986

The Revised Universal Soil Loss Equation

D. K. McCool, K. G. Renard and G. R. Foster[1]

ABSTRACT

The Universal Soil Loss Equation has been revised to more accurately estimate soil loss from both crop and rangeland areas. The revision is based on data not available at the time Agriculture Handbook No. 537 was completed in 1978. All factors R, K, LS, C and P have been reviewed and revised. R-values for the western United States were developed from hourly precipitation data. A time-variant K factor was included. New length and steepness (LS) factor relationships were developed. C factors are now computed by a subfactor approach, and P factor procedures were developed using the CREAMS model. The model has been computerized for use on personal computers with a DOS operating system.

INTRODUCTION

In 1985, at a meeting of the United States Department of Agriculture (USDA) and university erosion researchers, it was decided that two concurrent efforts were needed to improve the erosion prediction technology used in USDA conservation planning: 1) revise the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978) to incorporate technology developed after 1978; and 2) develop technology which would address interrill and rill erosion, as well as sediment transport and deposition associated with concentrated flow and ponded areas. Both of these projects are nearing fruition. This paper discusses the changes incorporated in the Revised Universal Soil Loss Equation (RUSLE).

---

1 Agricultural Engineer, USDA-ARS, Land Management and Water Conservation Research Unit, Pullman, Washington, USA; Research-Hydraulic Engineer, USDA-ARS Southwest Watershed Research Center, Tucson, Arizona, USA; and Director, USDA-ARS, National Sedimentation Laboratory, Oxford, Mississippi, USA.

Contribution from USDA-ARS, Land Management and Water Conservation Research Unit, Pullman, WA; USDA-ARS Southwest Watershed Research Center, Tucson, AZ; and USDA-ARS, National Sedimentation Laboratory, Oxford, MS; in cooperation with the College of Agriculture and Home Economics Research Center, Washington State University, Pullman, WA.

RUSLE DESCRIPTION

RUSLE maintains the basic structure of the USLE, namely:

$$A = R\,K\,L\,S\,C\,P \quad (1)$$

where A is the computed soil loss (ton $acre^{-1}$ $year^{-1}$), R is the rainfall-runoff erosivity factor (hundreds of foot tonf inch $acre^{-1}$ $hour^{-1}$ $year^{-1}$), K is the soil erodibility factor [ton acre hour (hundreds of acre foot tonf $inch)^{-1}$], L is the slope length factor (dimensionless), S is the slope steepness factor (dimensionless), C is the cover-management factor (dimensionless), and P is the supporting practices factor (dimensionless). This empirically based equation, derived from a large mass of plot and field data, computes combined interrill and rill erosion using values representing the four major factors affecting erosion. These factors are: climatic erosivity represented by R, soil erodibility represented by K, topography represented by LS, and land use and management represented by C and P. Whereas the basic USLE structure has been retained, the algorithms used to calculate the individual factors have been changed significantly in RUSLE. Perhaps most important has been computerization of the technology to assist with the determination of individual factors. This allows computation of the soil loss ratio (SLR) by 15-day intervals rather than by longer crop stage periods, and improves estimates of the factors affecting the SLR, such as roughness, crop growth and residue decomposition.

R-factor: Ideally, the R-factor is determined by analyzing long-term breakpoint precipitation data and calculating EI, the product of kinetic energy and maximum 30-minute intensity of each storm meeting certain characteristics, summing the EI for the entire period of record and dividing the summed EI value by the number of years. This process was used in developing the original R map for the eastern United States (US). This procedure is very time consuming and requires breakpoint precipitation data, which are unavailable for much of the western US. In the western US, new R values have been calculated using over 1,000 point values of EI developed from a relationship between 60-minute and 15-minute precipitation data (Istok et al., 1986):

$$(EI)_{15} = b(EI)_{60} \qquad (2)$$

where

$(EI)_{15}$ = EI calculated from 15-minute data

$(EI)_{60}$ = EI calculated from 60-minute data

b = regression parameter.

A b value was obtained for each climatically homogeneous area in the western US. The $(EI)_{15}$ values were then adjusted to an equivalent breakpoint basis using EI = 1.0667 $(EI)_{15}$ and R = 1.0667 $(R)_{15}$ (Weiss, 1964). Some changes were also made in the location of lines of equal erosivity in the eastern states (east of the 105th meridian). Another change in the R-factor was to reduce R values where flat slopes occur in regions of long intense rainstorms because ponded water on the soil surface reduces the erosivity of the rain. Finally, an R equivalent approach is being used in the Pacific Northwest area to reflect the combined effect of rain and snowmelt on partly thawed soil. These R equivalent relationships were developed from 10 years of erosion measurements (McCool et al., 1987a).

Part of the R-factor calculation involves a seasonal distribution to permit weighting of the soil erodibility value, K, and the cover-management factor, C by the percent of annual R occurring during each 15-day computation interval. To facilitate these calculations, climate data files have been developed (called a city code) for climatically homogeneous areas. These computer files require information such as the frost-free duration, monthly precipitation and temperature, and 15-day distributions of R. Typical values are included in the computer program for at least one station in each of 119 climatic regions of the contiguous 48 United States plus numerous stations in Hawaii.

K-Factor: The K-factor is a measure of the inherent erodibility of a given soil under the standard condition of the USLE unit plot maintained in continuous fallow. Values for K typically range from about 0.013 to 0.059 SI units, (0.10 to 0.45 US customary units)(Foster et al., 1981), with high-sand and high-clay content soils having the lower values and high-silt content soils having the higher values. Users in the US have little difficulty choosing a K-factor value because the US Soil Conservation Service (SCS) has identified K values for all major soil mapping units in the US. However, the site-specific K-value, and its seasonal variation, can be quite different from the K-value given in soil survey information.

The soil erodibility nomograph (Wischmeier et al., 1971) is a popular tool for estimating K values, but it does not apply to some soils. Updating the K-factor for RUSLE involved developing guides so the user could identify soils where the nomograph does not apply and estimate K using alternative methods. Erodibility data from around the world was reviewed, and an equation was developed that gives a useful estimate of K as a function of an "average" diameter of the soil particles (Romkens et al., 1994). Only soils with less than 10% rock fragments were considered. The equation in SI units (Foster et al., 1981) can be expressed as:

$$K = \left(0.0034 + 0.0405 \exp\left[-\frac{1}{2}\left(\frac{\log(Dg) + 1.659}{0.7101}\right)^2\right]\right) \qquad (3)$$

where

$$Dg(mm) = \exp\left[0.01 \sum_{i=1}^{N} f_i \ln m_i\right] \qquad (4)$$

Here, f_i is the primary particle size fraction in percent, and m_i is the arithmetic mean of the particle size limits of that size (Shirazi and Boersma, 1984). K-values for volcanic soils of Hawaii are also estimated with an alternative algorithm to the erodibility nomograph (El-Swaify and Dangler, 1976).

RUSLE also varies K seasonally. Experimental data show that K is not constant but varies with season, being highest in early spring when the soil is wet and lowest in mid-fall when the soil is dry. The seasonal variability is addressed by weighting the instantaneous estimate of K in proportion to EI (the percent of annual R) for 15-day intervals. Instantaneous estimates of K are made from equations relating K to the frost-free period and the annual R-factor.

An additional change incorporated in RUSLE is to account for rock fragments on and in the soil, a common occurrence on western US rangelands and croplands in many areas of the world. Rock fragments on the soil surface are treated like mulch in the C-factor, while K is adjusted for rock in the soil profile to account for effects on runoff. RUSLE also provides a procedure for identifying soils that are highly, moderately, or slightly susceptible to rill erosion compared with their susceptibility to interrill erosion.

L and S Factors: RUSLE uses four separate slope length relationships. Three are functions of slope steepness as in the USLE, and of the susceptibility of the soil to rill erosion relative to interrill erosion. A separate slope length relationship was developed specifically for the dryfarmed cropland region of the Pacific Northwest of the US (McCool et al., 1987a; 1989; 1993).

More questions and concerns have been expressed over the L-factor and its application than any of the USLE factors. One reason is that the choice of a slope length involves judgment; different users choose different slope lengths for similar situations. RUSLE includes improved guides for choosing slope length values to give greater consistency among users. The attention given to the L-factor is not always warranted, because soil loss is less sensitive to slope length than to slope steepness. For typical slope conditions, a 10% error in slope length results in a 5% error in computed soil loss.

Revised slope steepness relationships were developed from data from a large number of historical and current research plots (McCool et al., 1987b). A separate relationship was developed specifically for the dryfarmed cropland region of the Pacific Northwest US (McCool et al., 1987a; 1993).

Soil loss is much more sensitive to changes in slope steepness than to changes in slope length. In the USLE, a 10% error in slope steepness gives about a 20% error in computed soil loss. Thus, special attention should be given to obtaining good estimates of slope steepness. RUSLE has a closer-to-linear slope steepness relationship than the USLE. Computed soil loss for slopes less than 20% are similar in USLE and RUSLE. However, on very steep slopes, computed soil loss is reduced almost in half with RUSLE. Experimental data and field observations, especially on rangelands, do not support the USLE quadratic relationship when extended to steep slopes.

Tables 1, 2, 3, and 4 give LS values for uniform slopes. These tables should be used for slopes with a fairly uniform surface. Use table 1 for rangeland and pasture where the ratio of rill to interrill erosion is low. Use table 2 for cropland where the ratio of rill to interrill erosion is moderate. Use table 3 for construction sites where the ratio of rill to interrill erosion is high and the soil has a strong tendency to rill. Use table 4 for thawing soil where most of the erosion is caused by surface flow. Slope length in tables 1 through 4 is given in feet, but the proper LS value can be readily obtained by converting metric slope length to feet before entering the tables. LS values are dimensionless, as are C and P.

In most practical applications, a slope segment previously estimated as a single plane or uniform slope can be a poor representation of the topography. In RUSLE and its computer program, complex slopes can be readily represented to provide a better approximation of the topographic effect.

C-Factor: The C-factor is perhaps the most important USLE and RUSLE factor because it represents conditions that can most easily be managed to reduce erosion. Values for C can vary from near zero for a very well-protected soil to 1.2 for a finely tilled surface that produces much runoff and leaves the soil highly susceptible to rill erosion.

Values for C are a weighted average of soil loss ratios that represent the soil loss for a given condition at a given time, to that of the unit fallow plot. Thus, soil loss ratios vary during the year as soil and cover conditions change. To compute C, soil loss ratios are weighted according to the distribution of erosivity during a year (i.e., from the information in the city code climate data).

In RUSLE, a subfactor method is used to compute soil loss ratios as a function of four subfactors (Laflen et al., 1985) given as:

$$C = PLU * CC * SC * SR \qquad (5)$$

where PLU is prior land use, CC is crop canopy, SC is surface or ground cover (including erosion pavement) and SR is the surface roughness.

The prior land use subfactor (PLU) expresses the influence on soil erosion of (1) prior cropping, (2) dominant tillage practice, (3) soil consolidation, (4) time, and (5) biological activity. These components account for the residual effects of cropping.

The canopy cover subfactor expresses the effect of vegetative canopy on reducing rainfall energy impacting the soil surface. While most rainfall intercepted by crop canopy eventually reaches the soil surface, it usually does so with much less energy than non-intercepted rainfall. These intercepted raindrops either fracture into smaller drops with less energy, drip from leaf edges or travel down crop stems to the ground.

Surface cover affects erosion by reducing transport capacity of runoff water (Foster, 1982), by causing deposition in ponded areas (Laflen, 1983), and by decreasing the surface area susceptible to raindrop impact. For most cropland surface cover is perhaps the single most important subfactor in determining soil erosion. Surface cover includes crop residue, rocks, cryptogams, or other nonerodible material in direct contact with the soil surface (Simanton et al., 1984; Box, 1981; Meyer et al., 1972). The effect of surface cover on soil erosion is given by a negative exponential relationship, $SC = e^{-bm}$, where the surface cover subfactor is SC and the fraction of the land area covered by surface cover is m. The coefficient b indicates the effectiveness of surface cover in reducing soil erosion. Laflen et al. (1980) and Laflen and Colvin (1981) found that b values ranged from 3.0 to 7.0 for row crops, while Dickey et al. (1983) found b values of 2.4 to 3.2 in a rainfall simulation study on small grains. Within the Pacific Northwest, b values greater than 5.0 have been found for small grain (McCool, 1985; 1989 - personal communication).

Surface roughness has been shown to affect soil erosion (Cogo et al., 1984). Random roughness, an index of surface roughness (Allmaras et al., 1966), can be used to predict soil erosion. A rough surface, expressed by a large surface roughness index, has many depressions and barriers. During a rainfall event, these trap water and sediment, and erode at lower rates than do smooth surfaces under similar conditions. Increasing surface roughness decreases transport capacity and detachment of runoff by reducing flow velocity. Consolidation from rainfall decreases surface roughness over time.

Figure 1 illustrates the sensitivity of the soil loss ratio in RUSLE version SWCS 1.02 to several subfactor elements. The base condition was a small grain crop during the early growth stages (20 percent canopy cover). A surface cover of 30 percent and a b value of 3.5 were assumed. Surface roughness and incorporated residue were typical of small grain fields with a combination of sheet and rill erosion. Under the assumed conditions, soil erosion is more responsive to surface cover than to plant canopy, canopy height, below ground biomass (a major component of the PLU subfactor) or surface roughness.

P-Factor: Of the USLE and RUSLE factors, values for the P-factor are the least reliable. The P-factor mainly represents how surface conditions affect flow paths and flow hydraulics. For example, with contouring, tillage marks are credited with forcing runoff to flow around the slope at much reduced grades. However, slight changes in grade can greatly change the erosivity of runoff. In experimental field studies, small changes in such features as row grade and their effect on erosion are difficult to document, leading to much scatter in measured data. For example, the effectiveness of contouring in field studies conducted on a given slope have ranged from no reduction in soil loss to a 90% reduction. Likewise, identifying these subtle characteristics in the field is difficult when applying RUSLE. Thus, P-factor values represent broad, general effects of such practices as contouring.

In RUSLE, extensive data have been analyzed to reevaluate the effect of contouring. The results have been interpreted to give factor values for contouring as a function of ridge height, furrow grade, and climatic erosivity. New P-factor values for the effect of terracing account for grade along the terrace, while a broader array of stripcropping conditions are considered in RUSLE than in USLE. The CREAMS model (Knisel, 1980) was used in developing the new P-factor values.

Finally, P factors in RUSLE have been developed to reflect conservation practices on rangelands such as pitting, ripping, root plowing and land imprinting. Evaluation of the practices requires estimates of surface roughness and runoff reduction.

SUMMARY

The USLE has been revised to reflect new technology and analysis of data acquired since 1978 when Agriculture Handbook No. 537 was completed. The RUSLE is available in handbook form or on disc for use with a personal computer. Currently, all computations are in US customary units. Conversions to SI units can be made readily using factors developed by Foster et al. (1981).

REFERENCES

Allmaras, R. R., R. E. Burwell, W. E. Larson, R. F. Holt, and W. W. Nelson. 1966. Total porosity and random roughness of the interrow zones influenced by tillage. U.S. Department of Agriculture, Conservation Research Report 7, 22 pp. U.S. Government Printing Office, Washington, DC.

Box, J. E., Jr. 1981. The effects of surface slaty fragments on soil erosion by water. Soil Science Society of America Journal 45:111-116.

Cogo, N. D., W. C. Moldenhauer, and G. R. Foster. 1984. Soil loss reduction from conservation tillage practices. Soil Science Society of America Journal 48:368-373.

Dickey, E. C., C. R. Fenster, J. M. Laflen, and R. H. Mickelson. 1983. Effects of tillage on soil erosion in a wheat-fallow rotation. TRANSACTIONS of the American Society of Agricultural Engineers 26(3):814-820.

El-Swaify, S. A. and E. W. Dangler. 1976. Erodibilities of selected tropical soils in relation to structural and hydrologic parameters. In: Soil Erosion: Prediction and Control, pp. 105-114, Soil Conservation Society of America, Ankeny, IA.

Foster, G. R. 1982. Modeling the erosion process. p. 297-380. In: C. T. Haan, H. P. Johnson, D. L. Brakensiek (eds.). Hydrologic modeling of small watersheds. ASAE Monograph No. 5. American Society of Agricultural Engineers, St. Joseph, MI.

Foster, G. R., D. K. McCool, K. G. Renard and W. C. Moldenhauer. 1981. Conversion of the Universal Soil Loss Equation to SI metric units. Journal of Soil and Water Conservation 36(6):355-359.

Istok, J. D., D. K. McCool, L. G. King and L. Boersma. 1986. Effect of rainfall measurement interval on EI calculation. Transactions of the American Society of Agricultural Engineers 29(3):730-734.

Knisel, Walter G., editor. 1980. CREAMS: A field-scale model for chemicals, runoff, and erosion from agricultural management systems. United States Department of Agriculture, Conservation Research Report 26, 643 p. U.S. Government Printing Office, Washington, DC.

Laflen, J. M. 1983. Tillage and residue effect on erosion from cropland. In: D. A. DeCoursey, ed. Natural Resources Modeling Symposium, pp. 438-441, United States Department of Agriculture-Agricultural Research Service, Pingree Park, CO.

Laflen, J. M., W. C. Moldenhauer, and T. S. Colvin. 1980. Conservation tillage and soil erosion on continuously row-cropped land. In: Crop Production with Conservation in the 80's, pp. 121-133, American Society of Agricultural Engineers, St. Joseph, MI.

Laflen, J. M. and T. S. Colvin. 1981. Effect of crop residue on soil loss from continuous row cropping. TRANSACTIONS of the American Society of Agricultural Engineers 24(3):605-609.

Laflen, J. M., G. R. Foster, and C. A. Onstadt. 1985. Simulation of individual-storm soil loss for modeling impact of erosion on crop productivity. p. 285-295. In: Soil erosion and conservation, Proc. Intl. Conf. on Soil Erosion and Conservation, Honolulu, HI. Jan 16-22, 1983. Soil Conservation Society of America, Ankeny, IA.

McCool, D. K. 1985. Crop residue effects on erosion from dry-farmed cropland in the Pacific Northwest. American Society of Agricultural Engineers. Paper #85-2046.

McCool, D. K., J. F. Zuzel, J. D. Istok, G. E. Formanek, Myron Molnau, K. E. Saxton, and L. F. Elliott. 1987a. Erosion processes and prediction for the Pacific Northwest. In: Proceedings: STEEP Soil conservation concepts and accomplishments. Spokane, WA. May 20-21, 1986.

McCool, D. K., L. C. Brown, G. R. Foster, C. K. Mutchler, and L. D. Meyer. 1987b. Revised slope steepness factor for the Universal Soil Loss Equation. Transactions of the American Society of Agricultural Engineers 30(5):1387-1396.

McCool, D. K., G. R. Foster, C. K. Mutchler, and L. D. Meyer. 1989. Revised slope length factor for the Universal Soil Loss Equation. Transactions of the American Society of Agricultural Engineers 32(5):1571-1576.

McCool, D. K., G. O. George, M. Freckleton, C. L. Douglas, Jr., and R. I. Papendick. 1993. Topographic Effect on Erosion from Cropland in the Northwestern Wheat Region. Transactions of the American Society of Agricultural Engineers 36(3):771-775.

Meyer, L. D., C. B. Johnson, and G. R. Foster. 1972. Stone and woodchip mulches for erosion control on construction sites. Journal of Soil and Water Conservation 27(6):264-269.

Römkens, M. J. M., R. A. Young, J. W. A. Poesen, D. K. McCool, S. A. El-Swaify, and J. M. Bradford. 1994. Soil erodibility factor (K). Chapter 3. In: Predicting Soil Erosion by Water - A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE). United States Department of Agriculture-Agricultural Research Service, Agriculture Handbook No. XXX (Pending Review).

Shirazi, M. A. and L. Boersma. 1984. A unifying quantitative analysis of soil texture. Soil Science Society of America Journal 48:142-147.

Simanton, J. R., E. Rawitz and E. D. Shirley. 1984. The effects of rock fragments on erosion of semiarid rangeland soils. In: Erosion and Productivity of Soils Containing Rock Fragments, Chapter 7, SSA Special Publication 13, pp. 65-72, Soil Science Society of America, Madison, WI.

Weiss, L. L. 1964. Ratio of true to fixed-interval maximum rainfall. Journal of Hydraulics Division, American Society of Civil Engineers, 90(HY1):77-82.

Wischmeier, W. H. and D. D. Smith. 1978. Predicting rainfall erosion losses: A guide to conservation planning. United States Department of Agriculture, Agriculture Handbook No. 537. U.S. Government Printing Office, Washington, DC.

Wischmeier, W. H., C. B. Johnson, and B. V. Cross. 1971. A soil erodibility nomograph for farmland and construction sites. Journal of Soil and Water Conservation 26:189-193.

Figure 1. Sensitivity of Soil Loss Ratio to Subfactor Elements.

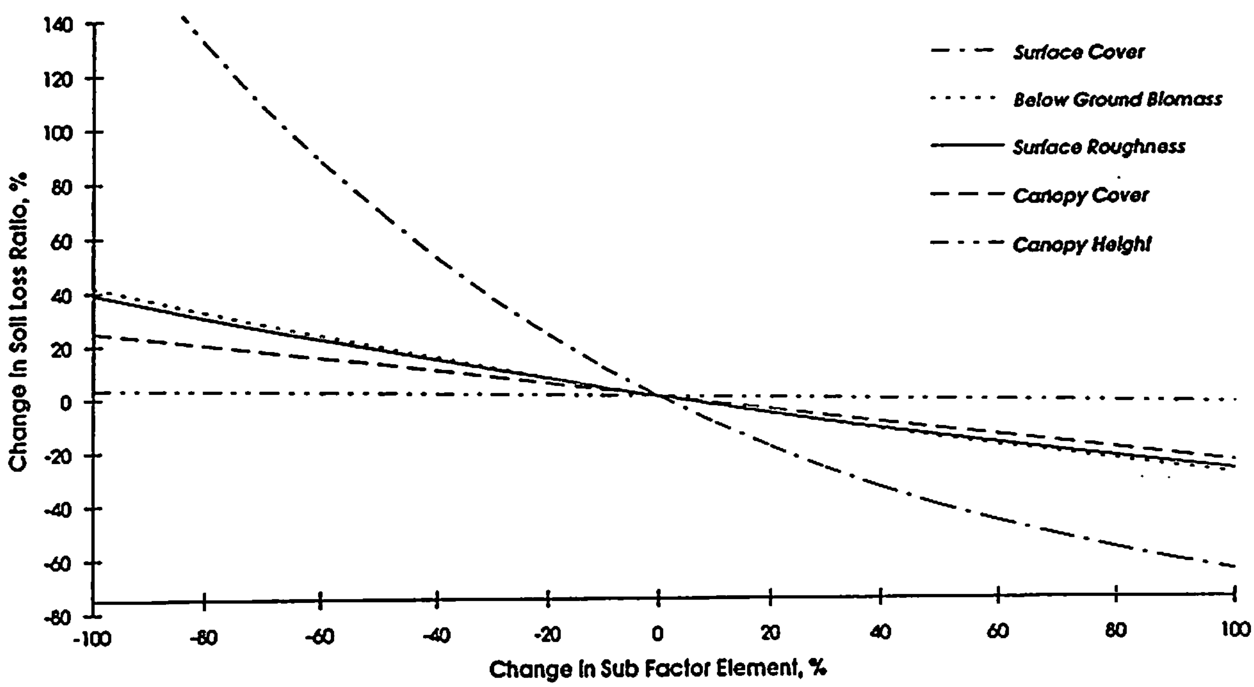

Table 1.
Values for topographic factor, LS, for low ratio of rill to interrill erosion, such as for rangeland and other consolidated soil conditions with cover (applicable to thawing soil where both interrill and rill erosion are significant).

	Slope length in feet																
Slope	<3	6	9	12	15	25	50	75	100	150	200	250	300	400	600	800	1000
percent																	
0.2	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
0.5	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
1.0	0.12	0.12	0.12	0.12	0.12	0.13	0.13	0.14	0.14	0.15	0.15	0.15	0.15	0.16	0.16	0.17	0.17
2.0	0.20	0.20	0.20	0.20	0.20	0.21	0.23	0.25	0.26	0.27	0.28	0.29	0.30	0.31	0.33	0.34	0.35
3.0	0.26	0.26	0.26	0.26	0.26	0.29	0.33	0.36	0.38	0.40	0.43	0.44	0.46	0.48	0.52	0.55	0.57
4.0	0.33	0.33	0.33	0.33	0.33	0.36	0.43	0.46	0.50	0.54	0.58	0.61	0.63	0.67	0.74	0.78	0.82
5.0	0.38	0.38	0.38	0.38	0.38	0.44	0.52	0.57	0.62	0.68	0.73	0.78	0.81	0.87	0.97	1.04	1.10
6.0	0.44	0.44	0.44	0.44	0.44	0.50	0.61	0.68	0.74	0.83	0.90	0.95	1.00	1.08	1.21	1.31	1.40
8.0	0.54	0.54	0.54	0.54	0.54	0.64	0.79	0.90	0.99	1.12	1.23	1.32	1.40	1.53	1.74	1.91	2.05
10.0	0.60	0.63	0.65	0.66	0.68	0.81	1.03	1.19	1.31	1.51	1.67	1.80	1.92	2.13	2.45	2.71	2.93
12.0	0.61	0.70	0.75	0.80	0.83	1.01	1.31	1.52	1.69	1.97	2.20	2.39	2.56	2.85	3.32	3.70	4.02
14.0	0.63	0.76	0.85	0.92	0.98	1.20	1.58	1.85	2.08	2.44	2.73	2.99	3.21	3.60	4.23	4.74	5.18
16.0	0.65	0.82	0.94	1.04	1.12	1.38	1.85	2.18	2.46	2.91	3.28	3.60	3.88	4.37	5.17	5.82	6.39
20.0	0.68	0.93	1.11	1.26	1.39	1.74	2.37	2.84	3.22	3.85	4.38	4.83	5.24	5.95	7.13	8.10	8.94
25.0	0.73	1.05	1.30	1.51	1.70	2.17	3.00	3.63	4.16	5.03	5.76	6.39	6.96	7.97	9.65	11.04	12.26
30.0	0.77	1.16	1.48	1.75	2.00	2.57	3.60	4.40	5.06	6.18	7.11	7.94	8.68	9.99	12.19	14.04	15.66
40.0	0.85	1.36	1.79	2.17	2.53	3.30	4.73	5.84	6.78	8.37	9.71	10.91	11.99	13.92	17.19	19.96	22.41
50.0	0.91	1.52	2.06	2.54	3.00	3.95	5.74	7.14	8.33	10.37	12.11	13.65	15.06	17.59	21.88	25.55	28.82
60.0	0.97	1.67	2.29	2.86	3.41	4.52	6.63	8.29	9.72	12.16	14.26	16.13	17.84	20.92	26.17	30.68	34.71

Table 2.
Values for topographic factor, LS, for moderate ratio of rill to interrill erosion, such as for row-cropped agricultural and other moderately consolidated soil conditions with little to moderate cover (not applicable to thawing soil)

	Slope length in feet																
Slope	<3	6	9	12	15	25	50	75	100	150	200	250	300	400	600	800	1000
percent																	
0.2	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06
0.5	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.10	0.10	0.10	0.10
1.0	0.11	0.11	0.11	0.11	0.11	0.12	0.13	0.14	0.14	0.15	0.16	0.17	0.17	0.18	0.19	0.20	0.20
2.0	0.17	0.17	0.17	0.17	0.17	0.19	0.22	0.25	0.27	0.29	0.31	0.33	0.35	0.37	0.41	0.44	0.47
3.0	0.22	0.22	0.22	0.22	0.22	0.25	0.32	0.36	0.39	0.44	0.48	0.52	0.55	0.60	0.68	0.75	0.80
4.0	0.26	0.26	0.26	0.26	0.26	0.31	0.40	0.47	0.52	0.60	0.67	0.72	0.77	0.86	0.99	1.10	1.19
5.0	0.30	0.30	0.30	0.30	0.30	0.37	0.49	0.58	0.65	0.76	0.85	0.93	1.01	1.13	1.33	1.49	1.63
6.0	0.34	0.34	0.34	0.34	0.34	0.43	0.58	0.69	0.78	0.93	1.05	1.16	1.25	1.42	1.69	1.91	2.11
8.0	0.42	0.42	0.42	0.42	0.42	0.53	0.74	0.91	1.04	1.26	1.45	1.62	1.77	2.03	2.47	2.83	3.15
10.0	0.46	0.48	0.50	0.51	0.52	0.67	0.97	1.19	1.38	1.71	1.98	2.22	2.44	2.84	3.50	4.06	4.56
12.0	0.47	0.53	0.58	0.61	0.64	0.84	1.23	1.53	1.79	2.23	2.61	2.95	3.26	3.81	4.75	5.56	6.28
14.0	0.48	0.58	0.65	0.70	0.75	1.00	1.48	1.86	2.19	2.76	3.25	3.69	4.09	4.82	6.07	7.15	8.11
16.0	0.49	0.63	0.72	0.79	0.85	1.15	1.73	2.20	2.60	3.30	3.90	4.45	4.95	5.86	7.43	8.79	10.02
20.0	0.52	0.71	0.85	0.96	1.06	1.45	2.22	2.85	3.40	4.36	5.21	5.97	6.68	7.97	10.23	12.20	13.99
25.0	0.56	0.80	1.00	1.16	1.30	1.81	2.82	3.65	4.39	5.69	6.83	7.88	8.86	10.65	13.80	16.58	19.13
30.0	0.59	0.89	1.13	1.34	1.53	2.15	3.39	4.42	5.34	6.98	8.43	9.76	11.01	13.30	17.37	20.99	24.31
40.0	0.65	1.05	1.38	1.68	1.95	2.77	4.45	5.87	7.14	9.43	11.47	13.37	15.14	18.43	24.32	29.60	34.48
50.0	0.71	1.18	1.59	1.97	2.32	3.32	5.40	7.17	8.78	11.66	14.26	16.67	18.94	23.17	30.78	37.65	44.02
60.0	0.76	1.30	1.78	2.23	2.65	3.81	6.24	8.33	10.23	13.65	16.76	19.64	22.36	27.45	36.63	44.96	52.70

Table 3.
Values for topographic factor, LS, for high ratio of rill to interrill erosion, such as for freshly prepared construction and other highly disturbed soil conditions with little or no cover (not applicable to thawing soil)

Slope	Slope length in feet																
	<3	6	9	12	15	25	50	75	100	150	200	250	300	400	600	800	1000
per-cent																	
0.2	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06
0.5	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.09	0.09	0.10	0.10	0.10	0.11	0.12	0.12	0.13
1.0	0.09	0.09	0.09	0.09	0.09	0.10	0.13	0.14	0.15	0.17	0.18	0.19	0.20	0.22	0.24	0.26	0.27
2.0	0.13	0.13	0.13	0.13	0.13	0.16	0.21	0.25	0.28	0.33	0.37	0.40	0.43	0.48	0.56	0.63	0.69
3.0	0.17	0.17	0.17	0.17	0.17	0.21	0.30	0.36	0.41	0.50	0.57	0.64	0.69	0.80	0.96	1.10	1.23
4.0	0.20	0.20	0.20	0.20	0.20	0.26	0.38	.0.47	0.55	0.68	0.79	0.89	0.98	1.14	1.42	1.65	1.86
5.0	0.23	0.23	0.23	0.23	0.23	0.31	0.46	0.58	0.68	0.86	1.02	1.16	1.28	1.51	1.91	2.25	2.55
6.0	0.26	0.26	0.26	0.26	0.26	0.36	0.54	0.69	0.82	1.05	1.25	1.43	1.60	1.90	2.43	2.89	3.30
8.0	0.32	0.32	0.32	0.32	0.32	0.45	0.70	0.91	1.10	1.43	1.72	1.99	2.24	2.70	3.52	4.24	4.91
10.0	0.35	0.37	0.38	0.39	0.40	0.57	0.91	1.20	1.46	1.92	2.34	2.72	3.09	3.75	4.95	6.03	7.02
12.0	0.36	0.41	0.45	0.47	0.49	0.71	1.15	1.54	1.88	2.51	3.07	3.60	4.09	5.01	6.67	8.17	9.57
14.0	0.38	0.45	0.51	0.55	0.58	0.85	1.40	1.87	2.31	3.09	3.81	4.48	5.11	6.30	8.45	10.40	12.23
16.0	0.39	0.49	0.56	0.62	0.67	0.98	1.64	2.21	2.73	3.68	4.56	5.37	6.15	7.60	10.26	12.69	14.96
20.0	0.41	0.56	0.67	0.76	0.84	1.24	2.10	2.86	3.57	4.85	6.04	7.16	8.23	10.24	13.94	17.35	20.57
25.0	0.45	0.64	0.80	0.93	1.04	1.56	2.67	3.67	4.59	6.30	7.88	9.38	10.81	13.53	18.57	23.24	27.66
30.0	0.48	0.72	0.91	1.08	1.24	1.86	3.22	4.44	5.58	7.70	9.67	11.55	13.35	16.77	23.14	29.07	34.71
40.0	0.53	0.85	1.13	1.37	1.59	2.41	4.24	5.89	7.44	10.35	13.07	15.67	18.17	22.95	31.89	40.29	48.29
50.0	0.58	0.97	1.31	1.62	1.91	2.91	5.16	7.20	9.13	12.75	16.16	19.42	22.57	28.60	39.95	50.63	60.84
60.0	0.63	1.07	1.47	1.84	2.19	3.36	5.97	8.37	10.63	14.89	18.92	22.78	26.51	33.67	47.18	59.93	72.15

Table 4.
Values for topographic factor, LS, for thawing soils where most of the erosion is caused by surface flow.

Slope	Slope length in feet												
	15	25	50	75	100	150	200	250	300	400	600	800	1000
per-cent													
0.2	0.02	0.03	0.04	0.05	0.06	0.07	0.09	0.10	0.10	0.12	0.15	0.17	0.19
0.5	0.04	0.05	0.07	0.09	0.10	0.12	0.14	0.16	0.17	0.20	0.24	0.28	0.31
1.0	0.06	0.08	0.11	0.14	0.16	0.20	0.23	0.26	0.28	0.32	0.40	0.46	0.51
2.0	0.11	0.14	0.20	0.25	0.29	0.35	0.41	0.46	0.50	0.58	0.71	0.82	0.91
3.0	0.16	0.21	0.29	0.36	0.42	0.51	0.59	0.66	0.72	0.83	1.02	1.17	1.31
4.0	0.21	0.27	0.38	0.47	0.54	0.66	0.77	0.86	0.94	1.08	1.33	1.53	1.71
5.0	0.26	0.33	0.47	0.58	0.67	0.82	0.94	1.06	1.16	1.34	1.64	1.89	2.11
6.0	0.31	0.40	0.56	0.69	0.79	0.97	1.12	1.26	1.38	1.59	1.95	2.25	2.51
8.0	0.41	0.52	0.74	0.91	1.05	1.28	1.48	1.65	1.81	2.09	2.56	2.96	3.31
10.0	0.48	0.62	0.88	1.08	1.25	1.53	1.77	1.98	2.16	2.50	3.06	3.54	3.95
12.0	0.54	0.70	0.98	1.21	1.39	1.71	1.97	2.20	2.41	2.78	3.41	3.94	4.40
14.0	0.59	0.76	1.08	1.32	1.53	1.87	2.16	2.41	2.64	3.05	3.74	4.31	4.82
16.0	0.64	0.82	1.17	1.43	1.65	2.02	2.33	2.61	2.86	3.30	4.04	4.67	5.22
20.0	0.73	0.94	1.33	1.63	1.88	2.30	2.66	2.97	3.25	3.76	4.60	5.31	5.94
25.0	0.83	1.07	1.51	1.85	2.13	2.61	3.02	3.37	3.69	4.27	5.23	6.03	6.75
30.0	0.91	1.18	1.67	2.05	2.36	2.89	3.34	3.73	4.09	4.72	5.78	6.68	7.47
40.0	1.07	1.38	1.95	2.39	2.75	3.37	3.90	4.36	4.77	5.51	6.75	7.79	8.71
50.0	1.19	1.54	2.18	2.67	3.08	3.77	4.35	4.87	5.33	6.16	7.54	8.71	9.74
60.0	1.30	1.67	2.37,	2.90	3.35	4.10	4.74	5.30	5.80	6.70	8.20	9.47	10.59

Ken Renard

Proceedings of an

INTERNATIONAL WORKSHOP ON SOIL EROSION

Moscow, Russia

September 20-24, 1993

Edited by:

G.A. Larionov & M.A. Nearing

Proceedings of an International Workshop on Soil Erosion

Moscow, Russia
September 20-24, 1993

Edited by:

G.A. Larionov
Institute of Soil Erosion and Channel Processes
Faculty of Geography, Moscow State University
Moscow, Russia

and

M.A. Nearing
USDA Agricultural Research Service
National Soil Erosion Research Laboratory
West Lafayette, Indiana, USA

Published by:

The Center for Technology Transfer and Pollution Prevention
1146 Agricultural Engineering Building
Purdue University
West Lafayette, IN 47907-1146

Preface

The soil erosion workshop which was held in Moscow during the month of September, 1993 represents a brilliant moment for the science of soil erosion and for the cause of soil conservation throughout the world. The idea for the conference was born from a true desire on the part of Russians, Ukrainians, and Americans to better understand each other and to advance the scientific knowledge of soil erosion through cooperation of the dedicated workers in both countries. The papers in these proceedings are an indication of the interest in the conference and the effort that went into making the meeting a success. The greater product of the conference is what is not seen here, that being the links of cooperation which were forged between individual scientists who attended the meeting and had the opportunity to discuss and exchange information on topics of mutual interest. These interactions have continued after the meeting and we expect that they will grow yet stronger in the future.

We would like to thank the Geography Department at Moscow State University and the USDA-Agricultural Research Service for making the conference possible. We also must thank the USDA Office of International Cooperation and Development for its contribution to travel funds without which several of the scientists from the United States would not have been able to attend.

G.A. Larionov and M.A. Nearing

April, 1994