AGRICULTURAL
MU Guide
PUBLISHED BY UNIVERSITY EXTENSION, UNIVERSITY OF MISSOURI-COLUMBIA

Estimating Soil Erosion For Conservation Planning

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Soil type, crop rotation, rainfall, tillage practices, topography and conservation practices used are a few of the factors that determine the potential for soil erosion at specific sites within fields. Over the years, several equations have been used to estimate erosion for various agricultural conservation planning programs. The most effective tool was developed by W. H. Wischmeier and D. D. Smith of the Agricultural Research Service/USDA, and is called the Universal Soil Loss Equation (USLE). The USLE was based on more than 10,000 plot-years of soil erosion research conducted at 49 locations in the United States. The equation has proven to be effective for evaluating the impact on the potential for erosion control of such factors as crop rotation, tillage systems, vegetative cover, contouring and terraces.

Precautions

Wischmeier cautioned that the USLE was designed to predict average annual soil movement from a given field slope under specified land use and management conditions. It estimates soil movement from sheet and rill erosion but not from gullies. The equation does not predict soil loss for a field, since the eroded soil is frequently deposited in flatter areas, waterways and terraces within the field. However, the USLE is quite useful in comparing alternative practices that you may consider for reducing your soil erosion and for meeting the conservation compliance provisions of the Food Security Act of 1985.

Conservation planning

Developing an effective erosion control program (conservation plan) is dependent on an individual's understanding of the factors that affect erosion and practices for its control. The USLE can be used as a guide in selecting agronomic and mechanical practices that will best conserve your soil. As you learn to use the USLE, you will find that there are a variety of practices, or combinations thereof, which can help you meet soil loss goals.

Since farming is a business, you will probably want to evaluate the economic implications of various alternatives. Assistance in making economic evaluations is available from extension agricultural specialists and from Soil Conservation Service personnel.

Factors affecting soil loss

The Universal Soil Loss Equation predicts the average annual soil erosion (A) as a function of five factors:

A = R x K x LS x C x P, where

A = Soil erosion in tons per acre per year
R = Rainfall factor
K = Soil erodibility factor
LS = Slope length and steepness factor
C = Cover and management factor
P = Erosion control practice factor

Rainfall (R). The R factor is a measure of rainfall energy and intensity rather than just rainfall. A short, intense 4-inch storm will cause much more erosion than a slow, steady 4-inch rain. The R factor varies from about 200 in northern Missouri to about 250 in southern Missouri (Figure 1), where intense thunderstorms are more common.

Soil erodibility (K). Soil erodibility is a measure of a soil particle's resistance to detachment from the bulk soil. The larger the K value, the more easily that particular soil will erode. Selected K values are given in Table 1. Contact your local Soil Conservation Service office or check your county soil survey for additional values.

Soils containing large amounts of silt and fine sand are easily eroded. Soils with large amounts of clay, coarse sand particles or coarse aggregates are less erosive. Erosivity decreases with increasing soil permeability and organic matter content.

Slope length, steepness (LS). Slope length (L) is the length of water flow to the point where flow enters a defined channel such as a terrace or to where sediment is deposited. The slope length is usually much less than the distance from the top to the bottom of the hill. Slope steepness (S) is the amount of vertical change in elevation over some fixed horizontal distance. Slope is always measured perpendicular to the contour lines.

A relative value of 1 has been assigned to a slope of 9 percent and a slope length of 72.6 feet (based on the standard soil erosion research plots used to develop the USLE). The LS values for slopes of varying steepness and length may be read from Table 2. Note, for example, that the erosion rate for a given soil on a 16 percent slope with a slope length of 180 feet will erode at 4 times the rate of an 8 percent slope that is 120 feet long.

Average LS values for some common Missouri soils are given in Table 1. They may be used for making general comparisons, but they do not replace actual field determinations when completing an SCS conservation plan.

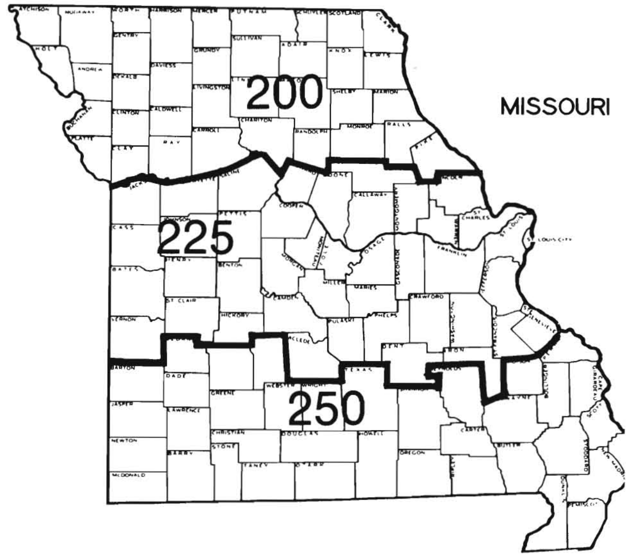

Figure 1. Average annual rainfall factor (R) values.

Cover and management (C). Vegetative cover, crop rotation, fertility level, tillage practices, crop residue management and related conditions have an important effect on erosion. The C factor is the ratio of soil loss from an area with specified cover and management to that from an identical area in clean-tilled, continuous fallow (which has a C value of 1). Most cropping systems have C values (and soil losses) considerably less than that for fallow reference plots, thanks to the soil cover from previous crop residues and/or the canopy of the growing crop.

The C factors used by the Soil Conservation Service (SCS) in Missouri for estimating soil loss and evaluating management alternatives for many tillage and crop regimes are shown in Table 3. The C factor values in Table 3 combine the effects of crop canopy and crop residue remaining on the soil surface. Additional tables are available that list C factors for pasture and wood-

Table 1. Typical values of slope, slope length, average length factor (LS), erodibility (K) and erosion tolerance (T) for selected soils.

Soil series	Slope range (%)	Erosion phase	Length of slope (feet)	Percent slope	LS value	K value	T value
Gara	9-14	Eroded	148	12	2.20	0.28	5
Shelby	9-14	Eroded	204	12	2.60	0.28	5
Marshall	5-9	Slight	165	7	1.03	0.32	5
Knox	9-14	Severe	151	12	2.20	0.32	5
Napier	2-5	Slight	99	3	0.29	0.32	5
Ladoga	2-5	Eroded	155	7	1.00	0.32	5
Armstrong	9-14	Eroded	154	12	2.20	0.32	3
Lamoni	5-9	Severe	200	7	1.18	0.32	2
Kilwinning	2-5	Eroded	180	4	0.51	0.37	3
Mexico	1-5	Eroded	190	3	0.35	0.43	3
Putnam	0-2	Slight	225	1	0.16	0.43	3
Leonard	5-9	Eroded	156	7	1.00	0.37	3
Lindley	14-20	Severe	121	17	3.50	0.32	4
Menfro	9-14	Eroded	130	12	2.00	0.37	5
Winfield	9-14	Severe	145	12	2.20	0.37	4
Hatton	5-9	Slight	144	7	1.01	0.43	4
Keswick	9-14	Eroded	152	12	2.20	0.37	3
Weller	5-9	Eroded	179	7	1.15	0.43	3
Gasconade	14-20	Slight	174	17	4.30	0.20	2

land. Selection of the correct C factor is difficult because there are so many choices. However, changing the C factor of your farming system is one of the easiest and most cost-effective ways of reducing soil loss.

Keys to reducing soil erosion include production of a dense crop canopy and/or producing and maintaining large amounts of crop residue on the soil surface. The ground cover will reduce raindrop impact and slow the movement of water across the ground surface. Minimizing tillage helps to retain surface residue. In general, no-till systems (which leave the maximum amount of residue on the surface) result in the lowest C factors and minimal erosion.

Percent cover is frequently determined by stretching a 100-foot steel tape diagonally across the rows of a field and counting the number of foot marks underlain by a piece of residue capable of absorbing the impact of a raindrop. The number of residue particles per 100 feet is the percent ground cover. Average at least 3 or 4 random checks for a valid estimate of percent cover. For more details on residue management and conservation tillage, see MU publication G1650, *Conservation Tillage and Residue Management to Reduce Soil Erosion.*

Erosion control (P and P_t). Mechanical erosion control practices include contour tillage, contour strip-cropping and terracing. The P factor is the ratio of soil loss with one of these practices to the corresponding loss without the practice. If no mechanical erosion control practices are used, then P and P_t equal 1.

Contouring is the practice of performing all tillage and planting operations on the contour (across the slope). It is most effective on slopes of 2 to 8 percent and slope lengths of less than 300 feet. To obtain the full benefit of contouring, fields should be relatively free of gullies and waterways should be grassed. The P values and slope-length limits used in Missouri by the SCS are listed in Table 4.

If the slope length exceeds those shown in Table 4, contouring should be used in combination with terraces or some other means of breaking up the slope.

Contour strip-cropping is a practice in which contoured strips of sod are alternated with equal-width strips of row crops or small grains. It is more effective than contouring alone in controlling erosion. Strip-crop studies have shown that much of the soil eroded from a cultivated strip was filtered out of the runoff as it was slowed and spread within the first several feet of the adjacent sod strip. This deposited soil is not considered lost because it remains on the slope. Therefore, the P value is less than for contouring alone.

When sod strips are not equal in width to the cultivated strips, it is technically called buffer strip-cropping. In Missouri, this is considered as strip-cropping but the P factor has been modified to represent the percentage of a slope (field) that is in grass. Strip-cropping P factors are given in Tables 5 and 6.

Table 2. Slope steepness and length factor (LS).

Length of slope (feet)	Percent slope (S) 0.5	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	12.0	14.0	16.0	18.0	20.0
20	0.06	0.08	0.12	0.18	0.21	0.24	0.30	0.36	0.44	0.52	0.61	0.81	1.00	1.20	1.60	1.80
40	0.08	0.10	0.15	0.22	0.28	0.34	0.43	0.52	0.63	0.75	0.87	1.20	1.40	1.80	2.20	2.60
60	0.08	0.11	0.17	0.25	0.33	0.41	0.52	0.63	0.77	0.90	1.00	1.40	1.80	2.20	2.60	3.00
80	0.09	0.12	0.19	0.27	0.37	0.48	0.60	0.74	0.89	1.00	1.20	1.60	2.00	2.60	3.00	3.50
100	0.10	0.13	0.20	0.29	0.40	0.54	0.67	0.82	0.99	1.20	1.40	1.80	2.30	2.80	3.40	4.10
120	0.10	0.14	0.21	0.30	0.43	0.59	0.74	0.88	1.00	1.30	1.60	2.00	2.60	3.00	4.00	4.50
140	0.10	0.14	0.22	0.32	0.46	0.63	0.80	0.95	1.20	1.40	1.60	2.20	2.80	3.50	4.00	5.00
160	0.11	0.15	0.23	0.33	0.48	0.68	0.85	1.00	1.20	1.50	1.80	2.20	3.00	3.50	4.50	5.00
180	0.11	0.15	0.24	0.34	0.51	0.72	0.90	1.10	1.40	1.60	1.80	2.40	3.00	4.00	4.50	5.50
200	0.11	0.16	0.25	0.35	0.53	0.76	0.95	1.20	1.40	1.70	1.90	2.60	3.20	4.00	4.90	5.80
250	0.12	0.17	0.26	0.38	0.58	0.85	1.20	1.30	1.60	1.80	2.20	2.80	3.60	4.50	5.50	6.50
300	0.12	0.18	0.28	0.40	0.62	0.93	1.20	1.40	1.70	2.00	2.40	3.10	4.00	4.90	6.00	7.10
350	0.12	0.19	0.29	0.42	0.66	1.00	1.30	1.50	1.90	2.20	2.60	3.40	4.20	5.30	6.40	7.60
400	0.13	0.20	0.30	0.44	0.70	1.10	1.40	1.60	2.00	2.30	2.70	3.60	4.60	5.70	6.90	8.20
500	0.13	0.21	0.33	0.47	0.76	1.20	1.50	1.80	2.20	2.60	3.10	4.00	5.10	6.40	7.70	9.10
600	0.14	0.22	0.34	0.49	0.82	1.30	1.60	2.00	2.40	2.80	3.40	4.40	5.60	7.00	8.40	10.00
700	0.14	0.23	0.36	0.52	0.87	1.40	1.80	2.20	2.60	3.10	3.60	4.80	6.00	7.50	9.00	10.80
800	0.14	0.24	0.38	0.54	0.92	1.50	1.90	2.30	2.80	3.30	3.90	5.10	6.50	8.00	9.70	11.50

Table 3. C factors for cropland in Missouri.[1]

			CHISEL - DISK - RIDGE[2]						NO-TILL				
	FALL	SPRING	% COVER AFTER PLANTING						% COVER AFTER PLANTING				
CROP SEQUENCE	**PLOW**	**PLOW**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**60%**	**70%**	**80%**	**90%**	
Corn Silage after Corn Silage	.48	.40	.33										
Corn Grain after Corn Silage[3]	.45	.31	.29										
Corn Grain after Corn Grain[3]	.36	.29	.21	.18	.15	.12	.09	.08	.08	.06	.05	.03	
Corn Grain after Small Grain[3]	.37	.30	.23	.20	.16	.13	.10	.09	.09	.06	.05	.03	
Corn Grain after Meadow[4]	.17	.13	.12	.10	.09	.08	.06	.04	.03	.02	.02	.01	
Corn 2nd year after Meadow[4]	.32	.24	.19	.16	.15	.14	.12	.09	.05	.04	.03	.02	
Soybeans after Corn Grain													
Wide Row (>20 inches)	.40	.33	.23	.20	.16	.13	.12	.11	.10	.07	.05	.03	
Drilled (<20 inches)	.30	.25	.18	.15	.13	.12	.11	.10	.08	.06	.04	.03	
Soybeans after Small Grain													
Wide Row (>20 inches)	.43	.34	.26	.23	.17	.14	.13	.12	.09	.06	.04	.03	
Drilled (<20 inches)	.32	.23	.19	.16	.14	.12	.12	.11	.08	.06	.04	.03	
Soybeans after Meadow[4]													
Wide Row (>20 inches)	.20	.15	.12	.10	.09	.08	.06	.05	.03	.02	.01	.01	
Drilled (<20 inches)	.15	.12	.11	.09	.08	.07	.05	.04	.03	.02	.01	.01	
Soybeans 2nd. year after Meadow[4]													
Wide Row (>20 inches)	.36	.27	.18	.15	.12	.10	.09	.08	,08	.06	.04	.03	
Drilled (<20 inches)	.27	.22	.15	.13	.11	.10	.09	.08	.08	.06	.04	.03	
Small Grain after:													
Corn Grain[5]	.12		.09	.08	.07	.06	.05	.04	.04	.03	.02	.02	
Corn Silage[6]	.17		.16						.13				
Small Grain after Small Grain	.15		.12	.11	.09	.08			.05	.04	.03	.02	
Small Grain after Meadow													
Ist. year after	.08		.07			.04					.03		
2nd. year after	.12		.10			.07					.04		
AFTER SOYBEANS									**20%**	**30%**	**40%**	**50%**	**80%[7]**
Corn Grain after Soybeans[3]	.42	.36	.35	.30	.25	.20			.25	.19	.14	.13	
Corn Grain after Soybeans with winter cover[3]	.41	.30	.24	.22	.17	.12			.17	.13	.12	.10	.07[8]
Soybeans after Soybeans													
Wide Row (>20 inches)	.48	.41	.37	.35	.25	.20			.26	.20	.16	.15	
Drilled (<20 inches)	.38	.32	.31	.30	.23	.19			.20	.16	.13	.12	
Soybeans after Soybeans with winter cover (>20 inches)	.48	.32	.27	.24	.19	.14			.18	.15	.12	.11	.08[8]
Small Grain after Soybeans[5]	.14	.12	.11	.10	.09	.08			.09	.07	.05	.03	

Wheat/Soybeans (Drilled and Double Cropped)[9]

		Tillage for Beans after Wheat		
		Plow	Chis/disk	No-till
Tillage for Wheat after Soybeans	Plow	.28	.18	.17
	Chis//disk	.21	.11	.10
	No-till	.17	.07	.06

		Tillage for Beans after Wheat		
		Plow	Chis/disk	No-till
Tillage for Wheat after Corn Silage	Plow	.30	.20	.19
	Chis//disk	.29	.19	.18
	No-till	.27	.17	.16

		Tillage for Beans after Wheat		
		Plow	Chis/disk	No-till
Tillage for Wheat after Corn Grain	Plow	.27	.17	.16
	Chis//disk	.19	.09	.08
	No-till	.15	.05	.04

Meadow (Full Year - Established)	
Grass-Legume	.004
Legume	.020

1. Values in this table are based on a high level of management with yields equal to or exceeding the following: corn - 100 bu/ac; soybeans - 40 bu/ac; wheat - 45 bu/ac; oats - 60 bu/ac; meadow - 3 ton/ac. For medium level of management multiply factors by 1.2.
2. Values for chisel and disk systems are for one fall primary tillage operation and zero to two secondary tillage operations prior to planting, depending on the type of crop residue and the percent ground cover desired after planting. For primary tillage in the spring and ridge planting up and down the hill, multiply the values by 0.8. For ridge planting on the contour, multiply the values by 0.6. Ridge planting is applicable only for row crops following row crops.
3. For drilled Milo, multiply values by 0.80.
4. Values are based on sod or a grass-legume mixture consisting of at least 50% grass and has been established at least one full growing season. If meadow stand is primarily legume, multiply factor by 1.2.
5. The same factors are applicable for both small grain with and without meadow seedings.
6. Factors for disk and no-till are for a tillage system with $\leq$ 20% residue on the surface after planting.
7. Percentages apply only to crops following soybeans.
8. Assuming 80% ground cover by no-tilling into a winter cover crop aerially seeded before leaf drop and before September 15.
9. When beans are planted wide row after plowing, add 0.04 to the given C value. For chisel/disk and no-till, use same values as for drilled beans.

$C = T/(R \times K \times LS \times P \times P_t)$, or
$C = 3/(200 \times 0.37 \times 0.78 \times 0.5 \times 0.6) = 0.173$ or less

From Table 3, we find that 40 percent residue cover after no-till planting (corn after soybeans) is required to get C less than 0.173 (C = 0.14). The following calculation is for no-till planting with 40 percent cover: soil loss = 200 x 0.37 x 0.78 x 0.14 x 0.5 x 0.6 = 2.4 tons/acre/year.

Next we want to complete the rotation where we plant soybeans into corn residue. The numbers in the preceding calculation will remain the same except for the C factor. Since we used a tillage system for corn that produced a C value of 0.14 (which is 0.033 less than the allowed maximum average C value of 0.173), we could select a tillage system for soybeans with a C value of 0.173 + 0.033 = 0.203, or less. From Table 3, soybeans after corn (wide rows), a C value of 0.20 can be obtained by using conservation tillage (chisel, disk or ridge till) leaving at least 20 percent of the ground surface covered with residue after planting the soybeans. The soil loss for that year of the rotation is:

Soil loss = 200 x 0.37 x 0.64 x 0.20 x 0.5 x 0.6
= 2.8 tons/acre/year

Thus, for the corn-soybean rotation with no-till planting of corn into soybean residue and conservation tillage for soybeans planted into corn residue, the soil loss can be kept below T each year.

If no-till corn is not desired, an alternative might allow the soil erosion to exceed T for corn following soybeans. But choose a higher residue system for planting soybeans after corn that would bring the average annual soil loss for the 2-year rotation below T.

Table 7. P(t), terrace "P" factors. Note: if contouring or stripcropping P factors are appropriate, they can be multiplied by the terrace P factor for the composite P factor.

Horizontal Interval (feet)	Closed Outlets[1]	Open outlets, with % Grade[2] 0.1-0.3	0.4-0.7	0.8
< 110	0.5	0.6	0.7	1.0
110-140	0.6	0.7	0.8	1.0
140-180	0.7	0.8	0.9	1.0
180-225	0.8	0.8	0.9	1.0
225-300	0.9	0.9	1.0	1.0
> 300	1.0	1.0	1.0	1.0

[1]"P" factors for closed outlet terraces also apply to terraces with underground outlets and to level terraces with open outlets.

[2]The channel grade is measured on the 300 feet of terrace or the one-third of total terrace length closest to the outlet, whichever distance is less.

For example, using a chisel-disk-ridge tillage system leaving at least 40 percent cover after planting corn produces C = 0.25, and leaving at least 50 percent cover after drilling soybeans produces C = 0.10 for an average C = 0.175 (only slightly more than the desired 0.173 value).

Similar calculations may be used to determine the average annual soil loss for other rotations, tillage/planting systems and mechanical practices.

Computer programs to calculate soil loss may be available from your county Soil Conservation Service office and/or University Extension center.

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