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GUIDE

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Estimating Soil Losses in Northern Missouri

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Soil erosion varies considerably throughout the country. A method was needed to help predict annual soil loss from an individual's land.

The equation described below takes into account the variability in conditions such as rainfall, soil type, crop rotation, conservation practices used and topography. It was designed to help the individual farmer select practices that will reduce soil erosion.

This equation is used by the Soil Conservation Service in developing soil conservation programs. It is used also by engineers and architects to plan erosion control. Originally designed for farmland, it is, therefore, especially valuable to the farmer in planning his own soil conservation program.

New federal and state programs will encourage a more dedicated effort towards conserving the soil. Information included in this guide should be helpful in these programs.

Precautions

The equation estimates long-term average annual soil loss for a specific situation. It will estimate soil losses from sheet and rill erosion but not from gullies. It is unusual for all the soil loss predicted by this equation to be transported from a field. Some is deposited in terrace channels, waterways or in flatter areas. The value you calculate for your soil loss should be considered as a rough estimate only. However, it should point out alternative solutions to reducing your soil loss.

Factors Affecting Soil Loss

To develop an effective erosion control program, you should evaluate the factors affecting erosion and practices for its control. In planning your farm layout, select the combination of agronomic and mechanical practices that will best conserve your soil and provide you with an efficient business operation.

It is not possible to avoid all erosion loss, but there is a point where soil loss will be sufficiently small that crop production can be carried on and the productivity of the soil maintained or perhaps increased through the years. The most effective tool for evaluating soil losses was developed by the Agricultural Research Service and is often called the Universal Soil Loss Equation:

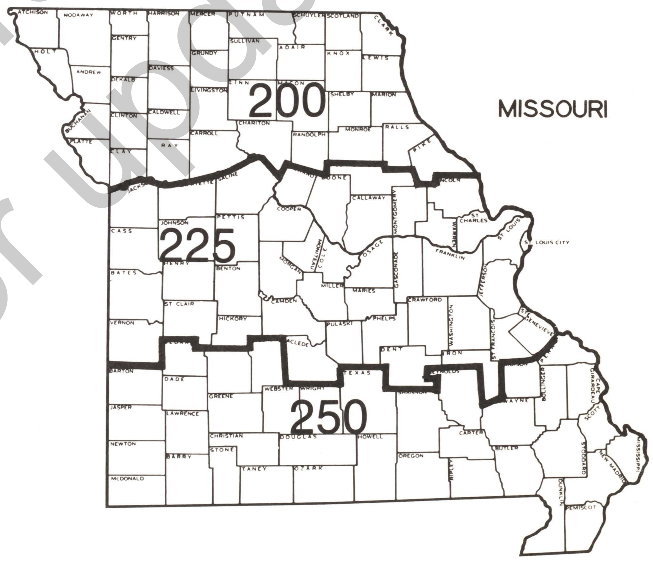


FIGURE 1. Average Annual Values of the Rainfall Factor (R)

$$A = R \times K \times LS \times C \times P$$

A = soil loss in tons per acre per year
R = rainfall factor
K = soil erodibility factor
LS = slope length and steepness factor
C = cropping-management factor
P = erosion control practice factor

Rainfall (R)

This factor is a measure of rainfall energy rather than just rainfall. A short, intense 4-inch storm will cause much more erosion than a slow, steady 4-inch rain. These R factors (See Figure 1) vary from about 200 in northern Missouri to about 250 in southern Missouri, where intense thunderstorms are more common. In northern Missouri, 50 percent of the year's erosive rainfall occurs in May, June and July.

Soil Erodibility (K)

Soil erodibility is a measure of the relative resistance to erosion of the soil itself. The larger the value of K, the easier that particular soil will erode. Generally sandy soils are less erodible than medium-textured soils.

Table 1 lists erodibility (K) and erosion tolerance (T) values for a broad grouping of several sloping upland soils. The first T value is an acceptable soil loss for that soil. Use the second T value if the soil already has been eroded severely.

Slope Length and Steepness (LS)

Slope (steepness or gradient) and slope length are two important factors that affect erosion. A relative value of 1.0 has been assigned to a 9 percent slope with a length of 73 feet. The effects of slope steepness and length have been combined into LS values as shown in Table 2. The average slope is estimated and found across the top of the table. The slope length is read on the side of the table and is the length from where flow begins to where sediment is deposited, or where runoff enters a well defined channel such as a terrace. For example, a 5 percent slope 100 feet in length has an LS value of 0.6, while a 14 percent slope of 300 feet in length has an LS value of 4.0.

TABLE 1. Erodibility (K) and Erosion Tolerance (T) Factors

	K	T
Marshall - Knox - Napier Deep loess soils adjacent to Missouri River bottom north and west of Glasgow	.32	5-4
Sharpsburg - Grundy - Ladoga - Pershing Moderately deep loess of west central Missouri	.37	3-2
Adair - Shelby - Armstrong - Gara Dark soil on slopes below loess deposits often used for forages and pasture	.28	3-2
Mexico - Putnam Claypan soils of northeast Missouri, level to moderately rolling	.40	3-2
Menfro - Winfield - Weldon River hills along Missouri River from central Missouri to St. Louis and Mississippi River hills north of St. Louis	.37	4-3
Lindley - Keswick - Hatton Sloping less fertile soils of north central and northeast Missouri, usually pasture or timber	.37	3-2

TABLE 2. Slope Steepness and Length Factor (LS)

Length of Slope (L) (in feet)	Percent Slope (S)															
	2	3	4	5	6	7	8	9	10	12	14	16	18	20	22	24
20	*	.2	.2	.2	.2	.4	.4	.6	.6	.8	1.0	1.2	1.6	1.8	2.2	2.6
30	.2	.2	.2	.2	.4	.4	.6	.6	.8	1.0	1.2	1.6	2.0	2.2	2.6	3.0
40	.2	.2	.2	.4	.4	.6	.6	.8	.8	1.2	1.4	1.8	2.2	2.6	3.0	3.5
50	.2	.2	.2	.4	.4	.6	.6	.8	1.0	1.2	1.6	2.0	2.4	3.0	3.5	4.0
60	.2	.2	.4	.4	.6	.6	.8	1.0	1.0	1.4	1.8	2.2	2.8	3.0	4.0	4.5
70	.2	.2	.4	.4	.6	.6	.8	1.0	1.2	1.6	2.0	2.4	3.0	3.5	4.0	5.0
80	.2	.2	.4	.4	.6	.8	.8	1.0	1.2	1.6	2.0	2.6	3.0	3.5	4.5	5.0
90	.2	.2	.4	.6	.6	.8	1.0	1.2	1.2	1.8	2.2	2.8	3.5	4.0	4.5	5.5
100	.2	.4	.4	.6	.6	.8	1.0	1.2	1.4	1.8	2.4	2.8	3.5	4.0	5.0	5.5
110	.2	.4	.4	.6	.8	.8	1.0	1.2	1.4	1.8	2.4	3.0	3.5	4.5	5.0	6.0
120	.2	.4	.4	.6	.8	.8	1.0	1.2	1.4	2.0	2.6	3.0	4.0	4.5	5.5	6.0
130	.2	.4	.4	.6	.8	1.0	1.2	1.4	1.6	2.0	2.6	3.5	4.0	5.0	5.5	7
140	.2	.4	.4	.6	.8	1.0	1.2	1.4	1.6	2.2	2.8	3.5	4.0	5.0	6.0	7
150	.2	.4	.6	.6	.8	1.0	1.2	1.4	1.6	2.2	2.8	3.5	4.5	5.0	6.0	7
160	.2	.4	.6	.6	.8	1.0	1.2	1.4	1.8	2.2	3.0	3.5	4.5	5.5	6.0	7
180	.2	.4	.6	.8	.8	1.0	1.4	1.6	1.8	2.4	3.0	4.0	4.5	5.5	7	8
200	.4	.4	.6	.8	1.0	1.2	1.4	1.6	2.0	2.6	3.5	4.0	5.0	6.0	7	8
250	.4	.4	.6	.8	1.0	1.2	1.6	1.8	2.2	2.8	3.5	4.5	5.5	7	8	9
300	.4	.6	.8	1.0	1.2	1.4	1.8	2.0	2.4	3.0	4.0	5.0	6.0	7	9	10
350	.4	.6	.8	1.0	1.2	1.6	1.8	2.2	2.6	3.5	4.5	5.5	7	8	9	11
400	.4	.6	.8	1.0	1.4	1.6	2.0	2.4	2.8	3.5	4.5	5.5	7	8	10	11
500	.4	.6	1.0	1.2	1.4	1.8	2.2	2.6	3.0	4.0	5.0	6.0	8	9	11	13
600	.6	.8	1.0	1.4	1.6	2.0	2.4	2.8	3.5	4.5	5.5	7	9	10	12	14
700	.6	.8	1.0	1.4	1.8	2.2	2.6	3.0	3.5	5.0	6.0	8	9	11	13	15
800	.6	.8	1.2	1.6	1.8	2.4	2.8	3.5	4.0	5.0	7	8	10	12	14	16
900	.6	1.0	1.2	1.6	2.0	2.4	3.0	3.5	4.0	5.5	7	9	10	13	15	17
1000	.6	1.0	1.2	1.6	2.2	2.6	3.0	3.5	4.5	5.5	7	9	11	13	16	18
1200	.8	1.0	1.4	1.8	2.4	2.8	3.5	4.0	4.5	6.0	8	10	12	14	17	20
1400	.8	1.2	1.6	2.0	2.4	3.0	3.5	4.5	5.0	7	9	11	13	16	18	21
1600	.8	1.2	1.6	2.2	2.6	3.5	4.0	4.5	5.5	7	9	11	14	17	20	23

Contour Limits—2 percent 400 feet, 8 percent 200 feet, 10 percent 100 feet, 14-24 percent 60 feet. The effectiveness of contouring beyond these limits is speculative.

TABLE 3. "C" Factors for Cropland—Conventional Tillage

Cropping System	Spring Plow, Residue Left	Fall Plow, Residue Left	Spring Plow, Residue Removed*	Fall Plow, Residue Removed*
Cont. Sb**	.42	.46	.54	.58
CSb**	.40	.44	.52	.56
CCSb**	.39	.43	.51	.55
Cont. C.	.38	.42	.50	.54
CCOx	.24	.27	.27	.30
CCWx	.22	.26	.24	.28
COx	.17	.19	.21	.23
CWx	.15	.17	.19	.21
CCCOM	.15	.17	.19	.21
CCCWM	.14	.16	.18	.20
CCOM	.12	.13	.18	.19
CCWM	.12	.13	.16	.17
CxCOM	.11	.12	.15	.16
CxCWM	.11	.12	.14	.15
CCOMM	.10	.11	.14	.15
CCWMM	.095	.11	.13	.14
CxCOMM	.090	.10	.10	.11
CxCWMM	.089	.10	.11	.12
CCOMMM	.082	.09	.12	.13
CCWMMM	.079	.09	.11	.12
CxCOMMM	.076	.085	.10	.11
CxCWMMM	.075	.085	.093	.103
COWMM	.067	.075	.091	.101
COM	.060	.070	.097	.107
CWM	.052	.060	.088	.096
COMM	.046	.050	.074	.078
CWMM	.040	.050	.067	.077
CWMMM	.033	.037	.054	.058
CWMMMM	.028	.032	.046	.050

C = Corn - Sb = Soybeans W = Winter grain M = Meadow
O = Spring grain X = Cover or green manure crop
* Residue removed includes corn stover and grain stover.
** Rotations with soybeans are calculated with 1500 pounds residue for each year of soybeans.
A factor for plow planting may be calculated by multiplying the factor for conventional tillage by 0.6.

Cropping Management (C)

Vegetative cover, crop rotation, fertility level, tillage practices, crop residue management and related conditions have an important effect on erosion. All of these factors are involved in developing a C factor. Selection of the correct C factor is more difficult because there are so many more choices. However, changing the C factor of your farming system is one of the easiest, yet still very effective, ways of reducing soil loss. When comparing these values, remember C = 1.0 for a tilled, continuously bare field.

The factors in Tables 3 and 4 take into account the stage of plant growth and condition of soil surface throughout the year, as well as the timing of erosive rains.

Conventional Tillage "C" Factor

The information in Table 3 was developed for a conventional moldboard plow system with various crop rotations and a high level of fertility. High fertility would mean an average yield of 75+ bushels per acre of corn. For lower fertility fields, soil loss may be 10 to 25 percent greater.

The C value increases as the hazard for erosion increases. Notice the effect of plowing season and whether residue was removed or not. For continuous corn, the C factor increases from 0.38 for spring plow and residue left to 0.54 for fall plow and residue removed, a 42 percent increase. Notice that close-growing crops such as wheat and meadow reduce the C factor. Continuous wheat has a C value of 0.21, which is 55 percent of fall plowed and residue left continuous corn.

Reduced Tillage "C" Factor

As the amount of residue increases and is left on the surface, the hazard of erosion is decreased. Table 4 has the C values for strip tilled (33 percent soil surface tilled) and no tillage (10 percent soil surface tilled) farming systems.

To estimate amount of residues from crop yields, consider that for each pound of corn produced there is 1 pound of residue (100 bushels per acre of shelled corn equals 5,600

TABLE 4. "C" Factors for Cropland—Conservation Tillage

	33% Soil surface tilled							10% Soil surface tilled						
	ROW CROP RESIDUE*					SOD RESIDUE**		ROW CROP RESIDUE*					SOD RESIDUE**	
CROPPING SYSTEM	1500 lb	2000-3000 lb	3000-4000 lb	4000-6000 lb	6000+ lb	2000-3000 lb	3000+ lb	1500 lb	2000-3000 lb	3000-4000 lb	4000-6000 lb	6000+ lb	2000-3000 lb	3000+ lb
Cont.R***	.311	.243	.188	.131	.080	.034	.027	.249	.192	.130	.070	.030	.016	.008
RRROx	.287	.245	.194	.173	.131	.037	.032	.251	.198	.155	.135	.102	.024	.018
RROx	.253	.223	.200	.177	.161	.038	.033	.229	.205	.181	.165	.123	.028	.021
RRROM	.197	.156	.123	.089	.058	.031	.027	.160	.125	.088	.052	.028	.020	.015
RROM	.168	.134	.107	.078	.053	.030	.026	.138	.109	.078	.048	.028	.021	.017
RROMM	.136	.109	.087	.064	.043	.025	.022	.111	.088	.063	.039	.023	.018	.015
RROMMM	.114	.091	.073	.054	.037	.022	.019	.093	.074	.054	.034	.020	.016	.013
ROM						.028	.026						.022	.020
ROMM						.023	.021						.018	.016
ROMMM						.019	.018						.015	.014
ROMMMM						.017	.015						.014	.013

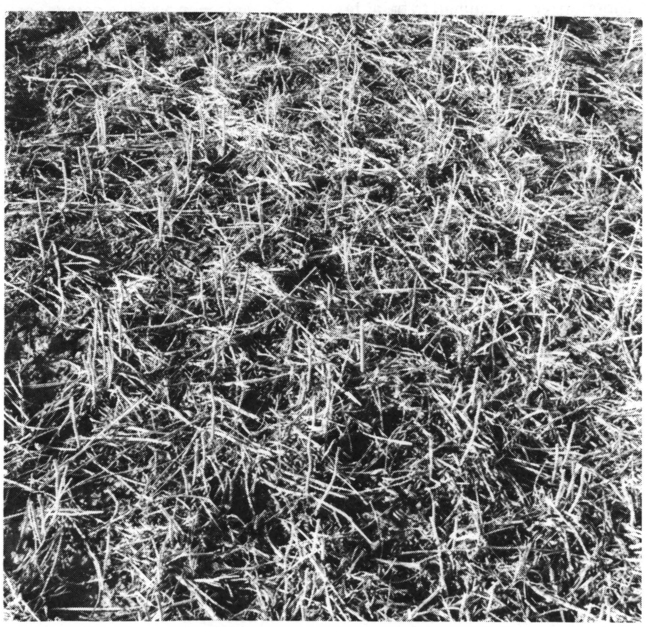
The quantities of crop residue listed above refer to the amounts of cover in pounds per acre still remaining on the soil surface after planting.
* When meadows or green manure crops are included in the rotation, the calculations are based on plowing in the conventional manner for the first year corn and the balance of the years of corn are mulch tilled.
** When planted in sod residue, calculations are based on planting in sod without plowing for first year corn. All succeeding corn is planted with 6000+ lbs of residue cover.
*** R = Corn or Soybeans. The amount of residue produced by the crop determines the erosion potential.

Corn Residue at 1,000 lb/A.

Corn Residue at 2,800 lb/A.

Corn Residue at 5,800 lb/A.

Corn Residue at 6,700 lb/A.



Soybean Residue at 2,800 lb/A.

Wheat Residue at 2,500 lb/A.

FIGURE 2. Varying Amounts of Surface Residue

Photographs courtesy of
USDA—Soil Conservation Service

pounds per acre of residue). For each bushel of small grain there are 100 pounds of residue (30 bushels per acre wheat equals 3,000 pounds per acre of residue). Soybean residue usually averages 1,500 to 2,500 pounds per acre. For sod residue, estimate the amount of hay the residue would make (3,000 pounds per acre gives optimum erosion control). (See Figure 2 for photos of varying amounts of surface residue.)

Compare the difference between continuous corn, spring plow, residue left with a C of 0.38 and continuous corn, no till (10 percent soil surface tilled) with 6,000 + pounds of residue with a C of 0.03. The reason for the large difference is that with no till (or other conservation tillage) the surface is protected 12 months of the year. With conventional tillage, spring plowed land is unprotected 3 or 4 months, while fall plowed land may be unprotected up to 9 months each year.

Unfortunately, few C values have been evaluated for many other reduced tillage systems such as chisel plow and till-plant systems. An estimate can be made by estimating the surface residue and using Table 5. A chisel plow will reduce surface residue from 20 to 50 percent, and a disc will reduce surface residue about 50 percent each time it is used.

Double cropping is also an effective way of reducing soil erosion, since a growing crop is always on the soil. Planting soybeans in wheat stubble not only saves time and moisture but also reduces soil erosion. Values of C for double cropping are not now available, but they certainly should be comparable to conservation tillage.

TABLE 5. "C" Factors for Annual Cover and Various Quantities of Mulch

Cover or Mulch	"C" Factor
bare areas	1.0
¼ ton straw mulch	.52
½ ton straw mulch	.35
¾ ton straw mulch	.24
1 ton straw mulch	.18
1½ ton straw mulch	.10
2 ton straw mulch	.06
3 ton straw mulch	.03
4 ton straw mulch	.02
annual cover	.15

Pasture, Range and Idle Land "C" Factor

Table 6 points out the importance of the amount and type of cover in pasture land. The greater the ground cover,

TABLE 6. "C" Factors for Permanent Pasture, Rangeland and Idle Land[1]

Vegetal Canopy		Cover That Contacts the Surface						
Type and Height of Raised Canopy[2]	Canopy Cover[3]	Type[4]	Percent Ground Cover					
			0	20	40	60	80	95-100
Column No.:	2	3	4	5	6	7	8	9
No appreciable canopy		G	.45	.20	.10	.042	.013	.003
		W	.45	.24	.15	.090	.043	.011
Canopy of tall weeds or short brush (0.5 m fall ht.)	25	G	.36	.17	.09	.038	.012	.003
		W	.36	.20	.13	.082	.041	.011
	50	G	.26	.13	.07	.035	.012	.003
		W	.26	.16	.11	.075	.039	.011
	75	G	.17	.10	.06	.031	.011	.003
		W	.17	.12	.09	.067	.038	.011
Appreciable brush or bushes (2 m fall ht.)	25	G	.40	.18	.09	.040	.013	.003
		W	.40	.22	.14	.085	.042	.011
	50	G	.34	.16	.085	.038	.012	.003
		W	.34	.19	.13	.081	.041	.011
	75	G	.28	.14	.08	.036	.012	.003
		W	.28	.17	.12	.077	.041	.011
Trees but no appreciable low brush (4 m fall ht.)	25	G	.42	.19	.10	.041	.013	.003
		W	.42	.23	.14	.087	.042	.011
	50	G	.39	.18	.09	.040	.013	.003
		W	.39	.21	.14	.085	.042	.011
	75	G	.36	.17	.09	.039	.012	.003
		W	.36	.20	.13	.083	.041	.011

[1] All values shown assume: (1) random distribution of mulch or vegetation, and (2) mulch of appreciable depth where it exists.

[2] Average fall height of waterdrops from canopy to soil surface: m = meters.

[3] Portion of total-area surface that would be hidden from view by canopy in a vertical projection, (a bird's-eye view).

[4] G: Cover at surface is grass, grasslike plants, decaying compacted duff, or litter at least 2 inches deep.

W: Cover at surface is mostly broadleaf herbaceous plants (as weeds) with little lateral-root network near the surface, and/or undecayed residue.

TABLE 7. "C" Factors for Woodland

Stand Condition	Tree Canopy % of Area[1]	Forest Litter % of Area[2]	Undergrowth[3]	"C" Factor
Well Stocked	100-75	100-90	Managed[4]	.001
			Unmanaged[4]	.003-.011
Medium Stocked	70-40	85-75	Managed	.002-.004
			Unmanaged	.01 -.04
Poorly Stocked	35-20	70-40[5]	Managed	.003-.009
			Unmanaged	.02 -.09[5]

[1] When tree canopy is less than 20%, the area will be considered as grassland, or cropland for estimating soil loss.

[2] Forest litter is assumed to be at least two inches deep over the percent ground surface area covered.

[3] Undergrowth is defined as shrubs, weeds, grasses, vines, etc., on the surface area not protected by forest litter. Usually found under canopy openings.

[4] Managed—grazing and fires are controlled.
Unmanaged—stands that are overgrazed or subjected to repeated burning.

[5] For unmanaged woodland with litter cover of less than 75%, C values should be derived by taking 0.7 of the appropriate values in Table 5. The factor of 0.7 adjusts for the much higher soil organic matter on permanent woodland

TABLE 8. "P" Factors for Erosion Control Practices

% Slope	Up-Down Hill	Contouring	Contour Strip Cropping
2-7	1.0	0.5	0.25
7-12	1.0	0.6	0.30
12-18	1.0	0.8	0.40
18-24	1.0	0.9	0.45

the lower the C value. Also notice that grass type cover gives greater protection than weeds.

A tall fescue pasture with an excellent stand of grass would have no appreciable raised canopy, cover that contacts the ground is grass or G and percent ground cover is 95-100. The C factor is 0.003.

A bluegrass pasture with a poor stand of grass would have a raised canopy of tall weeds with a 25 percent canopy cover; the grass covers 60 percent of the ground. The C factor is 0.038.

Woodland "C" Factor

Soil erosion from wooded areas is almost always very low. Use Table 7 to find the appropriate C value.

Erosion Control Practices (P)

Erosion control practices include contour tillage, contour strip-cropping and terracing. Contouring and strip-cropping have been assigned P values depending upon slope and are given in Table 8.

Contouring is the practice of planting all row crops and performing all tillage across the slope. It is most effective on slopes from 2-7 percent where it reduces erosion 50 percent as compared to up and down hill farming. To get full benefit of contouring, fields should be relatively free of gullies and waterways should be grassed. Slope length limits for contouring are given in Table 9.

Contour strip-cropping is the practice of alternating strips of sod with row crops or small grain, all planted on the contour. The sod strips trap much of the sediment, and soil loss from the field is only one half that of contouring alone. Strip widths range from 60 feet on steep (13 to 18 percent) slopes to 100 feet for 2 to 7 percent slopes. Actual width can be adjusted to fit machinery size. Strip-cropping is not a common practice in Missouri, but it is another alternative.

Terracing is a very effective means of erosion control, because it effectively divides the slope into segments equal to the terrace spacing. Much of the effectiveness of terraces is due to reducing the LS factor in the soil loss equation. With terracing, as much as 90 percent of the soil moved to the channel will stay in the channel. This soil is not lost from the field and may result in extra terrace maintenance.

If the crop is planted on contour with the terraces, use a P value from Table 8. This will estimate the soil loss between terraces. Only about 20 percent of this will finally be lost from the field. The remainder will be trapped in the terrace channel and waterway.

TABLE 9. Slope - Length Limits for Contouring

Land Slope (%)	Maximum Slope Length (in feet)
2	400
4-6	300
8	200
10	100
12	80
14-24	60

Applications of the Soil Loss Equation

The primary purpose of the soil loss equation is to help select adequate soil and water conservation practices for farm fields. The following example will illustrate the use of the equation.

Given: Assume a field in Knox county on Mexico silt loam (claypan type) soil with a 3 percent slope, 300 feet long. Corn and soybeans are rotated. The field is spring plowed up and down the slope and the residues are turned under. Yields are usually greater than 75 bushels of corn.

Calculate the average annual soil loss. A = R x K x LS x C x P.

R = 200	Figure 1
K = 0.40	Table 1
LS = 0.6	Table 2
C = 0.40	Table 3
P = 1.0	Table 8

A = 200 x 0.40 x 0.6 x 0.4 x 1.0
= 19.2 tons per acre per year

This soil loss is well in excess of the tolerable soil loss (T) of 3 tons per acre per year. At this rate an inch of top soil would be lost in an average of 8 to 10 years.

Management decisions influencing soil loss are usually made by affecting C or P in the equation. The factor L can be changed by terracing. The other factors R, K and S are essentially fixed. If the tolerable soil loss (T) is substituted for A, the required CP factor can be found. Using the previous example:

$$C \times P = \frac{T}{R \times K \times LS}$$

$$C \times P = \frac{3}{200 \times 0.40 \times 0.6} = 0.06$$

If planting and tillage are done on the contour, P = 0.5, then for C x P to equal 0.06, choose a system with a C factor of 0.12 or less. From Table 3 with the same spring plow tillage as before a rotation of corn, corn, wheat, meadow will lower C to 0.12. By using conservation tillage the C factor can be reduced to an acceptable level by maintaining 1½ tons of mulch per acre (See Table 5). Using no till (10 percent surface tilled, Table 4) with 6,000+ pounds of residue per acre with continuous row crop has a C of 0.03. Therefore, soil loss would average one half the goal of 3 tons per acre per year, even without contouring.

Summary

The Universal Soil Loss Equation was presented as a means to estimate soil loss, to point out factors that cause erosion, and to present alternatives for controlling erosion. The use of contouring, as well as reduced tillage systems that maintain much of the crop residue on the surface, can reduce soil loss to acceptable levels in many cases. Terraces and waterways will still be needed for many other situations.

A workable soil and water conservation plan will usually be a combination of all these various parts. Considerable thought should be used so that you can develop the best plan that fits into your overall goals.

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