stubble combined.