AGRICULTURAL
GUIDE
Published by the University of Missouri-Columbia Extension Division

Estimating Soil Erosion for Conservation Planning

John R. McCarthy, Soil Conservation Service
Donald L. Pfost, Agricultural Engineering Department
Nyle Wollenhaupt, Agronomy Department

Soil type, crop rotation, rainfall, tillage practices, topography and conservation practices used are a few of the factors which 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 U.S. The equation has proven to be effective for evaluating the impact of such factors as crop rotation, tillage systems, vegetative cover, contouring and terraces on the potential for erosion control.

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 <u>not from gullies</u>. 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 you may consider for reducing your soil erosion and for meeting the conservation compliance provisions of the Food Security Act of 1985.

Conservation Planning

The development of an effective erosion control program (conservation plan) is dependent on an individual's understanding of the factors which 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 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 on economic evaluations is available from the Missouri University Extension in the form of guide sheets and personal assistance 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:

$$A = R \times K \times LS \times C \times P, \quad \text{where}$$

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

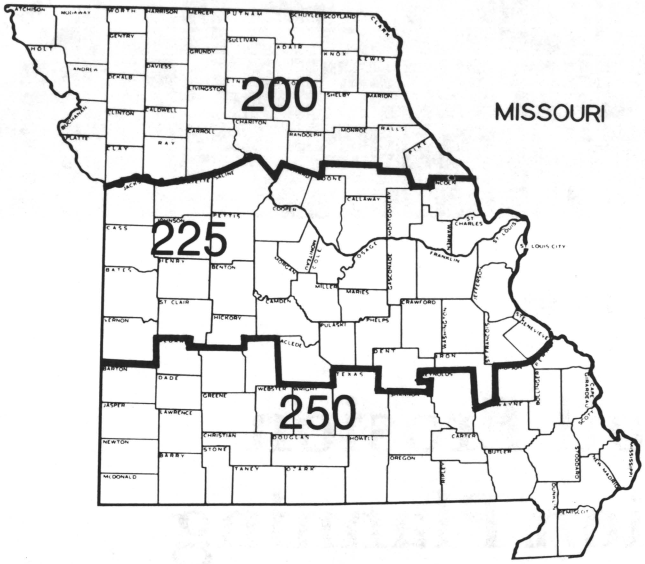

Figure 1. Average Annual Rainfall Factor (R) Values

4-inch rain. The R factor (Figure 1) varies from about 200 in northern Missouri to about 250 in southern Missouri, where intense thunderstorms are more common.

Soil Erodibility (K)

Soil erodibility is a measure of the resistance of a soil particle to detachment from the bulk soil. The larger the value of K, the easier 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,

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 (')	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

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

Length of Slope(')	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

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, 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 do not replace actual field determinations when completing an SCS conservation plan.

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 below 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 which list C factors for pasture and woodland. 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 UMC Guide 1650, "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 utilized in Missouri by the SCS are listed in Table 4.

Table 3. "C" Factors for Cropland in Missouri[1]
(This chart is to be used on an interim basis until charts are revised.)

CROP SEQUENCE		FALL PLOW	SPRING PLOW	CHISEL - DISK - RIDGE[2] %Cover After Plant 20%	30%	40%	50%	NO-TILL %Cover After Plant 60%	70%	80%	90%
								20%	30%	40%	[3]
CORN after Soybeans		.42	.36	.36	.30	.25	—	.25	.19	.14	
CORN after Corn		.36	.29	.21	.18	.15	.12	.09	.06	.05	.03
CORN after Small Grain		.37	.30	.23	.20	.16	.13	.09	.06	.05	.03
CORN after Meadow[4]		.17	.13	.12	.10	.09	.08	—	.02	.02	.01
CORN 2nd yr. after Meadow[4]		.32	.24	.19	.16	.15	.14				
								20%	30%	40%	80%[3]
SOYBEANS after Soybean	Wide Row	.48	.41	.37	.35	—	—	.26	.20	.16	.08[8]
	Drill	.38	.32	.31	.30	—	—	.20	.16	.13	
SOYBEANS after Corn[5]	Wide Row	.40	.33	.20	.17	.14	.12	.10	.07	.05	.03
	Drill	.30	.25	.18	.15	.13	.10	.08	.06	.04	.03
SOYBEANS after Sm. Grain[5]	Wide Row	.42	.30	.24	.20	.17	.14	.09	.06	.04	.03
	Drill	.32	.23	.19	.16	.14	.12	.08	.06	.04	.03
SOYBEANS after Meadow[4,5]	Wide Row	.20	.15	.12	.10	.09	.08	.03	.02	.01	.01
	Drill	.15	.12	.11	.09	.08	.08	.03	.02	.01	.01
SOYBEANS after Corn 2nd year after meadow[5]	Wide Row	.36	.27	.18	.15	.12	.10	.08	.06	.04	.03
	Drill	.27	.22	.15	.13	.11	.10	.08	.06	.04	.03
SMALL GRAIN after Corn (Grain)[6]		.12	.11	.09	.08	.07	.06	.08	.06	.04	.03
SMALL GRAIN after Corn (Silage)[7]		.17	---	.17	—	—	—	.13	—	—	—
								20%	30%	40%	[3]
SMALL GRAIN after Soybeans[6]		.13	.12	.11	.10	.09	.08	.09	.07	.05	
SMALL GRAIN after Sm. Grain[6]		.17	—	.12	.11	.09	.08	.05	.04	.03	.02

WHEAT/SOYBEANS (Double Crop)

Tillage for Soybeans

Tillage for wheat	Plow	Disk	No-Till
Plow	.28	.16	.13
Disk	.23	.10	.07
No-Till	.20	.08	.04

Meadow (Full Year - Established)

Grass Legume	.004
Legume	.02

Footnotes for "C" Factor Tables

1. Values in this table are based on high level 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 tons/ac. For medium level management multiply factors by 1.2.

2. Values for chisel and disk systems are for fall primary tillage and two secondary tillage operations prior to planting. For primary tillage in the spring and ridge planting up and down 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. Percentages apply only to crops following soybeans

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. Use wide row factors for row widths greater than 20 inches and drill factors for 20 inches and less.

6. The same factors are applicable for both small grain with and without meadow seedlings.

7. Factors for disk and No-till are for the tillage system with no residue on surface after planting.

8. Assuming 80% cover by no-tilling into a winter cover crop aerially seeded before leaf drop and before September 15.

Table 4. "P" factors and slope limits for contouring.

Slope Group (%)	Maximum Slope Length (') Residue Cover <50%	>50%	P Value
1-2	400	500	0.60
3-5	300	375	0.50
6-8	200	250	0.50
9-12	120	150	0.60
13-16	80	100	0.70
17-20	60	75	0.80

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 and is more effective in controlling erosion than contouring alone. Observations from strip-crop studies showed 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.

Terracing is an effective means of erosion control, because it divides a long slope into shorter segments about equal to the terrace spacing. After terracing, the slope length (L) becomes the distance from the top of a terrace ridge to the channel of the next terrace below. The reduction in slope length (L) results in a reduction of the LS factor.

Contact the Soil Conservation Service for more details on the latest method of calculating soil loss from broadbase, narrowbase and steep backslope terraces.

Terraces with underground outlets, or with channel grades not more than 0.3 percent, may trap as much as 82 to 95 percent of the soil moved from contour-farmed slopes between the terraces. A joint ARS-SCS work group has developed the following procedure to allow the P_t factors for terraces (Table 7).

Note: If contouring or strip-cropping P factors are appropriate, they can be multiplied by the terrace P_t factor to obtain a composite P factor. For both the strip-cropping and terrace factors to apply, each terrace interval must contain both types of strips (the row crop and the close-growing, filter-strip crop).

Example USLE Calculations

A landowner in north Missouri is presently growing corn and soybeanson the contour in rotation using spring plowing. The dominant soil type in the field is Leonard with an average slope of 7% and an average slope length of 180 feet. Calculate the current soil loss for the rotation beginning with corn following soybeans.

Soil Loss = R x K x LS x C x P

R = 200 - from Figure 1 for north Missouri
K = 0.37 - from Table 1 for Leonard soils
LS = 1.1 - from Table 2 for 7% slope and 180 ft. slope length
C = 0.36 - from Table 3 for spring plowing - corn after soybeans
P = 0.5 - from Table 4 for contour farming

Using the above values:

Soil loss = 200 x 0.37 x 1.1 x 0.36 x 0.5 = 14.6 tons per acre per year. That exceeds the tolerable soil loss (T), or 3 tons/acre/year (Table 1) for the Leonard soils.

If terraces were installed to reduce the slope length to 90 feet, from Table 2 the new LS would equal 0.78. If the terraces have an open outlet and a channel grade of 0.3 percent, then P_t = 0.6 (from Table 7) and:

Soil loss = 200 x 0.37 x 0.78 x 0.36 x 0.5 x 0.6 = 6.2 tons/acre/year.

This still exceeds the tolerable soil loss of 3 tons/acre/year. What other alternatives are there? Can we change tillage and residue to reduce the soil loss to "T"?

The following calculation determines the maximum average C value that will reduce the soil loss (with terraces @ 90') to T = 3 tons/acre/year:

C = T divided by (R x K x LS x P x P_t), or
C = 3/(200 x 0.37 x 0.78 x 0.5 x 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

Table 5. "P" factors for stripcropping (equal-width strips). Where grass and/or close grown strips are equal in width to cultivated strips.

Percent Slope	P Values A	B	C	D	Strip Width[1]	Max. Length[2]
1-2	0.30	0.45	0.55	0.60	130	800
3-5	0.25	0.38	0.45	0.50	100	600
6-8	0.25	0.38	0.45	0.50	100	400
9-12	0.30	0.45	0.55	0.60	80	240
13-16	0.35	0.52	0.65	0.70	80	160
17-20	0.40	0.60	0.75	0.80	60	120
21-25	0.45	0.68	0.85	0.90	50	100

A For 4-year rotation of row crop, small grain with meadow seeding, and 2-year of meadow. A second row crop can replace the small grain if meadow is established in it.

B For 4-year rotation of 2-year row crop, winter grain with meadow seeding, and 1-year meadow.

C For alternate strips of row crop and winter small grain.

D For alternate strips of row crop and spring seeded small grain.

1 Adjust strip-width limit, generally downward, to accomodate widths of farm equipment.

2 Limit may be increased by 10% if residue cover after crop planting will exceed 50%.

Table 6. "P" factors for stripcropping (unequal-width strip). Where permanent grass strips are narrower than the cultivated strips, use the following "P" factors.

Percent Slope	Percent of Slope in Grass 10%	20%	30%	40%	50%
1-2	0.55	0.50	0.40	0.35	0.30
3-5	0.45	0.40	0.35	0.30	0.25
6-8	0.45	0.40	0.35	0.30	0.25
9-12	0.55	0.50	0.40	0.35	0.30
13-16	0.65	0.55	0.50	0.40	0.35
17-20	0.70	0.65	0.55	0.50	0.4o
21-25	0.80	0.70	0.65	0.55	0.45

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(')	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 openoutlets.

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.

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.

For example, using a chisel-disk-ridge tillage system leaving at least 40% cover after planting corn produces C = 0.25 and leaving at least 50% 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.

University Extension
UNIVERSITY OF MISSOURI
LINCOLN UNIVERSITY

■ Issued in furtherance of Cooperative Extension Work Acts of May 8 and June 30, 1914 in cooperation with the United States Department of Agriculture. Gail L. Imig, Director, Cooperative Extension Service, University of Missouri and Lincoln University, Columbia, Missouri 65211. ■ An equal opportunity institution.