PREDICTING RAINFALL EROSION LOSSES

A GUIDE TO CONSERVATION PLANNING

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PREDICTING RAINFALL EROSION LOSSES

A GUIDE TO CONSERVATION PLANNING

Supersedes Agriculture Handbook No. 282,
"Predicting Rainfall-Erosion Losses From Cropland East of the Rocky Mountains"

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ABSTRACT

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The Universal Soil Loss Equation (USLE) enables planners to predict the average rate of soil erosion for each feasible alternative combination of crop system and management practices in association with a specified soil type, rainfall pattern, and topography. When these predicted losses are compared with given soil loss tolerances, they provide specific guidelines for effecting erosion control within specified limits. The equation groups the numerous interrelated physical and management parameters that influence erosion rate under six major factors whose site-specific values can be expressed numerically. A half century of erosion research in many States has supplied information from which at least approximate values of the USLE factors can be obtained for specified farm fields or other small erosion prone areas throughout the United States. Tables and charts presented in this handbook make this information readily available for field use. Significant limitations in the available data are identified.

The USLE is an erosion model designed to compute longtime average soil losses from sheet and rill erosion under specified conditions. It is also useful for construction sites and other nonagricultural conditions, but it does not predict deposition and does not compute sediment yields from gully, streambank, and streambed erosion.

Keywords: Conservation practices, conservation tillage, construction sites, crop canopy, crop sequence, delivery ratios, erosion factors, erosion index, erosion prediction, erosion tolerances, erosivity, gross erosion, minimum tillage, no-till, rainfall characteristics, rainfall data, residue mulch, runoff, sediment, sediment delivery, slope effect, water quality, soil erodibility.

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Walter H. Wischmeier and Dwight D. Smith[1]

PURPOSE OF HANDBOOK

Scientific planning for soil and water conservation requires knowledge of the relations between those factors that cause loss of soil and water and those that help to reduce such losses. Controlled studies on field plots and small watersheds have supplied much valuable information regarding these complex factor interrelations. But the greatest possible benefits from such research can be realized only when the findings are converted to sound practice on the numerous farms and other erosion prone areas throughout the country. Specific guidelines are needed for selecting the control practices best suited to the particular needs of each site.

The soil loss prediction procedure presented in this handbook provides such guidelines. The procedure methodically combines research information from many sources to develop design data for each conservation plan. Widespread field experience for more than two decades has proved it highly valuable as a conservation planning guide.

The procedure is founded on an empirical soil loss equation that is believed to be applicable wherever numerical values of its factors are available. Research has supplied information from which at least approximate values of the equation's factors can be obtained for specific farm fields or other small land areas throughout most of the United States. Tables and charts presented in this handbook make this information readily available for field use.

This revision of the 1965 handbook (*64*) updates the content and incorporates new material that has been available informally or from scattered research reports in professional journals. Some of the original charts and tables are revised to conform with additional research findings, and new ones are developed to extend the usefulness of the soil loss equation. In some instances, expanding a table or chart sufficiently to meet the needs for widespread field application required projection of empirical factor relationships appreciably beyond the physical limits of the data from which the relationships were derived. Estimates obtained in this manner are the best information available for the conditions they represent. However, the instances are identified in the discussions of the specific erosion factors, tables, and charts. Major research needs are suggested by these discussions and were recently summarized in an available publication by Stewart and others (*42*).

HISTORY OF SOIL LOSS EQUATIONS

Developing equations to calculate field soil loss began about 1940 in the Corn Belt. The soil loss estimating procedure developed in that region between 1940 and 1956 has been generally referred to as the slope-practice method. Zingg (*64*)[2] published an equation in 1940 relating soil loss rate to length and percentage of slope. The following year, Smith (*38, 39*) added crop and conservation practice factors and the concept of a specific soil loss limit, to develop a graphical method for

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[2] Numbers in parentheses refer to References p. 48.

determining conservation practices on Shelby and associated soils of the Midwest. Browning and associates (*6*) added soil and management factors and prepared a set of tables to simplify field use of the equation in Iowa. Research scientists and operations personnel of the Soil Conservation Service (SCS) in the North Central States worked together in developing the slope-practice equation for use throughout the Corn Belt.

A national committee met in Ohio in 1946 to adapt the Corn Belt equation to cropland in other regions. This committee reappraised the Corn Belt factor values and added a rainfall factor. The resulting formula, generally known as the Musgrave Equation (*31*), has been widely used for estimating gross erosion from watersheds in flood abatement programs. A graphical solution of the equation was published in 1952 (*19*) and used by the SCS in the Northeastern States.

The soil loss equation presented in this handbook has become known as the Universal Soil Loss Equation (USLE). Regardless of whether the designation is fully accurate, the name does distinguish this equation from the *regionally* based soil loss equations. The USLE was developed at the National Runoff and Soil Loss Data Center established in 1954 by the Science and Education Administration (formerly Agricultural Research Service) in cooperation with Purdue University. Federal-State cooperative research projects at 49 locations[3] contributed more than 10,000 plot-years of basic runoff and soil loss data to this center for summarizing and overall statistical analyses. After 1960, rainfall simulators (*23*) operating from Indiana, Georgia, Minnesota, and Nebraska were used on field plots in 16 states to fill some of the gaps in the data needed for factor evaluation.

Analyses of this large assembly of basic data provided several major improvements for the soil loss equation (*53*): (a) a rainfall erosion index evaluated from local rainfall characteristics; (b) a quantitative soil erodibility factor that is evaluated directly from soil property data and is independent of topography and rainfall differences; (c) a method of evaluating cropping and management effects in relation to local climatic conditions; and (d) a method of accounting for effects of interactions between crop system, productivity level, tillage practices, and residue management.

Developments since 1965 have expanded the use of the soil loss equation by providing techniques for estimating site values of its factors for additional land uses, climatic conditions, and management practices. These have included a soil erodibility nomograph for farmland and construction areas (*58*); topographic factors for irregular slopes (*12, 55*); cover factors for range and woodland (*57*); cover and management effects of conservation tillage practices (*54*); erosion prediction on construction areas (*61, 24, 25*); estimated erosion index values for the Western States and Hawaii (*5, 21, 55*); soil erodibility factors for benchmark Hawaii soils (*9*); and improved design and evaluation of erosion control support practices (*17, 36*).

Research is continuing with emphasis on obtaining a better understanding of the basic principles and processes of water erosion and sedimentation and development of fundamental models capable of predicting specific-storm soil losses and deposition by overland flow (*10, 11, 22, 26, 32*). The fundamental models have been helpful for understanding the factors in the field soil loss equation and for interpreting the plot data.

SOIL LOSS TOLERANCES

The term "soil loss tolerance" denotes the maximum level of soil erosion that will permit a high level of crop productivity to be sustained economically and indefinitely.

[3] The data were contributed by Federal-State cooperative research projects at the following locations: Batesville, Ark.; Tifton and Watkinsville, Ga.; Dixon Springs, Joliet, and Urbana, Ill.; Lafayette, Ind.; Clarinda, Castana, Beaconsfield, Independence, and Seymour, Iowa; Hays, Kans.; Baton Rouge, La.; Presque Isle, Maine; Benton Harbor and East Lansing, Mich.; Morris, Minn.; Holly Springs and State College, Miss.; Bethany and McCredie, Mo.; Hastings, Nebr.; Beemerville, Marlboro, and New Brunswick, N.J.; Ithaca, Geneva, and Marcellus, N.Y.; Statesville and Raleigh, N.C.; Coshocton and Zanesville, Ohio; Cherokee and Guthrie, Okla.; State College, Pa.; Clemson and Spartanburg, S.C.; Madison, S.Dak.; Knoxville and Greeneville, Tenn.; Temple and Tyler, Tex.; Blacksburg, Va.; Pullman, Wash.; LaCrosse, Madison, and Owen, Wis.; and Mayaguez, P.R.

The major purpose of the soil loss equation is to guide methodical decisionmaking in conservation planning on a site basis. The equation enables the planner to predict the average rate of soil erosion for each of various alternative combinations of crop system, management techniques, and control practices on any particular site. When these predicted losses can be compared with a soil loss tolerance for that site, they provide specific guidelines for effecting erosion control within the specified limits. Any cropping and management combination for which the predicted erosion rate is less than the tolerance may be expected to provide satisfactory erosion control. From the satisfactory alternatives indicated by this procedure, the one best suited to a particular farm or other enterprise may then be selected.

Soil loss tolerances ranging from 5 to 2 t/A/year for the soils of the United States were derived by soil scientists, agronomists, geologists, soil conservationists, and Federal and State research leaders at six regional workshops in 1961 and 1962. Factors considered in defining these limits included soil depth, physical properties and other characteristics affecting root development, gully prevention, on-field sediment problems, seeding losses, soil organic matter reduction, and plant nutrient losses. A deep, medium-textured, moderately permeable soil that has subsoil characteristics favorable for plant growth has a greater tolerance than soils with shallow root zones or high percentages of shale at the surface. Widespread experience has shown these soil loss tolerances to be feasible and generally adequate for sustaining high productivity levels indefinitely. Some soils with deep favorable root zones may exceed the 5-t tolerance without loss of sustained productivity.

Soil loss limits are sometimes established primarily for water quality control. The criteria for defining field soil loss limits for this purpose are not the same as those for tolerances designed to preserve cropland productivity. Soil depth is not relevant for offsite sediment control, and uniform limits on erosion rates will allow a range in the quantities of sediment per unit area that are delivered to a river. Soil material eroded from a field slope may be deposited in the field boundaries, in terrace channels, in depressional areas, or on flat or vegetated areas traversed by the overland flow before it reaches a river. The erosion damages the cropland on which it occurs, but sediment deposited near its place of origin is not directly relevant for water quality control.

If the soil loss tolerance designed for sustained cropland productivity fails to attain the desired water quality standard, flexible limits that consider other factors should be developed rather than uniformly lowering the soil loss tolerance. These factors include distance of the field from a major waterway, the sediment transport characteristics of the intervening area, sediment composition, needs of the particular body of water being protected, and the probable magnitude of fluctuations in sediment loads (*42*). Limits of sediment yield would provide more uniform water quality control than lowering the limits on soil movement from field slopes. They would also require fewer restrictions on crop system selection for fields from which only small percentages of the eroded soil become off-farm sediment.

SOIL LOSS EQUATION

The erosion rate at a given site is determined by the particular way in which the levels on numerous physical and management variables are combined at that site. Physical measurements of soil loss for each of the large number of possible combinations in which the levels of these variable factors can occur under field conditions would not be feasible. Soil loss equations were developed to enable conservation planners to project limited erosion data to the many localities and conditions that have not been directly represented in the research.

The USLE is an erosion model designed to predict the longtime average soil losses in runoff from specific field areas in specified cropping and management systems. Widespread field use has substantiated its usefulness and validity for this purpose. It is also applicable for such nonagricultural conditions as construction sites.

With appropriate selection of its factor values, the equation will compute the average soil loss for a multicrop system, for a particular crop year in a rotation, or for a particular cropstage period within a crop year. It computes the soil loss for a given site as the product of six major factors whose most likely values at a particular location can be expressed numerically. Erosion variables reflected by these factors vary considerably about their means from storm to storm, but effects of the random fluctuations tend to average out over extended periods. Because of the unpredictable short-time fluctuations in the levels of influential variables, however, present soil loss equations are substantially less accurate for prediction of specific events than for prediction of longtime averages.

The soil loss equation is

$$A = RKLSCP \qquad (1)$$

where

A is the computed soil loss per unit area, expressed in the units selected for **K** and for the period selected for **R**. In practice, these are usually so selected that they compute **A** in tons per acre per year, but other units can be selected.

R, the rainfall and runoff factor, is the number of rainfall erosion index units, plus a factor for runoff from snowmelt or applied water where such runoff is significant.

K, the soil erodibility factor, is the soil loss rate per erosion index unit for a specified soil as measured on a unit plot, which is defined as a 72.6-ft length of uniform 9-percent slope continuously in clean-tilled fallow.

L, the slope-length factor, is the ratio of soil loss from the field slope length to that from a 72.6-ft length under identical conditions.

S, the slope-steepness factor, is the ratio of soil loss from the field slope gradient to that from a 9-percent slope under otherwise identical conditions.

C, the cover and management factor, is the ratio of soil loss from an area with specified cover and management to that from an identical area in tilled continuous fallow.

P, the support practice factor, is the ratio of soil loss with a support practice like contouring, stripcropping, or terracing to that with straight-row farming up and down the slope.

The soil loss equation and factor evaluation charts were initially developed in terms of the English units commonly used in the United States. The factor definitions are interdependent, and direct conversion of acres, tons, inches, and feet to metric units would not produce the kind of integers that would be desirable for an expression of the equation in that system. Therefore, only the English units are used in the initial presentation of the equation and factor evaluation materials, and their counterparts in metric units are given in the Appendix under **Conversion to Metric System.**

Numerical values for each of the six factors were derived from analyses of the assembled research data and from National Weather Service precipitation records. For most conditions in the United States, the approximate values of the factors for any particular site may be obtained from charts and tables in this handbook. Localities or countries where the rainfall characteristics, soil types, topographic features, or farm practices are substantially beyond the range of present U.S. data will find these charts and tables incomplete and perhaps inaccurate for their conditions. However, they will provide guidelines that can reduce the amount of local research needed to develop comparable charts and tables for their conditions.

The subsection on **Predicting Cropland Soil Losses**, page 40 illustrates how to select factor values from the tables and charts. Readers who have had no experience with the soil loss equation may wish to read that section first. After they have referred to the tables and figures and located the values used in the sample, they may move readily to the intervening detailed discussions of the equation's factors.

The soil loss prediction procedure is more valuable as a guide for selection of practices if the user has a general knowledge of the principles and factor interrelations on which the equation is based. Therefore, the significance of each factor is discussed before presenting the reference table or chart from which local values may be obtained. Limitations of the data available for evaluation of some of the factors are also pointed out.

RAINFALL AND RUNOFF FACTOR (R)

Rills and sediment deposits observed after an unusually intense storm have sometimes led to the conclusion that the significant erosion is associated with only a few storms, or that it is solely a function of peak intensities. However, more than 30 years of measurements in many States have shown that this is not the case (*51*). The data show that a rainfall factor used to estimate average annual soil loss must include the cumulative effects of the many moderate-sized storms, as well as the effects of the occasional severe ones.

The numerical value used for **R** in the soil loss equation must quantify the raindrop impact effect and must also provide relative information on the amount and rate of runoff likely to be associated with the rain. The rainfall erosion index derived by Wischmeier (*49*) appears to meet these requirements better than any other of the many rainfall parameters and groups of parameters tested against the assembled plot data. The local value of this index generally equals **R** for the soil loss equation and may be obtained directly from the map in figure 1. However, the index does not include the erosive forces of runoff from thaw, snowmelt, or irrigation. A procedure for evaluating **R** for locations where this type of runoff is significant will be given under the topic **R Values for Thaw and Snowmelt.**

Rainfall Erosion Index

The research data indicate that when factors other than rainfall are held constant, storm soil losses from cultivated fields are directly proportional to a rainstorm parameter identified as the **EI** (defined below) (*49*). The relation of soil loss to this parameter is linear, and its individual storm values are directly additive. The sum of the storm **EI** values for a given period is a numerical measure of the erosive potential of the rainfall within that period. The average annual total of the storm **EI** values in a particular locality is the rainfall erosion index for that locality. Because of apparent cyclical patterns in rainfall data (*33*), the published rainfall erosion index values were based on 22-year station rainfall records.

Rain showers of less than one-half inch and separated from other rain periods by more than 6 hours were omitted from the erosion index computations, unless as much as 0.25 in of rain fell in 15 min. Exploratory analyses showed that the **EI** values for such rains are usually too small for practical significance and that, collectively, they have little effect on monthly percentages of the annual **EI**. The cost of abstracting and analyzing 4,000 location-years of rainfall-intensity data was greatly reduced by adopting the 0.5-in threshold value.

EI Parameter

By definition, the value of **EI** for a given rainstorm equals the product, total storm energy (**E**) times the maximum 30-min intensity (I_{30}), where **E** is in hundreds of foot-tons per acre and I_{30} is in inches per hour (in/h). **EI** is an abbreviation for energy-times-intensity, and the term should not be considered simply an energy parameter. The data show that rainfall energy, itself, is not a good indicator of erosive potential. The storm energy indicates the volume of rainfall and runoff, but a long, slow rain may have the same **E** value as a shorter rain at much higher intensity. Raindrop erosion increases with intensity. The I_{30} component indicates the prolonged-peak rates of detachment and runoff. The product term, **EI**, is a statistical interaction term that reflects how total energy and peak inensity are combined in each particular storm. Technically, it indicates how particle detachment is combined with transport capacity.

The energy of a rainstorm is a function of the amount of rain and of all the storm's component intensities. Median raindrop size increases with rain intensity (*62*), and terminal velocities of free-falling waterdrops increase with increased dropsize (*13*). Since the energy of a given mass in motion is proportional to velocity-squared, rainfall energy is directly related to rain intensity. The relationship is expressed by the equation,

$$E = 916 + 331 \log_{10} I, \tag{2}$$

where **E** is kinetic energy in foot-tons per acre-inch and **I** is intensity in inches per hour (*62*). A limit of 3 in/h is imposed on **I** by the finding that median dropsize does not continue to increase when intensities exceed 3 in/h (*7, 15*). The energy

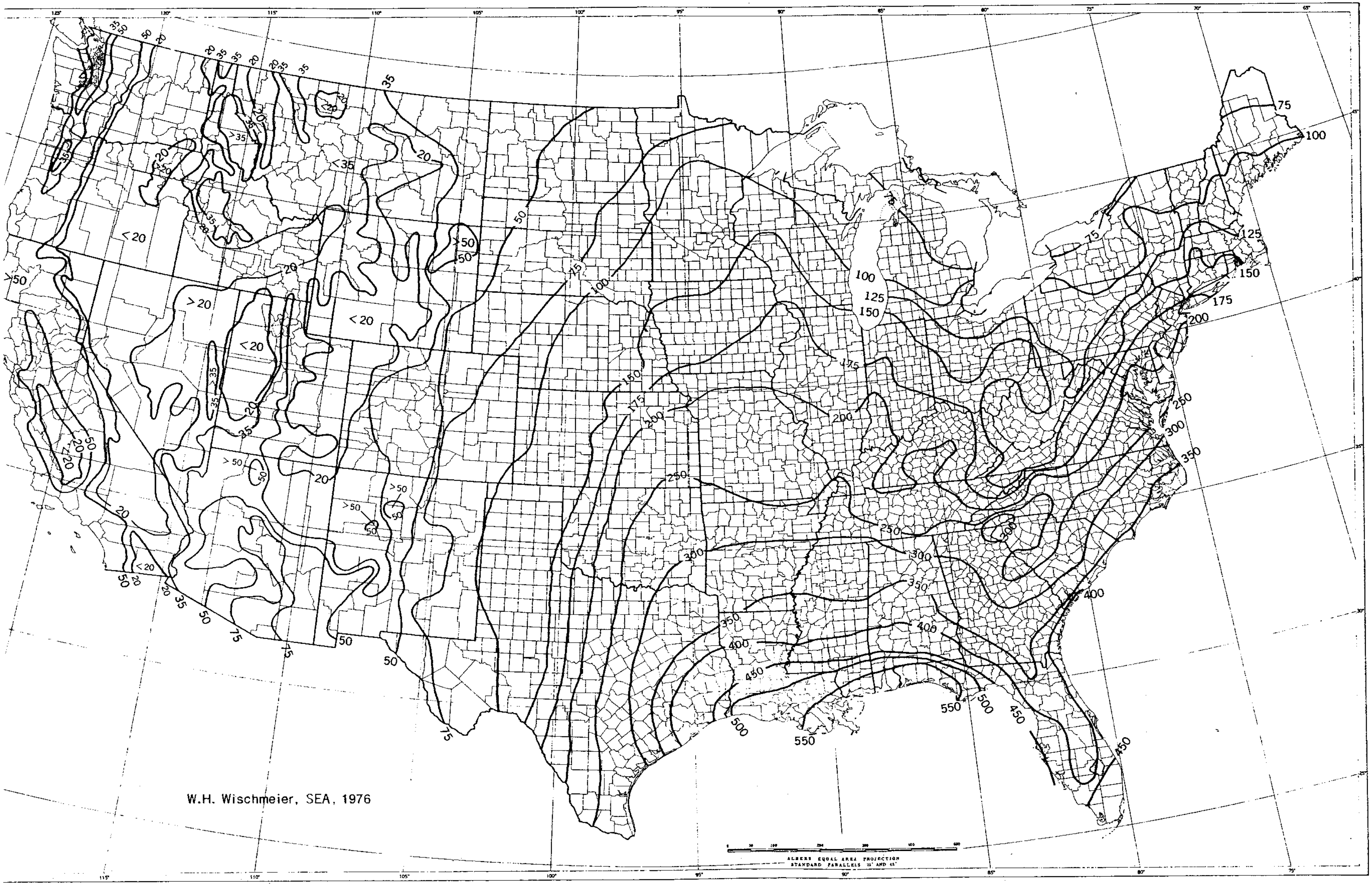

FIGURE 1.—Average annual values of the rainfall erosion index.

of a rainstorm is computed from recording-rain gage data. The storm is divided into successive increments of essentially uniform intensity, and a rainfall energy-intensity table derived from the above formula (app., table 19) is used to compute the energy for each increment. (Because the energy equation and energy-intensity table have been frequently published with energy expressed in foot-tons per acre-inch, this unit was retained in table 19. However, for computation of **EI** values, storm energy is expressed in hundreds of foot-tons per acre. Therefore, energies computed by the published formula or table 19 must be divided by 100 before multiplying by I_{30} to compute **EI**.)

Isoerodent Maps

Local values of the rainfall erosion index may be taken directly from the isoerodent maps, figures 1 and 2. The plotted lines on the maps are called isoerodents because they connect points of equal rainfall erosivity. Erosion index values for locations between the lines are obtained by linear interpolation.

The isoerodent map in the original version of this handbook (*64*) was developed from 22-year station rainfall records by computing the **EI** value for each storm that met the previously defined threshold criteria. Isoerodents were then located between these point values with the help of published rainfall intensity-frequency data (*47*) and topographic maps. The 11 Western States were omitted from the initial map because the rainfall patterns in this mountainous region are sporadic and not enough long-term, recording-rain gage records were available to establish paths of equal erosion index values.

The isoerodent map was extended to the Pacific Coast in 1976 by use of an estimating procedure. Results of investigations at the Runoff and Soil Loss Data Center at Purdue University showed that the known erosion index values in the Western Plains and North Central States could be approximated with reasonable accuracy by the quantity 27.38 $\mathbf{P}^{2.17}$, where **P** is the 2-year, 6-h rainfall amount (*55*). This relationship was used with National Weather Service isopluvial maps to approximate erosion index values for the Western States. The resulting isoerodents are compatible with the few point values that had been established within the 11 Western States and can provide helpful guides for conservation planning on a site basis. However, they are less precise than those computed for the 37-State area, where more data were available and rainfall patterns are less eratic. Also, linear interpolations between the lines will not always be accurate in mountain regions because values of the erosion index may change rather abruptly with elevation changes. The point values that were computed directly from long-term station rainfall records in the Western States are included in table 7, as reference points.

Figure 2 was developed by computing the erosion index for first-order weather stations in Hawaii and deriving the relation of these values to National Weather Service intensity-frequency data for the five major islands. When the present short-term, rainfall-intensity records have been sufficiently lengthened, more point values of the index should be computed by the standard procedure.

Figure 1 shows that local, average-annual values of the erosion index in the 48 conterminous States range from less than 50 to more than 500. The erosion index measures the combined effect of rainfall and its associated runoff. If the soil and topography were exactly the same everywhere, average annual soil losses from plots maintained in continuous fallow would differ in direct proportion to the erosion index values. However, this potential difference is partially offset by differences in soil, topography, vegetative cover, and residues. On fertile soils in the high rainfall areas of the Southern States, good vegetal cover protects the soil surface throughout most of the year and heavy plant residues may provide excellent cover also during the dormant season. In the regions where the erosion index is extremely low, rainfall is seldom adequate for establishing annual meadows and the cover provided by other crops is often for relatively short periods. Hence, serious soil erosion hazards exist in semiarid regions as well as in humid.

Frequency Distribution

The isoerodent maps present 22-year-average annual values of **EI** for the delineated areas. However, both the annual and the maximum-storm values at a particular location vary from year to year. Analysis of 181 station rainfall records showed that they tend to follow log-normal frequency distributions that are usually well defined by continuous records of from 20 to 25 years (*49*). Tables of specific probabilities of annual and maximum-storm **EI** values at the 181 locations are presented in the appendix (tables 17 and 18).

R Values for Thaw and Snowmelt

The standard rainfall erosion index estimates the erosive forces of the rainfall and its directly associated runoff. In the Pacific Northwest, as much as 90 percent of the erosion on the steeply rolling wheatland has been estimated to derive from runoff associated with surface thaws and snowmelt. This type of erosion is not accounted for by the rainfall erosion index but is considered either predominant or appreciable in much of the Northwest and in portions of the central Western States. A linear precipitation relationship would not account for peak losses in early spring because as the winter progresses, the soil becomes increasingly more erodible as the soil moisture profile is being filled, the surface structure is being broken down by repeated freezing and thawing, and puddling and surface sealing are taking place. Additional research of the erosion processes and means of control under these conditions is urgently needed.

In the meantime, the early spring erosion by runoff from snowmelt, thaw, or light rain on frozen soil may be included in the soil loss computations by adding a subfactor, $\mathbf{R_s}$, to the location's erosion index to obtain **R**. Investigations of limited data indicated that an estimate of $\mathbf{R_s}$ may be obtained by taking 1.5 times the local December-through-March precipitation, measured as inches of water. For example, a location in the North-

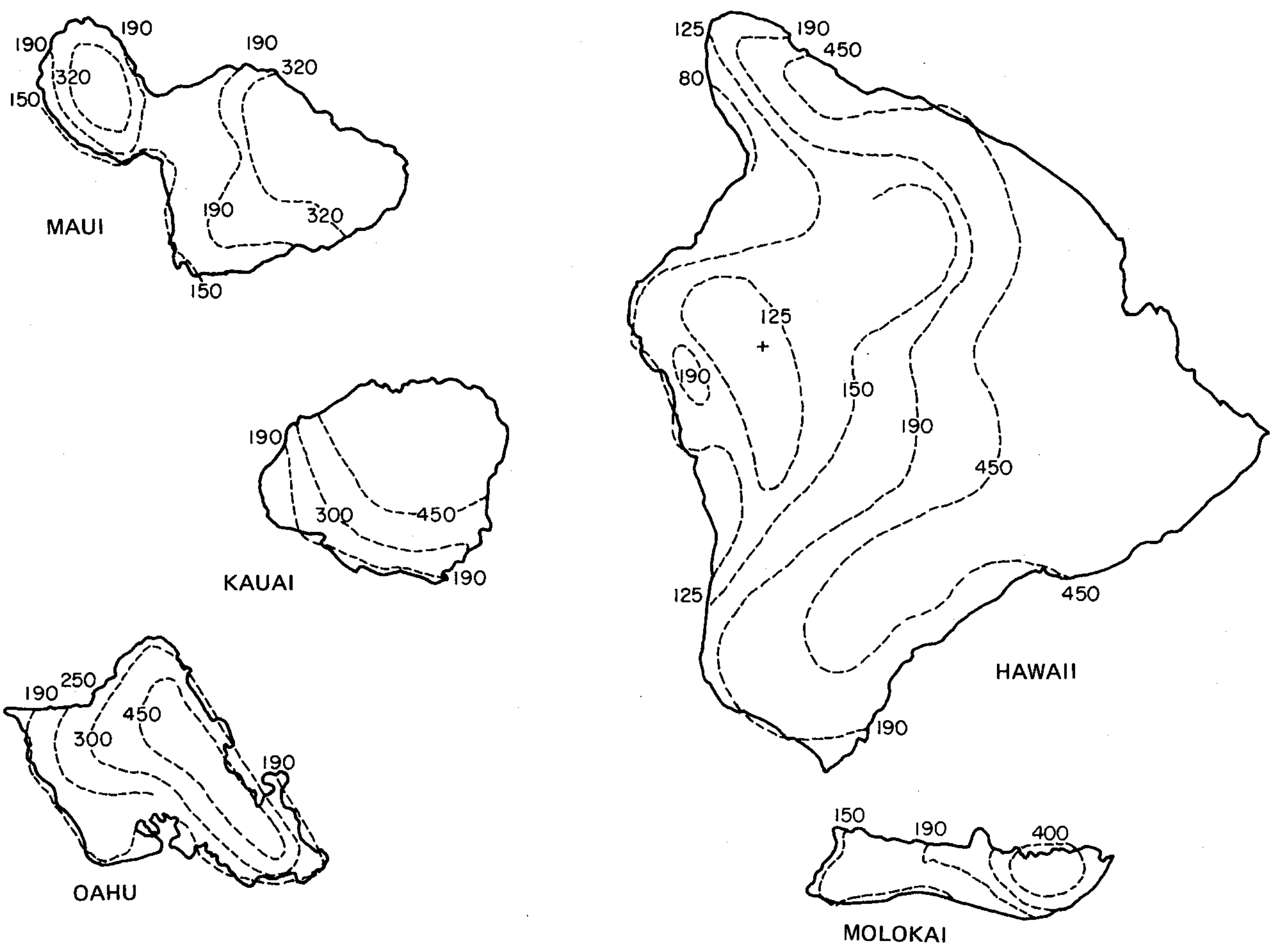

FIGURE 2.—Estimated average annual values of the rainfall erosion index in Hawaii.

west that has an erosion index of 20 (fig. 1) and averages 12 in of precipitation between December 1 and March 31 would have an estimated average annual **R** of 1.5(12) + 20, or 38.

This type of runoff may also be a significant factor in the northern tier of Central and Eastern States. Where experience indicates this to be the case, it should be included in **R** and also in the erosion index distribution curves as illustrated on page 27.

SOIL ERODIBILITY FACTOR (K)

The meaning of the term "soil erodibility" is distinctly different from that of the term "soil erosion." The rate of soil erosion, **A**, in the soil loss equation, may be influenced more by land slope, rainstorm characteristics, cover, and management than by inherent properties of the soil. However, some soils erode more readily than others even when all other factors are the same. This difference, caused by properties of the soil itself, is referred to as the soil erodibility. Several early attempts were made to determine criteria for scientific classifications of soils according to erodibility (*6, 18, 28, 35*), but classifications used for erosion prediction were only relative rankings.

Differences in the natural susceptibilities of soils to erosion are difficult to quantify from field observations. Even a soil with a relatively low erodibility factor may show signs of serious erosion when it occurs on long or steep slopes or in localities with numerous high-intensity rainstorms. A soil with a high natural erodibility factor, on the other hand, may show little evidence of actual erosion under gentle rainfall when it occurs on short and gentle slopes, or when the best possible management is practiced. The effects of rainfall differences, slope, cover, and management are accounted for in the prediction equation by the symbols **R, L, S, C,** and **P.** Therefore, the soil erodibility factor, **K,** must be evaluated independently of the effects of the other factors.

Definition of Factor K

The soil erodibility factor, **K,** in the USLE is a quantitative value experimentally determined. For a particular soil, it is the rate of soil loss per erosion index unit as measured on a "unit" plot, which has been arbitrarily defined as follows:

A unit plot is 72.6 ft long, with a uniform lengthwise slope of 9 percent, in continuous fallow, tilled up and down the slope. Continuous fallow, for this purpose, is land that has been tilled and kept free of vegetation for more than 2 years. During the period of soil loss measurements, the plot is plowed and placed in conventional corn seedbed condition each spring and is tilled as needed to prevent vegetative growth and severe surface crusting. When all of these conditions are met, **L, S, C,** and **P** each equal 1.0, and **K** equals **A/EI.**

The 72.6 ft length and 9 percent steepness were selected as base values for **L, S,** and **K** because they are the predominant slope length and about the average gradient on which past erosion measurements in the United States had been made. The designated management provides a condition that nearly eliminates effects of cover, management, and land use residual and that can be duplicated on any cropland.

Direct measurements of **K** on well-replicated, unit plots as described reflect the combined effects of all the soil properties that significantly influence the ease with which a particular soil is eroded by rainfall and runoff if not protected. However, **K** is an average value for a given soil, and direct measurement of the factor requires soil loss measurements for a representative range of storm sizes and antecedent soil conditions. (See **Individual Storm Soil Losses** under **APPLYING THE SOIL LOSS EQUATION.**) To evaluate **K** for soils that do not usually occur on a 9-percent slope, soil loss data from plots that meet all the other specified conditions are adjusted to this base by **S.**

Values of K for Specific Soils

Representative values of **K** for most of the soil types and texture classes can be obtained from tables prepared by soil scientists using the latest available research information. These tables are available from the Regional Technical Service Centers or State offices of SCS. Values for the exact

TABLE 1.—*Computed* **K** *values for soils on erosion research stations*

Soil	Source of data	Computed K
Dunkirk silt loam	Geneva, N.Y.	[1]0.69
Keene silt loam	Zanesville, Ohio	.48
Shelby loam	Bethany, Mo.	.41
Lodi loam	Blacksburg, Va.	.39
Fayette silt loam	LaCrosse, Wis.	[1].38
Cecil sandy clay loam	Watkinsville, Ga.	.36
Marshall silt loam	Clarinda, Iowa	.33
Ida silt loam	Castana, Iowa	.33
Mansic clay loam	Hays, Kans.	.32
Hagerstown silty clay loam	State College, Pa.	[1].31
Austin clay	Temple, Tex.	.29
Mexico silt loam	McCredie, Mo.	.28
Honeoye silt loam	Marcellus, N.Y.	[1].28
Cecil sandy loam	Clemson, S.C.	[1].28
Ontario loam	Geneva, N.Y.	[1].27
Cecil clay loam	Watkinsville, Ga.	.26
Boswell find sandy loam	Tyler, Tex.	.25
Cecil sandy loam	Watkinsville, Ga.	.23
Zaneis fine sandy loam	Guthrie, Okla.	.22
Tifton loamy sand	Tifton, Ga.	.10
Freehold loamy sand	Marlboro, N.J.	.08
Bath flaggy silt loam with surface stones > 2 inches removed	Arnot, N.Y.	[1].05
Albia gravelly loam	Beemerville, N.J.	.03

[1] Evaluated from continuous fallow. All others were computed from rowcrop data.

soil conditions at a specific site can be computed by use of the soil erodibility nomograph presented in the next subsection.

Usually a soil type becomes less erodible with decrease in silt fraction, regardless of whether the corresponding increase is in the sand fraction or the clay fraction. Overall, organic matter content ranked next to particle-size distribution as an indicator of erodibility. However, a soil's erodibility is a function of complex interactions of a substantial number of its physical and chemical properties and often varies within a standard texture class.

Values of **K** determined for 23 major soils on which erosion plot studies under natural rain were conducted since 1930 are listed in table 1. Seven of these values are from continuous fallow. The others are from row crops averaging 20 plot-years of record and grown in systems for which the cropping effect had been measured in other studies. Other soils on which valuable erosion studies have been conducted[4] were not included in the table because of uncertainties involved in adjustments of the data for effects of cropping and management.

Direct measurement of the erodibility factor is both costly and time consuming and has been feasible only for a few major soil types. To achieve a better understanding of how and to what extent each of various properties of a soil affects its erodibility, an interregional study was initiated in 1961. The study included the use of field-plot rainfall simulators in at least a dozen States to obtain comparative data on numerous soils, laboratory determinations of physical and chemical properties, and operation of additional fallow plots under natural rain. Several empirical erodibility equations were reported (*3, 60*). A soil erodibility nomograph for farmland and construction sites (*58*) provided a more generally applicable working tool. Approximate **K** values for 10 benchmark soils in Hawaii are listed in table 2.

[4] See footnote 3, p. 2.

TABLE 2.—*Approximate values of the soil erodibility factor,* **K**, *for 10 benchmark soils in Hawaii*

Order	Suborder	Great group	Subgroup	Family	Series	K
Ultisols	Humults	Tropohumults	Humoxic Tropohumults	Clayey, kaolinitic, isohyperthermic	Waikane	0.10
Oxisols	Torrox	Torrox	Typic Torrox	Clayey, kaolinitic, isohyperthermic	Molokai	.24
Oxisols	Ustox	Eutrustox	Tropeptic Eutrustox	Clayey, kaolinitic, isohyperthermic	Wahiawa	.17
Vertisols	Usterts	Chromusterts	Typic Chromusterts	Very fine, montmorillonitic, isohyperthermic	Lualualei	.28
					Kawaihae	.32
Aridisols	Orthids	Camborthids	Ustollic Camborthids	Medial, isohyperthermic	(Extremely stony phase)	
Inceptisols	Andepts	Dystrandepts	Hydric Dystrandepts	Thixotropic, isothermic	Kukaiau	.17
Inceptisols	Andepts	Eutrandepts	Typic Eutrandepts	Medial, isohyperthermic	Naolehu (Variant)	.20
Inceptisols	Andepts	Eutrandepts	Entic Eutrandepts	Medial, isohyperthermic	Pakini	.49
Inceptisols	Andepts	Hydrandepts	Typic Hydrandepts	Thixotropic, isohyperthermic	Hilo	.10
Inceptisols	Tropepts	Ustropepts	Vertic Ustropepts	Very fine, kaolinitic, isohyperthermic	Waipahu	.20

SOURCE: El-Swaify and Dangler (9).

Soil Erodibility Nomograph

The soil loss data show that very fine sand (0.05-0.10 mm) is comparable in erodibility to silt-sized particles and that mechanical-analysis data are much more valuable when expressed by an interaction term that describes the proportions in which the sand, silt, and clay fractions are combined in the soil. When mechanical analysis data based on the standard USDA classification are used for the nomograph in figure 3, the percentage of very fine sand (0.1-0.05 mm) must first be transferred from the sand fraction to the silt fraction. The mechanical analysis data are then effectively described by a particle-size parameter **M,** which equals percent silt (0.1-0.002 mm) times the quantity 100-minus-percent-clay. Where the silt fraction does not exceed 70 percent, erodibility varies approximately as the 1.14 power of this parameter, but prediction accuracy is improved by adding information on organic matter content, soil structure, and profile permeability class.

For soils containing less than 70 percent silt and very fine sand, the nomograph (fig. 3) solves the equation:

$$100\,K = 2.1\,M^{1.14}(10^{-4})(12 - a) + 3.25(b - 2) + 2.5(c - 3) \quad (3)$$

where

- **M** = the particle-size parameter defined above,
- **a** = percent organic matter,
- **b** = the soil-structure code used in soil classification, and
- **c** = the profile-permeability class.

The intersection of the selected percent-silt and percent-sand lines computes the value of **M** on the unidentified horizontal scale of the nomograph. (Percent clay enters into the computation as 100 minus the percentages of sand and silt.)

The data indicate a change in the relation of **M** to erodibility when the silt and very fine sand fraction exceeds about 70 percent. This change was empirically reflected by inflections in the percent-sand curves at that point but has not been described by a numerical equation.

Readers who would like more detail regarding the data and relationships underlying the nomograph equation may obtain this from journal articles (*58, 60*).

Nomograph Solution

With appropriate data, enter the scale at the left and proceed to points representing the soil's percent sand (0.10-2.0 mm), percent organic matter, structure code, and permeability class as illustrated by the dotted line on the nomograph. The horizontal and vertical moves must be made in the listed sequence. Use linear interpolations between plotted lines. The structure code and permeability classes are defined on the nomograph for reference.

Many agricultural soils have both fine granular topsoil and moderate permeability. For these soils, **K** may be read from the scale labeled "first approximation of **K**," and the second block of the graph is not needed. For all other soils, however, the procedure must be completed to the soil erodibility scale in the second half of the graph.

The mechanical analysis, organic matter, and structure data are those for the topsoil. For evaluation of **K** for desurfaced subsoil horizons, they pertain to the upper 6 in of the new soil profile. The permeability class is the profile permeability. Coarse fragments are excluded when determining percentages of sand, silt, and clay. If substantial, they may have a permanent mulch effect which can be evaluated from the upper curve of the chart on mulch and canopy effects (p. 19, fig. 6) and applied to the number obtained from the nomograph solution.

Confidence Limits

In tests against measured **K** values ranging from 0.03 to 0.69, 65 percent of the nomograph solutions differed from the measured **K** values by less than 0.02, and 95 percent of them by less than 0.04. Limited data available in 1971 for mechanically exposed **B** and **C** subsoil horizons indicated about comparable accuracy for these conditions. However, more recent data taken on desurfaced high-clay subsoils showed the nomograph solution to lack the desired sensitivity to differences in erodibilities of these soil horizons. For such soils the content of free iron and aluminum oxides ranks next to particle-size distribution as an indicator of erodibility (*37*). Some high-clay soils form what has been called irreversible aggregates on the surface when tilled. These behave like larger primary particles.

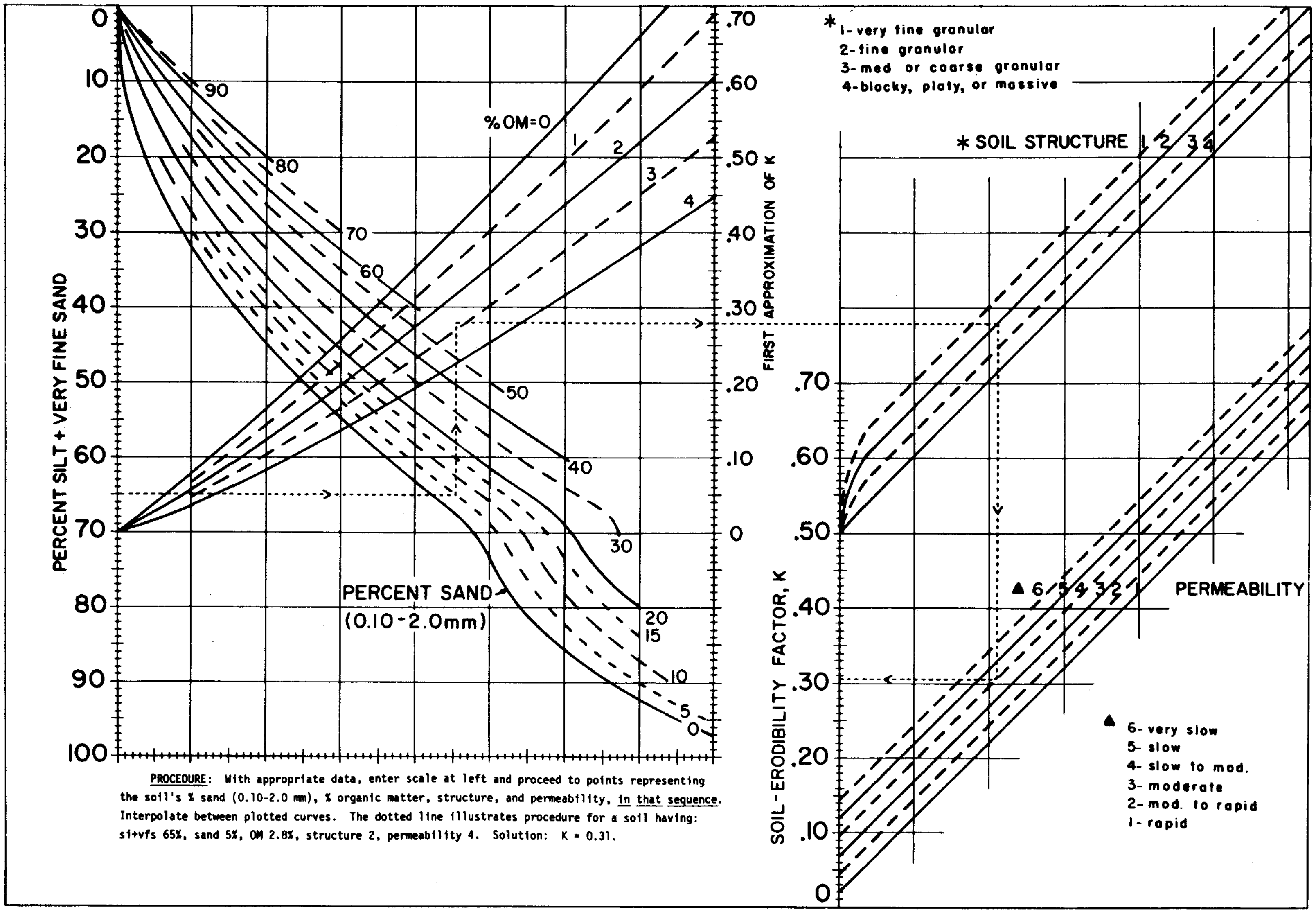

FIGURE 3.—The soil-erodibility nomograph. Where the silt fraction does not exceed 70 percent, the equation is $100\,K = 2.1\,M^{1.14}\,(10^{-4})\,(12 - a) + 3.25\,(b - 2) + 2.5\,(c - 3)$ where M = (percent si + vfs) (100 — percent c), a = percent organic matter, b = structure code, and c = profile permeability class.

TOPOGRAPHIC FACTOR (LS)

Both the length and the steepness of the land slope substantially affect the rate of soil erosion by water. The two effects have been evaluated separately in research and are represented in the soil loss equation by **L** and **S**, respectively. In field applications, however, considering the two as a single topographic factor, **LS**, is more convenient.

Slope-Effect Chart

LS is the expected ratio of soil loss per unit area from a field slope to that from a 72.6-ft length of uniform 9-percent slope under otherwise identical conditions. This ratio for specified combinations of field slope length and uniform gradient may be obtained directly from the slope-effect chart (fig. 4). Enter on the horizontal axis with the field slope length, move vertically to the appropriate percent-slope curve, and read **LS** on the scale at the left. For example, the **LS** factor for a 300-ft length of 10-percent slope is 2.4. Those who prefer a table may use table 3 and interpolate between listed values.

To compute soil loss from slopes that are appreciably convex, concave, or complex, the chart **LS** values need to be adjusted as indicated in the section **LS Values for Irregular Slopes.** Figure 4 and table 3 assume slopes that have essentially uniform gradient. The chart and table were derived by the equation

$$\mathbf{LS} = (\lambda/72.6)^{\mathbf{m}}\ (65.41\ \sin^2\theta + 4.56\ \sin\theta + 0.065) \qquad (4)$$

where λ = slope length in feet;
θ = angle of slope; and
m = 0.5 if the percent slope is 5 or more, 0.4 on slopes of 3.5 to 4.5 percent, 0.3 on slopes of 1 to 3 percent, and 0.2 on uniform gradients of less than 1 percent.

The basis for this equation is given in the subsection discussing the individual effects of slope length and steepness. However, the relationships expressed by the equation were derived from data obtained on cropland, under natural rainfall, on slopes ranging from 3 to 18 percent in steepness and about 30 to 300 ft in length. How far beyond these ranges in slope characteristics the relationships derived from the data continue to be accurate has not been determined by direct soil loss measurements.

The Palouse Region of the Northwest represents

TABLE 3.—*Values of the topographic factor, **LS**, for specific combinations of slope length and steepness*[1]

Percent slope	Slope length (feet)											
	25	50	75	100	150	200	300	400	500	600	800	1,000
0.2	0.060	0.069	0.075	0.080	0.086	0.092	0.099	0.105	0.110	0.114	0.121	0.126
0.5	.073	.083	.090	.096	.104	.110	.119	.126	.132	.137	.145	.152
0.8	.086	.098	.107	.113	.123	.130	.141	.149	.156	.162	.171	.179
2	.133	.163	.185	.201	.227	.248	.280	.305	.326	.344	.376	.402
3	.190	.233	.264	.287	.325	.354	.400	.437	.466	.492	.536	.573
4	.230	.303	.357	.400	.471	.528	.621	.697	.762	.820	.920	1.01
5	.268	.379	.464	.536	.656	.758	.928	1.07	1.20	1.31	1.52	1.69
6	.336	.476	.583	.673	.824	.952	1.17	1.35	1.50	1.65	1.90	2.13
8	.496	.701	.859	.992	1.21	1.41	1.72	1.98	2.22	2.43	2.81	3.14
10	.685	.968	1.19	1.37	1.68	1.94	2.37	2.74	3.06	3.36	3.87	4.33
12	.903	1.28	1.56	1.80	2.21	2.55	3.13	3.61	4.04	4.42	5.11	5.71
14	1.15	1.62	1.99	2.30	2.81	3.25	3.98	4.59	5.13	5.62	6.49	7.26
16	1.42	2.01	2.46	2.84	3.48	4.01	4.92	5.68	6.35	6.95	8.03	8.98
18	1.72	2.43	2.97	3.43	4.21	3.86	5.95	6.87	7.68	8.41	9.71	10.9
20	2.04	2.88	3.53	4.08	5.00	5.77	7.07	8.16	9.12	10.0	11.5	12.9

[1] $\mathbf{LS} = (\lambda/72.6)^{\mathbf{m}}$ $(65.41\ \sin^2\theta + 4.56\ \sin\theta + 0.065)$ where λ = slope length in feet; **m** = 0.2 for gradients < 1 percent, 0.3 for 1 to 3 percent slopes, 0.4 for 3.5 to 4.5 percent slopes, 0.5 for 5 percent slopes and steeper; and θ = angle of slope. (For other combinations of length and gradient, interpolate between adjacent values or see fig. 4.)

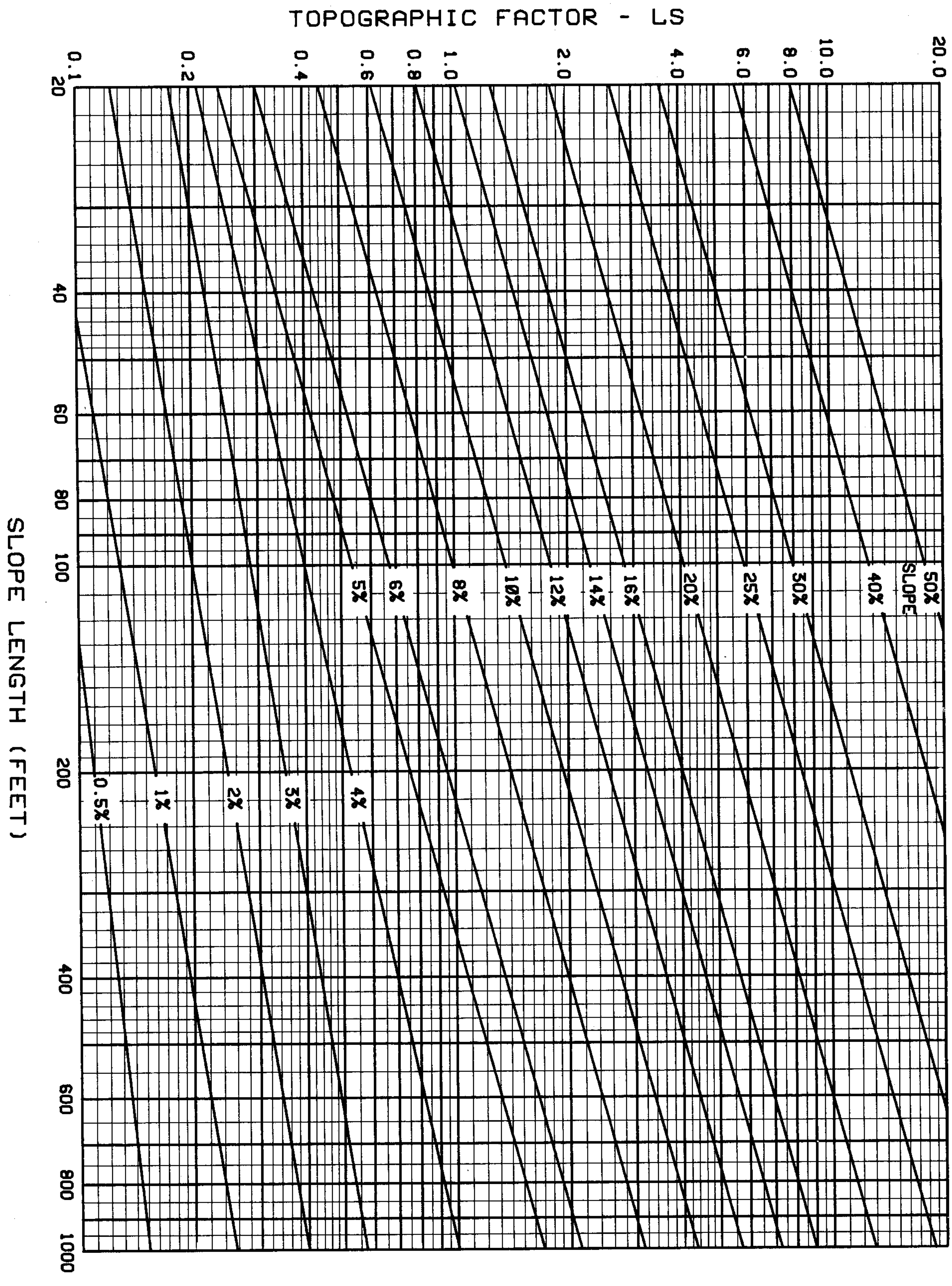

FIGURE 4.—Slope-effect chart (topographic factor, LS). LS = $(\lambda/72.6)^m (65.41 \sin^2\theta + 4.56 \sin\theta + 0.065)$ where λ = slope length in feet; θ = angle of slope; and m = 0.2 for gradients < 1 percent, 0.3 for 1 to 3 percent slopes, 0.4 for 3.5 to 4.5 percent slopes, and 0.5 for slopes of 5 percent or steeper.

a different situation. The rainfall erosion index is quite low because most of the rain comes as small drops and at low intensities. But many of the cropland slopes are long or steep, and substantial erosion occurs because of runoff from snowmelt or light rains over saturated soil surfaces. Limited erosion data from this region, mostly observational, strongly indicate that for this type of runoff (not accompanied by raindrop impact) the effects of percent and length of slope are of lower magnitude than indicated by the humid region data. Investigations designed to develop a more accurate **LS** equation for this region are underway at Pullman, Wash. (*21*). In the meantime, the researchers are temporarily recommending using a modified equation which computes **LS** values that are close to those that would be calculated by the equation given above if $\sin^{1.5}\theta$ were substituted for $\sin^2\theta$ and the length-exponent, **m**, were assumed to equal 0.3. Intuitively, these changes seem reasonable for the conditions under which about 90 percent of the erosion in this region occurs.

Slope-Length Effect

Slope length is defined as the distance from the point of origin of overland flow to the point where either the slope gradient decreases enough that deposition begins, or the runoff water enters a well-defined channel that may be part of a drainage network or a constructed channel (*40*). A change in land cover or a substantial change in gradient along a slope does not begin a new slope length for purposes of soil loss estimation.

The effect of slope length on annual *runoff* per unit area of cropland may generally be assumed negligible. In some of the studies runoff per unit area was slightly lower on the longer slopes during the growing season and slightly higher during the dormant season, but the differences were relatively small and neither of the relationships was consistent (*52*).

However, the *soil loss* per unit area generally increases substantially as slope length increases. The greater accumulation of runoff on the longer slopes increases its detachment and transport capacities.

The plot data showed average soil loss per unit area to be proportional to a power of slope length. Because **L** is the ratio of field soil loss to the corresponding loss from 72.6-ft slope length, its value may be expressed as $L = (\lambda/72.6)^m$, where λ is the field slope length in feet, and **m** assumes approximately the values given in the **LS** equation in the preceding section. These are average values of **m** and are subject to some variability caused by interaction effects which are not now quantitatively predictable.

The existing field plot data do not establish a general value greater than 0.5 for **m** on slopes steeper than 10 percent, as was suggested in 1965 (*64*). Although apparent values up to 0.9 were observed in some of the data (*63*), the higher values appear to have been related to soil, crop, and management variables rather than to greater slope steepness. However, basic modeling work has suggested that **m** may appreciably exceed 0.5 on steep slopes that are highly susceptible to rilling, like some construction slopes (*10*). Additional research data are greatly needed to quantify the significant interaction effects so that specific site values of **m** can be more precisely computed. Subdividing erosion between interrill (or sheet) erosion and rill erosion, being done in recent modeling work (*10, 11, 22*), promises to be quite helpful for solving this problem.

Some observations have indicated that the values of the length exponent that were derived from the plot data may overestimate soil loss when applied to lengths in the range of a quarter of a mile or more. This is logical because slopes of such lengths would rarely have a constant gradient along their entire length, and the slope irregularities would affect the amount of soil movement to the foot of the slope. By the definition of slope length quoted earlier, such slopes would usually consist of several lengths, between points where deposition occurs.

Slope length is difficult to determine for long slopes with an average gradient of less than 1 percent, unless they are precisely formed with a land leveler. On flat slopes, reflecting both the erosion and the deposition accurately by a length factor may not be possible. However, on a nearly zero-percent slope, increased length would have minor effect on runoff velocity, and the greater depths of accumulated runoff water would cushion the raindrop impact. An exponent of 0.2 for gradients of less than 1 percent is compatible with the scarce data available for such slopes and was used to derive figure 4 and table 3.

Distribution of Length Effect

LS values from figure 4 or table 3 predict the *average* erosion over the entire slope. But this erosion is not evenly distributed over the entire length. The rate of soil loss per unit of area increases as the m^{th} power of the distance from the top of the slope, where **m** is the length exponent in the preceding equation.

An equation by Foster and Wischmeier (*12*) estimates the relative amounts of soil loss from successive segments of a slope under conditions where there is no deposition by overland flow. When the gradient is essentially uniform and the segments are of equal length, the procedure can be shortened (*55*). Table 4, derived by this procedure, shows the proportionate amounts of soil detachment from successive equal-length segments of a uniform slope.

Table 4 is entered with the total number of equal-length segments, and the fraction of the soil loss for each segment is read beneath the applicable value of **m**. For example, three equal-length segments of a uniform 6-percent slope would be expected to produce 19, 35, and 46 percent, respectively, of the loss from the entire slope.

TABLE 4.—*Estimated relative soil losses from successive equal-length segments of a uniform slope*[1]

Number of segments	Sequence number of segment	Fraction of soil loss		
		m = 0.5	m = 0.4	m = 0.3
2	1	0.35	0.38	0.41
	2	.65	.62	.59
3	1	.19	.22	.24
	2	.35	.35	.35
	3	.46	.43	.41
4	1	.12	.14	.17
	2	.23	.24	.24
	3	.30	.29	.28
	4	.35	.33	.31
5	1	.09	.11	.12
	2	.16	.17	.18
	3	.21	.21	.21
	4	.25	.24	.23
	5	.28	.27	.25

[1] Derived by the formula:

$$\text{Soil loss fraction} = \frac{j^{m+1} - (j-1)^{m+1}}{N^{m+1}}$$

where **j** = segment sequence number; **m** = slope-length exponent (0.5 for slopes ≥ 5 percent, 0.4 for 4 percent slopes, and 0.3 for 3 percent or less); and **N** = number of equal-length segments into which the slope was divided.

Four segments would produce 12, 23, 30, and 35 percent, respectively. Segment No. 1 is always at the top of the slope.

Percent Slope

Runoff from cropland generally increases with increased slope gradient, but the relationship is influenced by such factors as type of crop, surface roughness, and profile saturation. In the natural rain slope-effect studies, the logarithm of runoff from row crops was linearly and directly proportional to percent slope. With good meadow sod and with smooth bare surfaces, the relationship was insignificant. The effect of slope on runoff decreased in extremely wet periods.

Soil loss increases much more rapidly than runoff as slopes steepen. The slope-steepness factor, **S**, in the soil loss equation is evaluated by the equation

$$S = 65.41 \sin^2 \theta + 4.56 \sin \theta + 0.065 \quad (5)$$

where θ is the angle of slope.

This equation was used to develop the slope-effect chart. The values reflect the average effect of slope steepness on soil loss in the plot studies. The relation of percent slope to soil loss is believed to be influenced by interactions with soil properties and surface conditions, but the interaction effects have not been quantified by research data. Neither are data available to define the limits on the equation's applicability.

This equation can be derived from the formerly published equation for **S**. Expressing the factor as a function of the sine of the angle of slope rather than the tangent is more accurate because raindrop-impact forces along the surface and runoff shear stress are functions of the sine. Substituting 100 sin θ for percent slope, which is 100 tan θ, does not significantly affect the initial statistical derivation or the equation's solutions for slopes of less than 20 percent. But as slopes become steeper, the difference between the sine and the tangent becomes appreciable and projections far beyond the range of the plot data become more realistic. The numerator was divided by the constant denominator for simplification.

Irregular Slopes

Soil loss is also affected by the shape of a slope. Many field slopes either steepen toward the lower end (convex slope) or flatten toward the lower end (concave slope). Use of the average gradient to enter figure 4 or table 3 would underestimate soil movement to the foot of a convex slope and would overestimate it for concave slopes. Irregular slopes can usually be divided into segments that have nearly uniform gradient, but the segments cannot be evaluated as independent slopes when runoff flows from one segment to the next.

However, where two simplifying assumptions can be accepted, **LS** for irregular slopes can be routinely derived by combining selected values from the slope-effect chart and table 4 (*55*). The assumptions are that (1) the changes in gradient are not sufficient to cause upslope deposition, and (2) the irregular slope can be divided into a small number of equal-length segments in such a manner that the gradient within each segment for practical purposes can be considered uniform.

After dividing the convex, concave, or complex slope into equal-length segments as defined earlier, the procedure is as follows: List the segment gradients in the order in which they occur on the slope, beginning at the upper end. Enter the slope-effect chart with the total slope length and read **LS** for each of the listed gradients. Multiply these by the corrresponding factors from table 4 and add the products to obtain **LS** for the entire slope. The following tabulation illustrates the procedure for a 400-ft convex slope on which the upper third has a gradient of 5 percent; the middle third, 10 percent; and the lower third, 15 percent:

Segment	*Percent slope*	*Table 3*	*Table 4*	*Product*
1	5	1.07	0.19	0.203
2	10	2.74	.35	.959
3	15	5.12	.46	2.355
				LS = 3.517

For the concave slope of the same length, with the segment gradients in reverse order, the values in the third column would be listed in reverse order. The products would then be 0.973, 0.959, and 0.492, giving a sum of 2.42 for **LS**.

Research has not defined just how much gradient change is needed under various conditions for deposition of soil particles of various sizes to begin, but depositional areas can be determined by observation. When the slope breaks are sharp enough to cause deposition, the procedure can be used to estimate **LS** for slope segments above and below the depositional area. However, it will not predict the total sediment moved from such an interrupted slope because it does not predict the amount of deposition.

Changes in Soil Type or Cover Along the Slope

The procedure for irregular slopes can include evaluation of changes in soil type within a slope length (*55*). The products of values selected from table 3 or figure 4 and table 4 to evaluate **LS** for irregular slopes are multiplied by the respective values of **K** before summing. To illustrate, assume the **K** values for the soils in the three segments of the convex slope in the preceding example were 0.27, 0.32, and 0.37, respectively. The average **KLS** for the slope would be obtained as follows:

Segment No.	*Table 3*	*Table 4*	K	*Product*
1	1.07	0.19	0.27	0.055
2	2.74	.35	.32	.307
3	5.12	.46	.37	.871
				KLS = 1.233

Within limits, the procedure can be further extended to account for changes in cover along the slope length by adding a column of segment **C** values. However, it is not applicable for situations where a practice change along the slope causes deposition. For example, a grass buffer strip across the foot of a slope on which substantial erosion is occurring induces deposition. The amount of this deposition is a function of transport relationships (*10*) and cannot be predicted by the USLE.

Equation for Soil Detachment on Successive Segments of a Slope

This procedure is founded on an equation (12) that can be applied also when the slope segments are not of equal length. Concepts underlying this equation include the following:

Sediment load at a location on a slope is controlled either by the transport capacity of the runoff and rainfall or by the amount of detached soil material available for transport. When the amount of detached material exceeds the transport capacity, deposition occurs and the sediment load is determined primarily by the transport capacity of the runoff at that location. Where upslope detachment has not equaled the transport capacity, sediment load at a given location is a function of erosion characteristics of the upslope area and can be computed by the USLE. Soil loss from a given segment of the slope can then be computed as the difference between the sediment loads at the lower and upper ends of the segment.

Foster and Wischmeier (12) present a procedure for using this equation to evaluate **LS** for irregular slopes and to account for the effects of the soil or coverage changes along a slope, so long as the changes do not cause deposition to occur.

COVER AND MANAGEMENT FACTOR (C)

Cover and management effects cannot be independently evaluated because their combined effect is influenced by many significant interrelations. Almost any crop can be grown continuously, or it can be grown in rotations. Crop sequence influences the length of time between successive crop canopies, and it also influences the benefits obtained from residual effects of crops and management. The erosion control effectiveness of meadow sod turned under before a row crop depends on the type and quality of the meadow and on the length of time elapsed since the sod was turned under. Seedbeds can be clean tilled, or they can be protected by prior crop residues. They can be left rough, with much available capacity for surface storage and reduction of runoff velocity, or they can be smoothed by secondary tillage.

Crop residues can be removed, left on the surface, incorporated near the surface, or plowed under. When left on the surface, they can be chopped or dragged down, or they can be allowed to remain as left by the harvesting operation. The effectiveness of crop residue management will depend on the amount of residue available. This, in turn, depends on the amount and distribution of rainfall, on the fertility level, and on the management decisions made by the farmer.

The canopy protection of crops not only depends on the type of vegetation, the stand, and the quality of growth, but it also varies greatly in different months or seasons. Therefore, the overall erosion-reducing effectiveness of a crop depends largely on how much of the erosive rain occurs during those periods when the crop and management practices provide the least protection.

Definition of Factor C

Factor **C** in the soil loss equation is the ratio of soil loss from land cropped under specified conditions to the corresponding loss from clean-tilled, continuous fallow. This factor measures the combined effect of all the interrelated cover and management variables.

The loss that would occur on a particular field if it were continuously in fallow condition is computed by the product of **RKLS** in the soil loss equation. Actual loss from the cropped field is usually much less than this amount. Just how much less depends on the particular combination of cover, crop sequence, and management practices. It also depends on the particular stage of growth and development of the vegetal cover at the time of the rain. **C** adjusts the soil loss estimate to suit these conditions.

The correspondence of periods of expected highly erosive rainfall with periods of poor or good plant cover differs between regions or locations. Therefore, the value of **C** for a particular cropping system will not be the same in all parts of the country. Deriving the appropriate **C** values for a given locality requires knowledge of how the erosive rainfall in that locality is likely to be distributed through the 12 months of the year and how much erosion control protection the growing plants, crop residues, and selected management practices will provide at the time when erosive rains are most likely to occur. A procedure is presented for deriving local values of **C** on the basis of available weather records and research data that reflect effects of crops and management in successive segments of a rotation cycle. The cropping and weather data needed for this purpose appear in reference form in the subsections entitled, **Soil Loss Ratios** and **Erosion Index Distribution Data.**

Cropstage Periods

The change in effectiveness of plant cover within the crop year is gradual. For practical purposes, the year is divided into a series of cropstage periods defined so that cover and management effects may be considered approximately uniform within each period.

Initially, five periods were used, with the seedling and establishment periods defined as the first and second months after crop seeding (50). Because of the existing ranges in soil fertility, row spacing, plant population, and general growing conditions, however, soil loss prediction accuracy is improved when the cropstage periods are defined according to percentage of canopy cover rather than for uniform time periods. The lengths of the respective periods will then vary with crop, climate, and management and will be determined by conditions in a particular geographic area.

The soil loss ratios presented in the next subsection for computation of **C** were evaluated for six cropstage periods defined as follows:

Period F (rough fallow)—Inversion plowing to secondary tillage.

Period SB (seedbed)—Secondary tillage for seedbed preparation until the crop has developed 10 percent canopy cover.

Period 1 (establishment)—End of *SB* until crop has developed a 50 percent canopy cover. (Exception: period 1 for cotton ends at 35 percent canopy cover.)

Period 2 (development)—End of period 1 until canopy cover reaches 75 percent. (60 percent for cotton.)

Period 3 (maturing crop)—End of period 2 until crop harvest. This period was evaluated for three levels of final crop canopy.

Period 4 (residue or stubble)—Harvest to plowing or new seeding.

Quantitative Evaluations of Crop and Management Effects

More than 10,000 plot-years of runoff and soil loss data from natural rain,[5] and additional data from a large number of erosion studies under simulated rainfall, were analyzed to obtain empirical measurements of the effects of cropping system and management on soil loss at successive stages of crop establishment and development. Soil losses measured on the cropped plots were compared with corresponding losses from clean-tilled, continuous fallow to determine the soil loss reductions ascribable to effects of the crop system and management. The reductions were then analyzed to identify and evaluate influential subfactors, interactions, and correlations. Mathematical relationships observed for one crop or geographic region were tested against data from other research sites for consistency. Those found compatible with all the relevant data were used to compute soil loss reductions to be expected from conditions not directly represented in the overall plot studies.

The value of **C** on a particular field is determined by many variables, one of which is weather. Major variables that can be influenced by management decisions include crop canopy, residue mulch, incorporated residues, tillage, land use residual, and their interactions. Each of these effects may be treated as a subfactor whose numerical value is the ratio of soil loss with the effect to corresponding loss without it (57). **C** is the product of all the pertinent subfactors.

Crop Canopy

Leaves and branches that do not directly contact the soil have little effect on amount and velocity of *runoff* from prolonged rains, but they reduce the effective rainfall energy by intercepting falling raindrops. Waterdrops falling from the canopy may regain appreciable velocity but usually less than the terminal velocities of free-falling

[5] See footnote 3, p. 2.

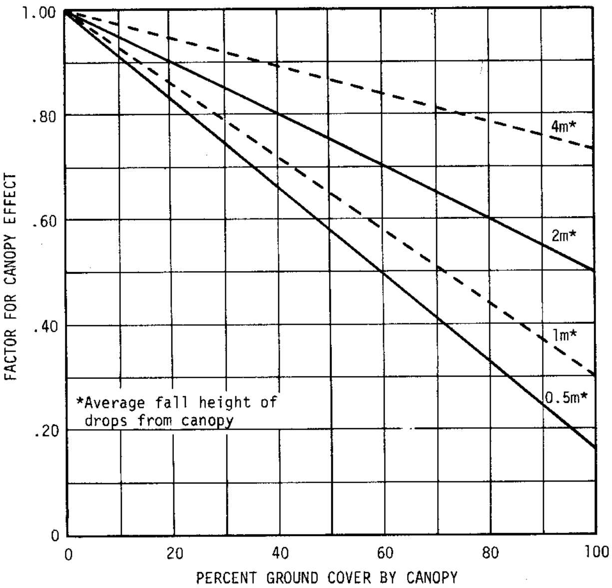

FIGURE 5.—Influence of vegetative canopy on effective EI values. Canopy factor is a subfactor of C.

raindrops. The amount by which energy expended at the soil surface is reduced depends on the height and density of the canopy. The subfactor for canopy effect can be estimated for specified conditions by reference to figure 5.

Residue Mulch

Residue mulches and stems from close-growing vegetation are more effective than equivalent percentages of canopy cover. Mulches intercept falling raindrops so near the surface that the drops regain no fall velocity, and they also obstruct runoff flow and thereby reduce its velocity and transport capacity. Measurements of the effectiveness of several types and rates of mulch have been published (*1, 2, 20, 27, 43*). Average subfactors for specific percentages of surface cover by plant materials at the soil surface are given by the upper curve of figure 6. Guides for estimating percent cover are given in the appendix.

If the cover includes both canopy and mulch, the two are not fully additive; the impact energy of drops striking the mulch is dissipated at that point regardless of whether canopy interception has reduced its velocity. The expected effects of mulch and canopy combinations have been computed and are given in figures 6 and 7. Figure 6 applies to corn, sorghum, and cotton in the maturing stage. Figure 7 applies to small grain, soybeans, potatoes, and the establishment period for taller row crops. Enter either figure 6 or 7 along the horizontal scale, move vertically to the appro-

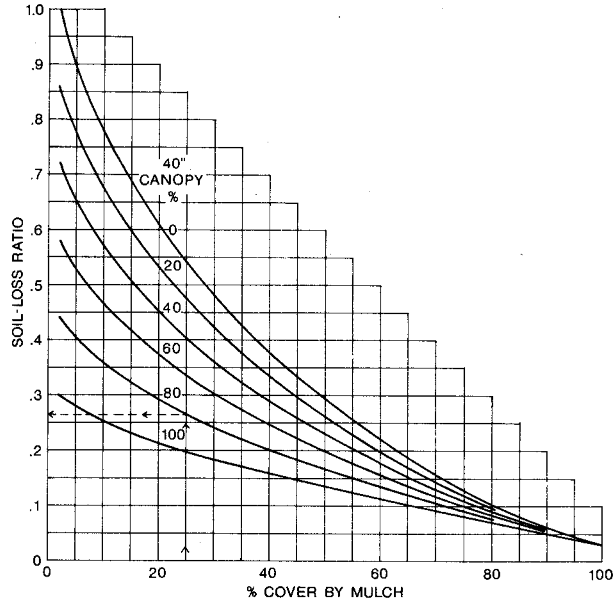

FIGURE 6.—Combined mulch and canopy effects when average fall distance of drops from canopy to the ground is about 40 inches (1 m).

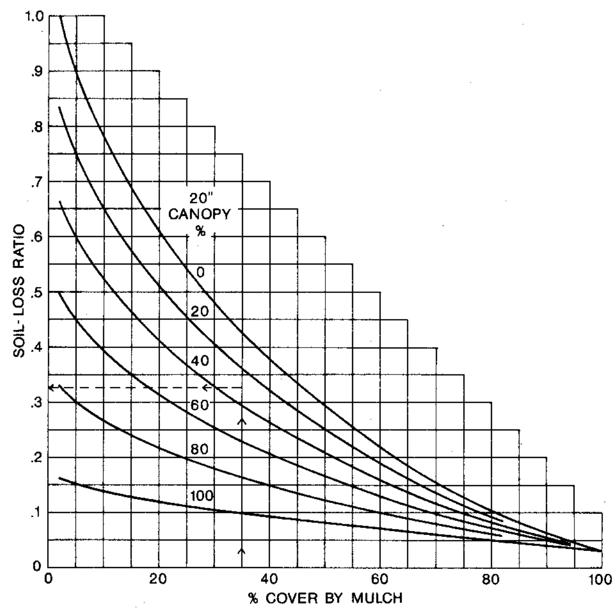

FIGURE 7.—Combined mulch and canopy effects when average fall distance of drops from canopy to the ground is about 20 inches (0.5 m).

priate percent-canopy curve, and read at the left the soil loss ratio from cover effect. This ratio is a subfactor that may be combined with other pertinent subfactors to account for the cropstage soil loss of table 5 or to estimate others.

Incorporated Residues

The plot data indicate that, at least during the seedbed and establishment periods, the erosion-reducing effectivensss of residues mixed into the upper few inches of soil by shallow tillage is appreciably greater than the residual effect of long-term annual incorporation with a moldboard plow. However, the incorporated residues are less effective than if left on the surface.

Tillage

The type, frequency, and timing of tillage operations influence porosity, roughness, cloddiness, compaction, and microtopography. These, in turn, affect water intake, surface storage, runoff velocity, and soil detachability, all of which are factors in potential erosion. These effects are highly correlated with cropland residual effects.

Land Use Residuals

These include effects of plant roots; long-term residue incorporation by plowing; changes in soil structure, detachability, density, organic matter content, and biological activity; and probably other factors. The residual effects are most apparent during seedbed and establishment periods.

Some residual effect will be apparent on nearly any cropland, but the magnitude of its erosion-reducing effectiveness will differ substantially with crops and practices. Tillage and land use residuals are influenced by so many factor interrelations that development of charts like those for canopy and mulch has not been feasible. However, apparent values of these subfactors for some situations were derived from the data and used for expansion of the soil loss ratio table to include conditions somewhat different from those directly represented in the plot studies.

Plowing residues down is far less effective than leaving them on the surface but better than burning them or removing them from the land. After several years of turning the crop residues under with a moldboard plow before row crop seeding in plot studies under natural rainfall, both runoff and soil loss from the row crops were much less than from similar plots from which cornstalks and grain straw were removed at harvesttimes (*52, 54, 59*).

Short periods of rough fallow in a rotation will usually lose much less soil than the basic, clean-tilled, continuous fallow conditions for which **C** = 1. This is largely because of residual effects and is also partly because of the roughness and cloddiness.

The most pronounced residual effect is that from long-term sod or forest. The effect of a grass-and-legume rotation meadow turned under diminishes gradually over about 2 years. In general, the erosion-reducing effectiveness of sod residual (from grass or grass-and-legume meadows) in the plot studies was directly proportional to hay yields. Site values of the subfactor for sod residuals in rotations can be obtained from soil loss ratio table 5-D. The effectiveness of virgin sod and of long periods of alfalfa in which grass became well established was longer lasting. Mixtures of grasses and legumes were more effective than legumes alone.

Residual effectiveness of winter cover crops plowed under in spring depends largely on the type and quality of the crop and its development stage at the time it is plowed under. The effectiveness of grass-and-legume catch crops turned under in spring was less and of shorter duration than that of full-year rotation meadows. Covers such as vetch and ryegrass seeded between corn or cotton rows before harvest and turned under in April were effective in reducing erosion during the winter and showed some residual effect in the following seedbed and establishment periods. Small grain seeded alone in corn or cotton residues showed no residual effect under the next crop. Small grain or vetch on fall-plowed seedbed and turned at spring planting time lost more soil than adjacent plots with undisturbed cotton residues on the surface.

Soil Loss Ratios

Factor **C** is usually given in terms of its average annual value for a particular combination of crop system, management, and rainfall pattern. To derive site values of **C**, soil loss ratios for the individual cropstage periods must be combined with erosion-index distribution data, as demonstrated later. Ratios of soil losses in each cropstage period of specified cropping and management systems to corresponding losses from the basic long-term fallow condition were derived from analysis of about a quarter million plot soil loss observations. The ratios are given in table 5 as percentages.

The observed soil loss ratios for given conditions often varied substantially from year to year because of influences of unpredictable random variables and experimental error. The percentages listed in table 5 are the best available averages for the specified conditions. To make the table inclusive enough for general field use, expected ratios had to be computed for cover, residue, and management combinations that were not directly represented in the plot data. This was done by using empirical relationships of soil losses to the subfactors and interactions discussed in the preceding subsection. The user should recognize that the tabulated percentages are subject to appreciable experimental error and could be improved through additional research. However, because of the large volume of data considered in developing the table, the listed values should be near enough to the true averages to provide highly valuable planning and monitoring guidelines. A ratio derived locally from 1-year rainfall simulator tests on a few plots would not necessarily represent the true average for that locality more accurately. Small samples are more subject to bias by random variables and experimental error than larger samples.

Table for Cropland

Table 5, with its supplements 5A, B, C, and D, replaces tables 2, 3, and 4 in the 1965 edition. The supplements had to be separated from the main table to accommodate changes in format requirements. The ratios are expressed as percentages in the tables to eliminate decimal points.

More than half the lines in table 5 are for conditions associated with conservation tillage practices (65), which were not included in the 1965 edition. Also, it provides a direct means of crediting effects of faster and more complete canopy development by improved fertility, closer row spacing, and greater plant population. Because the table includes several times as many specific conditions as the table in the 1965 edition and defines applicable field conditions more accurately, some simplicity has been sacrificed. However, it is not intended for direct use by each field technician or farmer.

Table 5 as presented here is designed to provide the details needed by a trained agronomist to develop simple handbook tables of **C** values for conditions in specific climatic areas. It is designed for use of the revised definitions of cropstage periods given in the preceding section. The agronomist will first determine, for the particular climatic area, the number of weeks normally required for the crop canopies to attain 10, 50, and 75 percent surface cover, respectively. The table will then be used as illustrated in the next major section. Linear interpolation between ratios listed in the table is recommended where appropriate.

Semiarid Regions

Water erosion is a serious problem also in subhumid and semiarid regions. Inadequate moisture and periodic droughts reduce the periods when growing plants provide good soil cover and limit the quantities of plant residue produced. Erosive rainstorms are not uncommon, and they are usually concentrated within the season when cropland is least protected. Because of the difficulty of establishing rotation meadows and the competition for available soil moisture, sod-based rotations are often impractical. One of the most important opportunities for a higher level of soil and moisture conservation is through proper management of available residues. The effects of mulch-tillage practices in these areas can be evaluated from lines 129 to 158 of table 5 and item 12 of 5-B.

Erosion Index Distribution Data

The rainfall factor, **R**, in the soil loss equation does not completely describe the effects of local differences in rainfall pattern on soil erosion. The erosion control effectiveness of a cropping system on a particular field depends, in part, on how the year's erosive rainfall is distributed among the six cropstage periods of each crop included in the system. Therefore, expected monthly distribution

TABLE 5.—*Ratio of soil loss from cropland to corresponding loss from continuous fallow*

Line No.	Cover, crop sequence, and management[1]	Spring residue[2]	Cover after plant[3]	Soil loss ratio[4] for cropstage period and canopy cover[5]							
				F	SB	1	2	3:80	90	96	4L[6]
		Lb	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*
	CORN AFTER C, GS, G OR COT IN MEADOWLESS SYSTEMS										
	Moldboard plow, conv till:										
1	RdL, sprg TP	4,500	—	31	55	48	38	—	—	20	23
2		3,400	—	36	60	52	41	—	24	20	30
3		2,600	—	43	64	56	43	32	25	21	37
4		2,000	—	51	68	60	45	33	26	22	47
5	RdL, fall TP	HP[2]	—	44	65	53	38	—	—	20	—
6		GP	—	49	70	57	41	—	24	20	—
7		FP	—	57	74	61	43	32	25	21	—
8		LP	—	65	78	65	45	32	26	22	—
9	RdR, sprg TP	HP	—	66	74	65	47	—	—	22	56
10		GP	—	67	75	66	47	—	27	23	62
11		FP	—	68	76	67	48	35	27	—	69
12		LP	—	69	77	68	49	35	—	—	74
13	RdR, fall TP	HP	—	76	82	70	49	—	—	22	—
14		GP	—	77	83	71	50	—	27	23	—
15		FP	—	78	85	72	51	35	27	—	—
16		LP	—	79	86	73	52	35	—	—	—
17	*Wheeltrack pl, RdL, TP*[8]	4,500	—	—	31	27	25	—	—	18	23
18		3,400	—	—	36	32	30	—	22	18	30
19		2,600	—	—	43	36	32	29	23	19	37
20		2,000	—	—	51	43	36	31	24	20	47
21	*Deep off-set disk or disk plow*	4,500	10	—	45	38	34	—	—	20	23
22		3,400	10	—	52	43	37	—	24	20	30
23		2,600	5	—	57	48	40	32	25	21	37
24		2,000	—	—	61	51	42	33	26	22	47
25	*No-till plant in crop residue*[9]	6,000	95	—	2	2	2	—	—	2	14
26		6,000	90	—	3	3	3	—	—	3	14
27		4,500	80	—	5	5	5	—	—	5	15
28		3,400	70	—	8	8	8	—	8	6	19
29		3,400	60	—	12	12	12	12	9	8	23
30		3,400	50	—	15	15	14	14	11	9	27
31		2,600	40	—	21	20	18	17	13	11	30
32		2,600	30	—	26	24	22	21	17	14	36
	Chisel, shallow disk, or fld cult, as only tillage:										
33	On moderate slopes	6,000	70	—	8	8	7	—	—	7	17
34			60	—	10	9	8	—	—	8	17
35			50	—	13	11	10	—	—	9	18
36			40	—	15	13	11	—	—	10	19
37			30	—	18	15	13	—	—	12	20
38			20	—	23	20	18	—	—	16	21
39	Do.	4,500	70	—	9	8	7	—	—	7	18
40			60	—	12	10	9	—	—	8	18
41			50	—	14	13	11	—	—	9	19
42			40	—	17	15	13	—	—	10	20
43			30	—	21	18	15	—	—	13	21
44			20	—	25	22	19	—	—	16	22

Line No.	Cover, crop sequence, and management[1]	Spring residue[2]	Cover after plant[3]	Soil loss ratio[4] for cropstage period and canopy cover[5]							
				F	SB	1	2	3:80	90	96	4L[6]
		Lb	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*
	CORN AFTER WC OF RYEGRASS OR WHEAT SEEDED IN C STUBBLE										
	WC reaches stemming stage:										
79	No-till pl in killed WC	4,000	—	—	7	7	7	—	7	6	([13])
80		3,000	—	—	11	11	11	11	9	7	
81		2,000	—	—	15	15	14	14	11	9	
82		1,500	—	—	20	19	18	18	14	11	
	Strip till one-fourth row space										
83	Rows U/D slope	4,000	—	—	13	12	11	—	11	9	([13])
84		3,000	—	—	18	17	16	16	13	10	
85		2,000	—	—	23	22	20	19	15	12	
86		1,500	—	—	28	26	24	22	17	14	
87	Rows on contour[11]	4,000	—	—	10	10	10	—	10	8	([13])
88		3,000	—	—	15	15	15	15	12	9	
89		2,000	—	—	20	20	19	19	15	12	
90		1,500	—	—	25	24	23	22	17	14	
91	TP, conv seedbed	4,000	—	36	60	52	41	—	24	20	([13])
92		3,000	—	43	64	56	43	31	25	21	
93		2,000	—	51	68	60	45	33	26	22	
94		1,500	—	61	73	64	47	35	27	23	
	WC succulent blades only:										
95	No-till pl in killed WC	3,000	—	—	11	11	17	23	18	16	([13])
96		2,000	—	—	15	15	20	25	20	17	
97		1,500	—	—	20	20	23	26	21	18	
98		1,000	—	—	26	26	27	27	22	19	
99	Strip till one-fourth row space	3,000	—	—	18	18	21	25	20	17	([13])
100		2,000	—	—	23	23	25	27	21	18	
101		1,500	—	—	28	28	28	28	22	19	
102		1,000	—	—	33	33	31	29	23	20	
	CORN IN SOD-BASED SYSTEMS										
	No-till pl in killed sod:										
103	3 to 5 tons hay yld	—	—	—	1	1	1	—	1	1	1
104	1 to 2 tons hay yld	—	—	—	2	2	2	2	2	2	2
	Strip till, 3-5 ton M:										
105	50 percent cover, tilled strips	—	—	—	2	2	2	—	2	2	4
106	20 percent cover, tilled strips	—	—	—	3	3	3	—	3	3	5
	Strip till, 1-2 ton M:										
107	40 percent cover, tilled strips	—	—	—	4	4	4	4	4	4	6
108	20 percent cover, tilled strips	—	—	—	5	5	5	5	5	5	7
	Other tillage after sod:			([14])	([14])	([14])	([14])	([14])	([14])	([14])	([14])
	CORN AFTER SOYBEANS										
109	*Sprg TP, conv till*	HP	—	40	72	60	48	—	—	25	29
110		GP	—	47	78	65	51	—	30	25	37
111		FP	—	56	83	70	54	40	31	26	44
112	*Fall TP, conv till*	HP	—	47	75	60	48	—	—	25	—
113		GP	—	53	81	65	51	—	30	25	—
114		FP	—	62	86	70	54	40	31	26	—

45	Do.	3,400	60	—	13	11	10	—	10	8	20
46			50	—	16	13	12	—	12	9	24
47			40	—	19	17	16	—	14	11	25
48			30	—	23	21	19	—	17	14	26
49			20	—	29	25	23	—	21	16	27
50			10	—	36	32	29	—	24	20	30
51	Do.	2,600	50	—	17	16	15	15	13	10	29
52			40	—	21	20	19	19	15	12	30
53			30	—	25	23	22	22	18	14	32
54			20	—	32	29	28	27	22	17	34
55			10	—	41	36	34	32	25	21	37
56	Do.	2,000	40	—	23	21	20	20	15	12	37
57			30	—	27	25	24	23	19	15	39
58			20	—	35	32	30	28	22	18	42
59			10	—	46	42	38	33	26	22	47
	On slopes > 12 percent.										
60	Lines 33-59 times factor of:	—	—	—	1.3	1.3	1.1	1.0	1.0	1.0	1.0
	Disk or harrow after spring chisel or fld cult:										
	Lines 33-59 times factor of:										
61	On moderate slopes	—	—	—	1.1	1.1	1.1	1.0	1.0	1.0	1.0
62	On slopes > 12 percent	—	—	—	1.4	1.4	1.2	1.0	1.0	1.0	1.0
	Ridge plant:[10]										
	Lines 33-59 times factor of:										
63	Rows on contour[11]	—	—	—	.7	.7	.7	.7	.7	.7	.7
64	Rows U/D slope < 12 percent	—	—	—	.7	.7	1.0	1.0	1.0	1.0	1.0
65	Rows U/D slope > 12 percent	—	—	—	.9	.9	1.0	1.0	1.0	1.0	1.0
	Till plant:										
	Lines 33-59 times factor of:										
66	Rows on contour[11]	—	—	—	.7	.85	1.0	1.0	1.0	1.0	1.0
67	Rows U/D slope < 7 percent	—	—	—	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	Strip till one-fourth of row spacing:										
68	Rows on contour[11]	4,500	[12]60	—	12	10	9	—	—	8	23
69		3,400	50	—	16	14	12	—	11	10	27
70		2,600	40	—	22	19	17	17	14	12	30
71		2,000	30	—	27	23	21	20	16	13	36
72	Rows U/D slope	4,500	[12]60	—	16	13	11	—	—	9	23
73		3,400	50	—	20	17	14	—	12	11	27
74		2,600	40	—	26	22	19	17	14	12	30
75		2,000	30	—	31	26	23	20	16	13	36
	Vari-till:										
76	Rows on contour[11]	3,400	40	—	13	12	11	—	—	11	22
77		3,400	30	—	16	15	14	14	13	12	26
78		2,600	20	—	21	19	19	19	16	14	34
115	Fall & sprg chisel or cult	HP	[15]30	—	40	35	29	—	—	23	29
116		GP	25	—	45	39	33	—	27	23	37
117		GP	20	—	51	44	39	34	27	23	37
118		FP	15	—	58	51	44	36	28	23	44
119		LP	10	—	67	59	48	36	28	23	54
120	*No-till pl in crop res'd*	HP	[15]40	—	25	20	19	—	14	11	26
121		GP	30	—	33	29	25	22	18	14	33
122		FP	20	—	44	38	32	27	23	18	40
	BEANS AFTER CORN										
123	*Sprg TP, RdL, conv till*	HP	—	33	60	52	38	—	20	17	([16])
124		GP	—	39	64	56	41	—	21	18	
125		FP	—	45	68	60	43	29	22	—	
126	*Fall TP, RdL, conv till*	HP	—	45	69	57	38	—	20	17	([16])
127		GP	—	52	73	61	41	—	21	18	
128		FP	—	59	77	65	43	29	22	—	
	Chisel or fld cult:			([17])	([17])	([17])	([17])	([17])	([17])	([17])	([18])
	BEANS AFTER BEANS			([18])	([18])	([18])	([18])	([18])	([18])	([18])	([16])
	GRAIN AFTER C, G, GS, COT[19]										
129	*In disked residues:*	4,500	70	—	12	12	11	7	4	2	([20])
130		3,400	60	—	16	14	12	7	4	2	
131			50	—	22	18	14	8	5	3	
132			40	—	27	21	16	9	5	3	
133			30	—	32	25	18	9	6	3	
134			20	—	38	30	21	10	6	3	
135	Do.	2,600	40	—	29	24	19	9	6	3	([20])
136			20	—	43	34	24	11	7	4	
137			10	—	52	39	27	12	7	4	
138	Do.	2,000	30	—	38	30	23	11	7	4	([20])
139			20	—	46	36	26	12	7	4	
140			10	—	56	43	30	13	8	5	
141	*In disked stubble, RdR*	—	—	—	79	62	42	17	11	6	([20])
142	*Winter G after fall TP, RdL*	HP	—	31	55	48	31	12	7	5	([20])
143		GP	—	36	60	52	33	13	8	5	
144		FP	—	43	64	56	36	14	9	5	
145		LP	—	53	68	60	38	15	10	6	
	GRAIN AFTER SUMMER FALLOW										
146	*With grain residues*	200	10	—	70	55	43	18	13	11	([21])
147		500	30	—	43	34	23	13	10	8	
148		750	40	—	34	27	18	10	7	7	
149		1,000	50	—	26	21	15	8	7	6	
150		1,500	60	—	20	16	12	7	5	5	
151		2,000	70	—	14	11	9	7	5	5	
152	*With row crop residues*	300	5	—	82	65	44	19	14	12	([21])
153		500	15	—	62	49	35	17	13	11	
154		750	23	—	50	40	29	14	11	9	
155		1,000	30	—	40	31	24	13	10	8	
156		1,500	45	—	31	24	18	10	8	7	
157		2,000	55	—	23	19	14	8	7	5	
158		2,500	65	—	17	14	12	7	5	4	
	POTATOES										
159	*Rows with slope*	—	—	43	64	56	36	26	19	16	
160	*Contoured rows, ridged when canopy cover is about 50 percent*[11]	—	—	43	64	56	18	13	10	8	

See footnotes, p. 24.

Footnotes for table 5.

[1] Symbols: B, soybeans; C, corn; conv till, plow, disk and harrow for seedbed; cot, cotton; F, rough fallow; fld cult, field cultivator; G, small grain; GS, grain sorghum; M, grass and legume meadow, at least 1 full year; pl, plant; RdL, crop residues left on field; RdR, crop residues removed; SB, seedbed period; sprg, spring; TP, plowed with moldboard; WC, winter cover crop; —, insignificant or an unlikely combination of variables.

[2] Dry weight per acre after winter loss and reductions by grazing or partial removal: 4,500 lbs represents 100 to 125 bu corn; 3,400 lbs, 75 to 99 bu; 2,600 lbs, 60 to 74 bu; and 2,000 lbs, 40 to 59 bu; with normal 30-percent winter loss. For RdR or fall-plow practices, these four productivity levels are indicated by HP, GP, FP and LP, respectively (high, good, fair, and low productivity). In lines 79 to 102, this column indicates dry weight of the winter-cover crop.

[3] Percentage of soil surface covered by plant residue mulch *after* crop seeding. The difference between spring residue and that on the surface after crop seeding is reflected in the soil loss ratios as residues mixed with the topsoil.

[4] The soil loss ratios, given as percentages, assume that the indicated crop sequence and practices are followed consistently. One-year deviations from normal practices do not have the effect of a permanent change. Linear interpolation between lines is recommended when justified by field conditions.

[5] Cropstage periods are as defined on p. 18. The three columns for cropstage 3 are for 80, 90, and 96 to 100 percent canopy cover at maturity.

[6] Column 4L is for all residues left on field. Corn stalks partially standing as left by some mechanical pickers. If stalks are shredded and spread by picker, select ratio from table 5-C. When residues are reduced by grazing, take ratio from lower spring-residue line.

[7] Period 4 values in lines 9 to 12 are for corn stubble (stover removed).

[8] Inversion plowed, no secondary tillage. For this practice, residues must be left and incorporated.

[9] Soil surface and chopped residues of *matured* preceding crop undisturbed except in narrow slots in which seeds are planted.

[10] Top of old row ridge sliced off, throwing residues and some soil into furrow areas. Reridging assumed to occur near end of cropstage 1.

[11] Where lower soil loss ratios are listed for rows on the contour, this reduction is in addition to the standard field contouring credit. The *P* value for contouring is used with these reduced loss ratios.

[12] Field-average percent cover; probably about three-fourths of percent cover on undisturbed strips.

[13] If again seeded to WC crop in corn stubble, evaluate winter period as a winter grain seeding (lines 132 to 148). Otherwise, see table 5-C.

[14] Select the appropriate line for the crop, tillage, and productivity level and multiply the listed soil loss ratios by sod residual factors from table 5-D.

[15] Spring residue may include carryover from prior corn crop.

[16] See table 5-C.

[17] Use values from lines 33 to 62 with appropriate dates and lengths of cropstage periods for beans in the locality.

[18] Values in lines 109 to 122 are best available estimates, but planting dates and lengths of cropstages may differ.

[19] When meadow is seeded with the grain, its effect will be reflected through higher percentages of cover in cropstages 3 and 4.

[20] Ratio depends on percent cover. See table 5-C.

[21] See item 12, table 5-B.

TABLE 5-A.—*Approximate soil loss ratios for cotton*

Expected final canopy percent cover:	65	80	95
Estimated initial percent cover from defoliation + stalks down:	30	45	60
Practice Number — Tillage operation(s)	Soil loss ratio[1]		
COTTON ANNUALLY:		*Percent*	
1....*None:*			
Defoliation to Dec. 31	36	24	15
Jan. 1 to Feb. or Mar. tillage:			
Cot Rd only	52	41	32
Rd & 20 percent cover vol veg[2]	32	26	20
Rd & 30 percent cover vol veg	26	20	14
2....*Chisel plow soon after cot harvest:*			
Chiseling to Dec. 31	40	31	24
Jan. 1 to sprg tillage	56	47	40
3....*Fall disk after chisel:*			
Disking to Dec. 31	53	45	37
Jan. 1 to sprg tillage	62	54	47
4....*Chisel plow Feb-Mar, no prior tillage:*			
Cot Rd only	50	42	35
Rd & 20 percent vol veg	39	33	28
Rd & 30 percent vol veg	34	29	25
5....*Bed ("hip") Feb-Mar, no prior tillage:*			
Cot Rd only	100	84	70
Rd & 20 percent vol veg	78	66	56
Rd & 30 percent vol veg	68	58	50
Split ridges & plant after hip, or Disk & plant after chisel (SB):			
Cot Rd only	61	54	47
Rd & 20 percent vol veg	53	47	41
Rd & 30 percent vol veg	50	44	38
Cropstage 1:			
Cot Rd only	57	50	43
Rd & 20 percent vol veg	49	43	38
Rd & 30 percent vol veg	46	41	36
Cropstage 2	45	39	34
Cropstage 3	40	27	17
6....*Bed (hip) after 1 prior tillage:*			
Cot Rd only	110	96	84
Rd & 20 percent veg	94	82	72
Rd & 30 percent veg	90	78	68
Split ridges after hip (SB):			
Cot Rd only	66	61	52
Rd & 20 to 30 percent veg	61	55	49
Cropstage 1:			
Cot Rd only	60	56	49
Rd & 20 to 30 percent veg	56	51	46
Cropstage 2	47	44	38
Cropstage 3	42	30	19
7....*Hip after 2 prior tillages:*			
Cot Rd only	116	108	98
Rd & 20-30 percent veg	108	98	88
Split ridges after hip (SB)	67	62	57
8....*Hip after 3 or more tillages:*	120	110	102
Split ridges after hip (SB)	68	64	59
9....*Conventional moldboard plow and disk:*			
Fallow period	42	39	36
Seedbed period	68	64	59
Cropstage 1	63	59	55
Cropstage 2	49	46	43
Cropstage 3	44	32	22
Cropstage 4 (See practtices 1, 2, and 3)			

COTTON AFTER SOD CROP:

For the first or second crop after a grass or grass-and-legume meadow has been turnplowed, multiply values given in the last five lines above by sod residual factors from table 5-D.

COTTON AFTER SOYBEANS:

Select values from above and multiply by 1.25.

See footnotes at right.

of erosive rainfall at a particular location is an element in deriving the applicable value of cover and management, **C.**

Central and Eastern States

A location's erosion index is computed by summing **EI** values of individual rainstorms over periods from 20 to 25 years. Thus, the expected monthly distribution of the erosion index can be computed from the same data. For each rainfall record abstracted for development of the isoerodent map, the monthly **EI** values were computed and expressed as percentages of the location's average annual erosion index. When the monthly percentages are plotted cumulatively against time, they define **EI** distribution curves such as illustrated in figure 8 for three locations. The three contrasting curves are presented to demonstrate how drastically the normal **EI** distribution can differ among climatic regions.

On the basis of observed seasonal distributions of **EI**, the 37 States east of the Rocky Mountains were divided into the 33 geographic areas delineated in figure 9. The changes in distribution are usually gradual transitions from one area to the next, but the average distribution within any one of the areas may, for practical purposes, be considered applicable for the entire area. The **EI** distributions in the 33 areas, expressed as cumulative percentages of annual totals, are given in table 6. The area numbers in the table correspond to those in figure 9. The data in the table were

[1] *Alternate procedure for estimating the soil loss ratios:*

The ratios given above for cotton are based on estimates for reductions in percent cover through normal winter loss and by the successive tillage operations. Research is underway in Mississippi to obtain more accurate residue data in relation to tillage practices. This research should provide more accurate soil loss ratios for cotton within a few years.

Where the reductions in percent cover by winter loss and tillage operations are small, the following procedure may be used to compute soil loss ratios for the preplant and seedbed periods: Enter figure 6 with the percentage of the field surface covered by residue mulch, move vertically to the upper curve, and read the mulch factor on the scale at the left. Multiply this factor by a factor selected from the following tabulation to credit for effects of land-use residual, surface roughness and porosity.

Productivitty level	No tillage	Rough surface	Smoothed surface
High	0.66	0.50	0.56
Medium	.71	.54	.61
Poor	.75	.58	.65

Values for the bedded period on slopes of less than 1 percent should be estimated at twice the value computed above for rough surfaces.

[2] Rd, crop residue; vol veg, volunteer vegetation.

TABLE 5-B.—*Soil loss ratios for conditions not evaluated in table 5*

COTTON:
See table 5-A.
CROPSTAGE 4 FOR ROWCROPS:
Stalks broken and partially standing: Use col. 4L.
Stalks standing after hand picking: Col. 4L times 1.15.
Stalks shredded without soil tillage: See table 5-C.
Fall chisel: Select values from lines 33-62, seedbed column.
CROPSTAGE 4 FOR SMALL GRAIN:
See table 5-C.
DOUBLE CROPPING:
Derive annual C value by selecting from table 5 the soil loss percentages for the successive cropstage periods of each crop.
ESTABLISHED MEADOW, FULL-YEAR PERCENTAGES:

Grass and legume mix, 3 to 5 t hay	0.4
Do. 2 to 3 t hay	.6
Do. 1 t hay	1.0
Sericea, after second year	1.0
Red clover	1.5
Alfalfa, lespedeza, and second-year sericea	2.0
Sweetclover	2.5

MEADOW SEEDING WITHOUT NURSE CROP:
Determine appropriate lengths of cropstage periods SB, 1, and 2 and apply values given for small grain seeding.
PEANUTS:
Comparison with soybeans is suggested.
PINEAPPLES:
Direct data not available. Tentative values derived analytically are available from the SCS in Hawaii or the Western Technical Service Center at Portland, Oreg. (Reference 5).
SORGHUM:
Select values given for corn, on the basis of expected crop residues and canopy cover.
SUGARBEETS:
Direct data not available. Probably most nearly comparable to potatoes, without the ridging credit.
SUGARCANE:
Tentative values available from sources given for pineapples.
SUMMER FALLOW IN LOW-RAINFALL AREAS, USE GRAIN OR ROW CROP RESIDUES:
The approximate soil loss percentage after each successive tillage operation may be obtained from the following tabulation by estimating the percent surface cover after that tillage and selecting the column for the appropriate amount of initial residue. The given values credit benefits of the residue mulch, residues mixed with soil by tillage, and the crop system residual.

Percent cover by mulch	Initial residue (lbs/A)			
	>4,000	3,000	2,000	1,500
90	4	—	—	—
80	8	[1]8	—	—
70	12	13	[1]14	—
60	16	17	[1]18	[1]19
50	20	22	24	[1]25
40	25	27	30	32
30	29	33	37	39
20	35	39	44	48
10	47	55	63	68

[1] For grain residue only.

WINTER COVER SEEDING IN ROW CROP STUBBLE OR RESIDUES:
Define cropstage periods based on the cover seeding date and apply values from lines 129 to 145.

TABLE 5-C.—*Soil loss ratios (percent) for cropstage 4 when stalks are chopped and distributed without soil tillage*

Mulch cover[1]	Corn or Sorghum: Tilled seedbed[2]	Corn or Sorghum: No-till	Soybeans: Tilled seedbed[2]	Soybeans: No-till in corn rd[3]	Grain Stubble[4]
20	48	34	60	42	48
30	37	26	46	32	37
40	30	21	38	26	30
50	22	15	28	19	22
60	17	12	21	16	17
70	12	8	15	10	12
80	7	5	9	6	7
90	4	3	—	—	4
95	3	2	—	—	3

[1] Part of a field surface directly covered by pieces of residue mulch.
[2] This column applies for all systems other than no-till.
[3] Cover after bean harvest may include an appreciable number of stalks carried over from the prior corn crop.
[4] For grain with meadow seeding, include meadow growth in percent cover and limit grain period 4 to 2 mo. Thereafter, classify as established meadow.

abstracted from the published EI distribution curves.

The percentage of the annual erosion index that is to be expected within each cropstage period may be obtained by reading from the appropriate line of table 6, the values for the last and first date of the period, and subtracting. Interpolate

TABLE 5-D.—*Factors to credit residual effects of turned sod*[1]

Crop	Hay yield	Factor for cropstage period: F	SB and 1	2	3	4
	Tons					
First year after mead:						
Row crop or grain ...	3-5	0.25	0.40	0.45	0.50	0.60
	2-3	.30	.45	.50	.55	.65
	1-2	.35	.50	.55	.60	.70
Second year after mead:						
Row crop	3.5	.70	.80	.85	.90	.95
	2-3	.75	.85	.90	.95	1.0
	1-2	.80	.90	.95	1.0	1.0
Spring grain	3-5	—	.75	.80	.85	.95
	2-3	—	.80	.85	.90	1.0
	1-2	—	.85	.90	.95	1.0
Winter grain	3-5	—	.60	.70	.85	.95
	2-3	—	.65	.75	.90	1.0
	1-2	—	.70	.85	.95	1.0

[1] These factors are to be multiplied by the appropriate soil loss percentages selected from table 5. They are directly applicable for sod-forming meadows of at least 1 full year duration, plowed not more than 1 month before final seedbed preparation.

When sod is fall plowed for spring planting, the listed values for all cropstage periods are increased by adding 0.02 for each additional month by which the plowing precedes spring seedbed preparation. For example, September plowing would precede May disking by 8 months and 0.02(8—1), or 0.14, would be added to each value in the table. For nonsod-forming meadows, like sweetclover or lespedeza, multiply the factors by 1.2. When the computed value is greater than 1.0, use as 1.0.

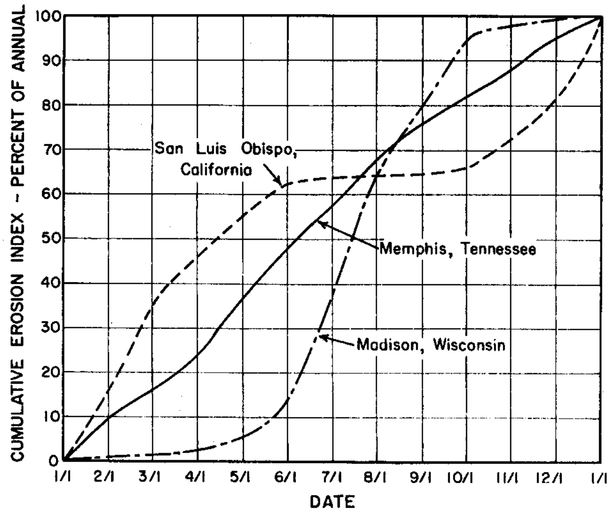

FIGURE 8.—Typical EI-distribution curves for three rainfall patterns.

between values in the selected line when the desired dates are not listed.

Western States, Hawaii, and Puerto Rico

Normal rainfall patterns in these mountainous States often change abruptly within a short distance. Figure 9 was not extended to include these States because long-term intensity data were not available for enough locations to delineate boundaries of homogeneous areas. However, **EI** distributions indicated by station records that were abstracted are given in table 7 for reference.

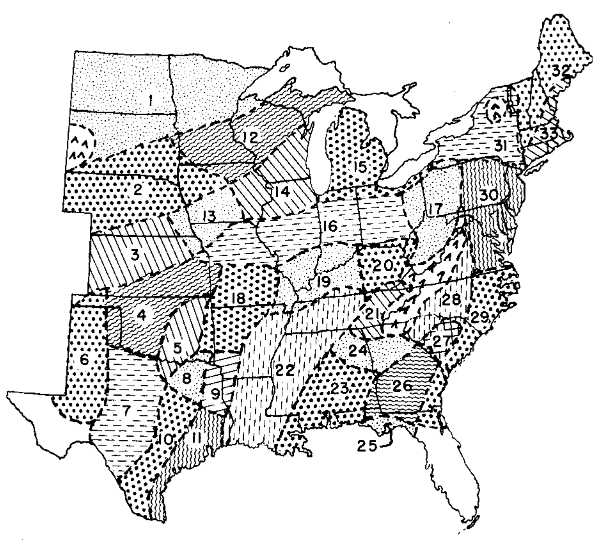

FIGURE 9.—Key map for selection of applicable EI-distribution data from table 6.

Winter Periods

Site **EI** values reflect only rain falling at erosive intensities. Where the winter precipitation comes as snow or light rain, **EI** distribution curves may show insignificant percentages for several winter months. Yet, snowmelt and low intensity rains on frozen soil may cause appreciable runoff that is erosive even though the associated maximum 30-minute rainfall intensity is extremely low or zero. The section on **Isoerodent Maps** pointed out that where this type of runoff is significant its erosive force must be reflected in an $\mathbf{R_s}$ value that is added to the **EI** value to obtain **R**. This additional erosive force must also be reflected in the *monthly distribution* of **R**. Otherwise, poor management during the winter period will not be reflected in the USLE estimate of annual soil loss because a zero cropstage **R** value would predict zero soil loss regardless of the relevant soil loss ratio.

Soil erosion by thaw runoff is most pronounced in the Northwest, where $\mathbf{R_s}$ values often exceed the average annual **EI**. However, it may also be significant in other Northern States. Probable amounts of thaw runoff were not available for inclusion in the calculations of the **EI** distributions given in tables 6 and 7, but the significance and probable time of occurrence of such runoff can be estimated by local people. The procedure for adjusting table 6 cumulative percentages to include this erosive potential will be illustrated.

Based on the previously described estimating procedure, $\mathbf{R_s}$ values in area No. 1, figure 9, appear to equal about 8 percent of the annual **EI**. Assuming that the thaw runoff in that area normally occurs between March 15 and April 15, the percentage in table 6 for April 1 is increased by 4, the April 15 and all subsequent readings are increased by 8, and all the adjusted readings are then divided by 1.08. This procedure corrects the data given in line 1, table 6, for dates April 1 to September 1 to the following cumulative percentages listed in chronological sequence: 5, 9, 10, 13, 18, 29, 41, 53, 66, 79, 91. The other values are unchanged. Such adjustments in monthly distribution of **R** where thaw runoff is significant will be particularly helpful when the USLE is used to estimate seasonal distribution of sediment from agricultural watersheds.

TABLE 6.—*Percentage of the average annual* **EI** *which normally occurs between January 1 and the indicated dates.*[1] *Computed for the geographic areas shown in figure 9*

Area No.	Jan.		Feb.		Mar.		Apr.		May		June		July		Aug.		Sept.		Oct.		Nov.		Dec.	
	1	15	1	15	1	15	1	15	1	15	1	15	1	15	1	15	1	15	1	15	1	15	1	15
1	0	0	0	0	0	0	1	2	3	6	11	23	36	49	63	77	90	95	98	99	100	100	100	100
2	0	0	0	0	1	1	2	3	6	10	17	29	43	55	67	77	85	91	96	98	99	100	100	100
3	0	0	0	0	1	1	2	3	6	13	23	37	51	61	69	78	85	91	94	96	98	99	99	100
4	0	0	1	1	2	3	4	7	12	18	27	38	48	55	62	69	76	83	90	94	97	98	99	100
5	0	1	2	3	4	6	8	13	21	29	37	46	54	60	65	69	74	81	87	92	95	97	98	99
6	0	0	0	0	1	1	1	2	6	16	29	39	46	53	60	67	74	81	88	95	99	99	100	100
7	0	1	1	2	3	4	6	8	13	25	40	49	56	62	67	72	76	80	85	91	97	98	99	99
8	0	1	3	5	7	10	14	20	28	37	48	56	61	64	68	72	77	81	86	89	92	95	98	99
9	0	2	4	6	9	12	17	23	30	37	43	49	54	58	62	66	70	74	78	82	86	90	94	97
10	0	1	2	4	6	8	10	15	21	29	38	47	53	57	61	65	70	76	83	88	91	94	96	98
11	0	1	3	5	7	9	11	14	18	27	35	41	46	51	57	62	68	73	79	84	89	93	96	98
12	0	0	0	0	1	1	2	3	5	9	15	27	38	50	62	74	84	91	95	97	98	99	99	100
13	0	0	0	1	1	2	3	5	7	12	19	33	48	57	65	74	82	88	93	96	98	99	100	100
14	0	0	0	1	2	3	4	6	9	14	20	28	39	52	63	72	80	87	91	94	97	98	99	100
15	0	0	1	2	3	4	6	8	11	15	22	31	40	49	59	69	78	85	91	94	96	98	99	100
16	0	1	2	3	4	6	8	10	14	18	25	34	45	56	64	72	79	84	89	92	95	97	98	99
17	0	1	2	3	4	5	6	8	11	15	20	28	41	54	65	74	82	87	92	94	96	97	98	99
18	0	1	2	4	6	8	10	13	19	26	34	42	50	58	63	68	74	79	84	89	93	95	97	99
19	0	1	3	6	9	12	16	21	26	31	37	43	50	57	64	71	77	81	85	88	91	93	95	97
20	0	2	3	5	7	10	13	16	19	23	27	34	44	54	63	72	80	85	89	91	93	95	96	98
21	0	3	6	10	13	16	19	23	26	29	33	39	47	58	68	75	80	83	86	88	90	92	95	97
22	0	3	6	9	13	17	21	27	33	38	44	49	55	61	67	71	75	78	81	84	86	90	94	97
23	0	3	5	7	10	14	18	23	27	31	35	39	45	53	60	67	74	80	84	86	88	90	93	95
24	0	3	6	9	12	16	20	24	28	33	38	43	50	59	69	75	80	84	87	90	92	94	96	98
25	0	1	3	5	7	10	13	17	21	24	27	33	40	46	53	61	69	78	89	92	94	95	97	98
26	0	2	4	6	8	12	16	20	25	30	35	41	47	56	67	75	81	85	87	89	91	93	95	97
27	0	1	2	3	5	7	10	14	18	22	27	32	37	46	58	69	80	89	93	94	95	96	97	99
28	0	1	3	5	7	9	12	15	18	21	25	29	36	45	56	68	77	83	88	91	93	95	97	99
29	0	1	2	3	4	5	7	9	11	14	17	22	31	42	54	65	74	83	89	92	95	97	98	99
30	0	1	2	3	4	5	6	8	10	14	19	26	34	45	56	66	76	82	86	90	93	95	97	99
31	0	0	0	1	2	3	4	5	7	12	17	24	33	42	55	67	76	83	89	92	94	96	98	99
32	0	1	2	3	4	5	6	8	10	13	17	22	31	42	52	60	68	75	80	85	89	92	96	98
33	0	1	2	4	6	8	11	13	15	18	21	26	32	38	46	55	64	71	77	81	85	89	93	97

[1] For dates not listed in the table, interpolate between adjacent values.

Procedure for Deriving Local C Values

Factor **C** in the USLE measures the combined effect of all the interrelated cover and management variables and is defined as the ratio of soil loss from land cropped under specified conditions to the corresponding loss from clean-tilled continuous fallow. It is usually expressed as an annual value for a particular cropping and management system. Soil loss ratios, as used in table 5, express a similar ratio for a short time interval within which cover and management effects are relatively uniform. The cropstage soil loss ratios must be combined in proportion to the applicable percentages of **EI** to derive annual **C** values.

To compute the value of **C** for any particular crop and management system on a given field, one needs first to determine the most likely seeding and harvest dates, rate of canopy development, and final canopy cover. Also, the system to be evaluated must be carefully defined with regard to crop and residue management details. Within the broad limits of tables 5 and 6, these tables then supply the research data needed to complete

TABLE 7.—*Monthly distribution of* **EI** *at selected raingage locations*

Location[1]	Average percentage of annual EI occurring from 1/1 to:											
	2/1	3/1	4/1	5/1	6/1	7/1	8/1	9/1	10/1	11/1	12/1	12/31
California												
Red Bluff (69)	18	36	47	55	62	64	65	65	67	72	82	100
San Luis Obispo (51)	19	39	54	63	65	65	65	65	65	67	83	100
Colorado												
Akron (91)	0	0	0	1	18	33	72	87	98	99	100	100
Pueblo (68)	0	0	0	5	14	23	40	82	84	100	100	100
Springfield (98)	0	0	1	4	26	36	60	94	96	99	100	100
Hawaii												
Hilo (770)	9	23	34	44	49	51	55	60	65	72	87	100
Honolulu (189)	19	33	43	51	54	55	56	57	58	62	81	100
Kahului (107)	14	32	49	62	67	68	69	70	71	76	86	100
Lihue (385)	19	29	36	41	44	45	48	51	56	64	80	100
Montana												
Billings (18)	0	0	1	6	22	49	86	88	96	100	100	100
Great Falls (17)	1	1	2	6	20	56	74	93	98	99	100	100
Miles City (28)	0	0	0	1	10	32	65	93	98	100	100	100
New Mexico												
Albuquerque (15)	1	1	2	4	10	21	52	67	89	98	99	100
Roswell (52)	0	0	2	7	20	34	55	71	92	99	99	100
Oregon												
Pendleton (6)	8	12	15	22	56	64	67	67	74	87	96	100
Portland (43)	15	27	35	37	40	45	46	47	54	65	81	100
Puerto Rico												
Mayaguez (600)	1	2	3	6	15	31	47	63	80	91	99	100
San Juan (345)	5	8	11	17	33	43	53	66	75	84	93	100
Washington												
Spokane (8)	5	9	11	15	25	56	61	76	84	90	94	100
Wyoming												
Casper (11)	0	0	1	6	32	44	70	90	96	100	100	100
Cheyenne (32)	0	1	2	5	17	42	73	90	97	99	100	100

[1] Numbers in parentheses are the observed average annual EI.

the computation of **C**. The procedure will be explained by an example that, for illustration purposes, was selected to include many changes in field conditions.

Problem. Evaluate **C** for a 4-year rotation of wheat-meadow-corn-corn on moderately sloping land in Central Illinois or Indiana, assuming the following management details and dates: Wheat is seeded October 15 in a 40-percent cover of disked corn residue, and a grass and legume meadow mix is seeded with the wheat. The wheat would normally develop a 10-percent cover by November 1, 50 percent by December 1, 75 percent by April 15, and nearly 100 percent in the maturing stage. It is harvested July 15, leaving an 80-percent surface cover of straw and small grass. The sod developed under 1 full year of meadow, yielding more than 3 t of hay, is turned under in April. The field is disked May 5 and is harrowed and planted to corn May 10. The first-year corn, harvested October 15, is followed by fall chiseling about November 15 and spring disking for second-year corn. Residue cover is 50 percent after fall chiseling and 30 percent after corn planting on May 10. Fertility, row spacing, and plant population for both corn years are such that 10, 50, and 75 percent canopy covers will be developed in 20, 40, and 60 days, respectively, from planting, and final canopy cover is more than 95 percent.

Procedure. Set up a working table similar to the one illustrated in table 8, obtaining the needed information as follows:

Column 1. List in chronological sequence all the land-cover changes that begin new cropstage periods, as previously defined.

Column 2. List the date on which each cropstage period begins.

Column 3. Select the applicable area number

TABLE 8.—*Sample working table for derivation of a rotation* **C** *value*

(1) Event	(2) Date	(3) Table 6, area 16	(4) Cropstage period	(5) EI in period	(6) Soil loss ratio[1]	(7) Sod Factor	(8) Cropstage C value	(9) Crop year
Pl W[2]	10/15	92	SB	0.03	0.27(132)	0.95	0.0077	
10 percent c	11/1	95	1	.03	.21	.95	.0060	
50 percent c	12/1	98	2	.12	.16	1.0	.0192	
75 percent c	4/15	10	3	.46	.03		.0138	
Hv W	7/15	56	4	.28	.07(5C)		.0196	0.066
Meadow	9/15	84		1.26	.004(5B)	1.0	.0050	.005
TP	4/15	10	F	.05	.36(2)	.25	.0045	
Disk	5/5	15	SB	.10	.60	.40	.0240	
Pl C	5/10	—						
10 percent c	6/1	25	1	.13	.52	.40	.0270	
50 percent c	6/20	38	2	.14	.41	.45	.0258	
75 percent c	7/10	52	3	.40	.20	.50	.0400	
Hv C	10/15	92	4L	.05	.30	.60	.0090	.130
Chisel	11/15	97	4c	.17	.16(46)	.60	.0163	
Disk	5/1	14	SB	.11	.25(48 & 61)	.80	.0220	
Pl C	5/10	—						
10 percent c	6/1	25	1	.13	.23	.80	.0239	
50 percent c	6/20	38	2	.14	.21	.85	.0250	
75 percent c	7/10	52	3	.40	.14(48)	.90	.0504	.138
Hv C & pl W	10/15	92						
Rotation totals				4.0			0.3392	
Average annual C value for rotation							.085	

[1] Numbers in parentheses are line numbers in table 5.

[2] Abbreviations: c, canopy cover; C, corn; hv, harvest; pl, plant; TP, moldboard plow; W, wheat.

from figure 9, and from the line in table 6 having the corresponding area number (in this case, 16), read the cumulative percentage of **EI** for each date in column 2. Values for the corn planting dates were omitted in table 8 because the seedbed periods had begun with the spring diskings. The **EI** percentage for May 5 was obtained by interpoiating between readings from May 1 and 15.

Column 4. Identify the cropstage periods.

Column 5. Subtract the number in column 3 from the number in the next lower line. If the cropstage period includes a year end, subtract from 100 and add the number in the next lower line. The differences are percentages and may be pointed off as hundredths.

Column 6. Obtain from table 5. Enter the table with crop and management, pounds of spring residue or production level, and percent mulch cover after planting, in that sequence. The data in the selected line are percentages and are used as hundredths in the computation of **C**. For cropstage 3, use the column whose heading corresponds with expected final canopy. For conditions not listed in the primary table, consult supplements 5-A to D. Lines used for the examples are given in parentheses in column 6.

Column 7. From table 5-D.

Column 8. The product of values in columns 5, 6 and 7. The sum of these products is the value of **C** for the entire rotation. Because **C** is usually desired as an average annual value, this sum is divided by the number of years in the rotation.

Column 9. The subtotals in this column are **C** values for the individual crop-years. They also show the relative contributions of the four crops to the rotation **C** value.

Changes in geographic area or in planting dates would affect the **C** value by changing columns 3 and 5. Changes in amount or disposition of residues, tillage practices, or canopy development would change column 6. Thus **C** can vary substantially for a given crop system.

Values of **C** for one-crop systems are derived by the same procedure but would require only a few lines. Also, column 7 is omitted for meadowless systems.

C-Value Tables for Cropland

It will rarely, if ever, be necessary for a field technician or farmer to compute values of **C**. Persons experienced in the procedures outlined above have prepared **C** value tables for specific geographic areas. Such a table will list all the one-crop and multicrop systems likely to be found within the designated area and will list the **C** values for each system for each of the combinations of management practices that may be associated with it. They are usually listed in ascending or descending order of magnitude of the **C** values. The user can then quickly determine all the potential combinations of cropping and management that have **C** values smaller than any given threshold value. Persons in need of **C** values for a particular locality can usually obtain a copy of the applicable table from the nearest SCS state office.

C Values for Construction Areas

Site preparations that remove all vegetation and also the root zone of the soil not only leave the surface completely without protection but also remove the residual effects of prior vegetation. This condition is comparable to the previously defined continuous fallow condition, and **C** = 1. Roots and residual effects of prior vegetation, and partial covers of mulch or vegetation, substantially reduce soil erosion. These reductions are reflected in the soil loss prediction by **C** values of less than 1.0.

Applied mulches immediately restore protective cover on denuded areas and drastically reduce **C** (*1, 2, 20, 27, 43*). Soil loss ratios for various percentages of mulch cover on field slopes are given by the upper curve of figure 6. Where residual effects are insignificant, these ratios equal **C**. The percentage of surface cover provided by a given rate of uniformly spread straw mulch may be estimated from figure 10 (appendix).

Straw or hay mulches applied on steep construction slopes and not tied to the soil by anchoring and tacking equipment may be less effective than equivalent mulch rates on cropland. In Indiana tests on a 20 percent slope of scalped subsoil, a 2.3-t rate of unanchored straw mulch allowed soil loss of 12 t/A when 5 in of simulated rain was applied at 2.5 in/h on a 35-ft plot (*61*). There was evidence of erosion from flow beneath the straw. Mulches of crushed stone at 135 or more t/A, or wood chips at 7 or more t/A, were more effective. (Broadcast seedings of grass after the tests gave good stands on the plots mulched with 135 or 240 t crushed stone, 70 t road gravel, 12 t wood chips, or 2.3 t straw. Stands were poor on the no-mulch and the 15-t rate of crushed stone mulch.)

Table 9 presents approximate **C** values for straw, crushed stone, and woodchip mulches on construction slopes where no canopy cover exists, and also shows the maximum slope lengths on which these values may be assumed applicable.

Soil loss ratios for many conditions on construc-

TABLE 9.—*Mulch factors and length limits for construction slopes*[1]

Type of mulch	Mulch Rate	Land Slope	Factor C	Length limit[2]
	Tons per acre	*Percent*		*Feet*
None	0	all	1.0	—
Straw or hay,	1.0	1-5	0.20	200
tied down by	1.0	6-10	.20	100
anchoring and				
tacking	1.5	1-5	.12	300
equipment[3]	1.5	6-10	.12	150
Do.	2.0	1-5	.06	400
	2.0	6-10	.06	200
	2.0	11-15	.07	150
	2.0	16-20	.11	100
	2.0	21-25	.14	75
	2.0	26-33	.17	50
	2.0	34-50	.20	35
Crushed stone,	135	<16	.05	200
¼ to 1½ in	135	16-20	.05	150
	135	21-33	.05	100
	135	34-50	.05	75
Do.	240	<21	.02	300
	240	21-33	.02	200
	240	34-50	.02	150
Wood chips	7	<16	.08	75
	7	16-20	.08	50
Do.	12	<16	.05	150
	12	16-20	.05	100
	12	21-33	.05	75
Do.	25	<16	.02	200
	25	16-20	.02	150
	25	21-33	.02	100
	25	34-50	.02	75

[1] From Meyer and Ports (*24*). Developed by an interagency workshop group on the basis of field experience and limited research data.

[2] Maximum slope length for which the specified mulch rate is considered effective. When this limit is exceeded, either a higher application rate or mechanical shortening of the effective slope length is required.

[3] When the straw or hay mulch is not anchored to the soil, **C** values on moderate or steep slopes of soils having K values greater than 0.30 should be taken at double the values given in this table.

tion and developmental areas can be obtained from table 5 if good judgment is exercised in comparing the surface conditions with those of agricultural conditions specified in lines of the table. Time intervals analogous to cropstage periods will be defined to begin and end with successive construction or management activities that appreciably change the surface conditions. The procedure is then similar to that described for cropland.

Establishing vegetation on the denuded areas as quickly as possible is highly important. A good sod has a **C** value of 0.01 or less (table 5-B), but such a low **C** value can be obtained quickly only by laying sod on the area, at a substantial cost. When grass or small grain is started from seed, the probable soil loss for the period while cover is developing can be computed by the procedure outlined for estimating cropstage-period soil losses. If the seeding is on topsoil, without a mulch, the soil loss ratios given in line 141 of table 5 are appropriate for cropstage **C** values. If the seeding is on a desurfaced area, where residual effects of prior vegetation are no longer significant, the ratios for periods SB, 1 and 2 are 1.0, 0.75 and 0.50, respectively, and line 141 applies for cropstage 3. When the seedbed is protected by a mulch, the pertinent mulch factor from the upper curve of figure 6 or table 9 is applicable until good canopy cover is attained. The combined effects of vegetative mulch and low-growing canopy are given in figure 7. When grass is established in small grain, it can usually be evaluated as established meadow about 2 mo after the grain is cut.

C Values for Pasture, Range, and Idle Land

Factor **C** for a specific combination of cover conditions on these types of land may be obtained from table 10 (57). The cover characteristics that must be appraised before consulting this table are defined in the table and its footnotes. Cropstage periods and **EI** monthly distribution data are generally not necessary where perennial vegetation has become established and there is no mechanical disturbance of the soil.

Available soil loss data from undisturbed land were not sufficient to derive table 10 by direct comparison of measured soil loss rates, as was done for development of table 5. However, analyses of the assembled erosion data showed that the research information on values of **C** can be extended to completely different situations by combining subfactors that evaluate three separate and distinct, but interrelated, zones of influence: (a) vegetative cover in direct contact with the soil surface, (b) canopy cover, and (c) residual and tillage effects.

Subfactors for various percentages of surface cover by mulch are given by the upper curve of

TABLE 10.—*Factor* **C** *for permanent pasture, range, and idle land*[1]

Vegetative canopy		Cover that contacts the soil surface						
Type and height[2]	Percent cover[3]	Type[4]	Percent ground cover					
			0	20	40	60	80	95+
No appreciable canopy		G	0.45	0.20	0.10	0.042	0.013	0.003
		W	.45	.24	.15	.091	.043	.011
Tall weeds or short brush with average drop fall height of 20 in	25	G	.36	.17	.09	.038	.013	.003
		W	.36	.20	.13	.083	.041	.011
	50	G	.26	.13	.07	.035	.012	.003
		W	.26	.16	.11	.076	.039	.011
	75	G	.17	.10	.06	.032	.011	.003
		W	.17	.12	.09	.068	.038	.011
Appreciable brush or bushes, with average drop fall height of 6½ ft	25	G	.40	.18	.09	.040	.013	.003
		W	.40	.22	.14	.087	.042	.011
	50	G	.34	.16	.08	.038	.012	.003
		W	.34	.19	.13	.082	.041	.011
	75	G	.28	.14	.08	.036	.012	.003
		W	.28	.17	.12	.078	.040	.011
Trees, but no appreciable low brush. Average drop fall height of 13 ft	25	G	.42	.19	.10	.041	.013	.003
		W	.42	.23	.14	.089	.042	.011
	50	G	.39	.18	.09	.040	.013	.003
		W	.39	.21	.14	.087	.042	.011
	75	G	.36	.17	.09	.039	.012	.003
		W	.36	.20	.13	.084	.041	.011

[1] The listed **C** values assume that the vegetation and mulch are randomly distributed over the entire area.

[2] Canopy height is measured as the average fall height of water drops falling from the canopy to the ground. Canopy effect is inversely proportional to drop fall height and is negligible if fall height exceeds 33 ft.

[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 in deep.

W: cover at surface is mostly broadleaf herbaceous plants (as weeds with little lateral-root network near the surface) or undecayed residues or both.

TABLE 11.—*Factor* **C** *for undisturbed forest land*[1]

Percent of area covered by canopy of trees and undergrowth	Percent of area covered by duff at least 2 in deep	Factor C[2]
100-75	100-90	.0001-.001
70-45	85-75	.002-.004
40-20	70-40	.003-.009

[1] Where effective litter cover is less than 40 percent or canopy cover is less than 20 percent, use table 6. Also use table 6 where woodlands are being grazed, harvested, or burned.

[2] The ranges in listed **C** values are caused by the ranges in the specified forest litter and canopy covers and by variations in effective canopy heights.

figure 6. Subfactors for various heights and densities of canopy cover are given in figure 5. The subfactor for residual effects of permanent pasture, range, idle land, or grazed or harvested woodland has been estimated to vary from 0.45 to 0.10 (57). Major influences on this subfactor are plant roots, organic matter buildup in the topsoil, reduced soil compaction, and surface stabilization after long periods without soil disturbance. The **C** values given in table 10 were derived by combining subfactors for specified combinations of type, height, and density of canopy cover; type and density of cover at the soil surface; and probable residual effects of longtime existence of the specified cover on the land. They are compatible with the rather scarce existing soil loss data from undisturbed land areas.

C Values for Woodland

Three categories of woodland are considered separately: (1) undisturbed forest land; (2) woodland that is grazed, burned, or selectively harvested; and (3) forest lands which have had site preparation treatments for re-establishment after harvest.

In undisturbed forests, infiltration rates and organic matter content of the soil are high, and much or all of the surface is usually covered by a layer of compacted decaying forest duff or litter several inches thick. Such layers of duff shield the soil from the erosive forces of runoff and of drop impact and are extremely effective against soil erosion. Where cover by trees and litter is incomplete, the spots with little or no litter cover are partially protected by undergrowth canopy. Factor **C** for undisturbed forest land may be obtained from table 11. These estimated **C** values are supported by the quite limited existing data and also by the subfactor-evaluation procedure discussed in the preceding subsection.

Woodland that is grazed or burned, or has been recently harvested, does not merit the extremely low **C** values of table 11. For these conditions, **C** is obtained from table 10. However, the buildup of organic matter in the topsoil under permanent woodland conditions is an added factor that should be accounted for by a reduction in the **C** value read from table 10. An earlier publication (57) recommended a factor of 0.7 for this purpose.

Site preparation treatments for re-establishing trees on harvested forest land usually alter the erosion factors substantially. Canopy effect is initially greatly reduced or lost entirely, and its restoration is gradual. Some of the forest litter is incorporated in the soil, and it may be entirely removed from portions of the area. A surface roughness factor is introduced. Windrowed debris, if across slope, may function as terraces by reducing effective slope length and inducing deposition above and in the windrows. The amount of residual effect retained depends on the amount and depth of surface scalping. Some of the changes are analogous to cropland situations. Some of the relationships available from tables 5 and 10 can be used to evaluate **C** for these conditions, but neither table is directly applicable.

Table 12 presents **C** values computed for Southern Pine Forests that have had site preparation treatments after harvesting. This table was jointly developed (in 1977) by representatives of SEA, SCS, and Forest Service, using factor relationships from tables 5, 10, and 11 as basic guides. Its application on forest lands in other climatic regions may require some modifications of factor values. Research designed to refine and improve tables 10, 11, and 12 is underway.

Tree plantings on converted cropland should, in the initial years, be evaluated similarly to cropland because the forest residual effect which underlies tables 10 to 12 will not be applicable. The subfactor for residual effects may be estimated by selecting from lines 1 to 16 of table 5 the line that most nearly describes the condition of the converted cropland and assuming a residual subfactor equal to the seedbed-period value given in that line. If the cropland has most recently been in

TABLE 12.—*Factor* **C** *for mechanically prepared woodland sites*

Site preparation	Mulch cover[1]	Soil condition[2] and weed cover[3]							
		Excellent		Good		Fair		Poor	
		NC	WC	NC	WC	NC	WC	NC	WC
	Percent								
Disked, raked, or bedded[4]	None	0.52	0.20	0.72	0.27	0.85	0.32	0.94	0.36
	10	.33	.15	.46	.20	.54	.24	.60	.26
	20	.24	.12	.34	.17	.40	.20	.44	.22
	40	.17	.11	.23	.14	.27	.17	.30	.19
	60	.11	.08	.15	.11	.18	.14	.20	.15
	80	.05	.04	.07	.06	.09	.08	.10	.09
Burned[5]	None	.25	.10	.26	.10	.31	.12	.45	.17
	10	.23	.10	.24	.10	.26	.11	.36	.16
	20	.19	.10	.19	.10	.21	.11	.27	.14
	40	.14	.09	.14	.09	.15	.09	.17	.11
	60	.08	.06	.09	.07	.10	.08	.11	.08
	80	.04	.04	.05	.04	.05	.04	.06	.05
Drum chopped[5]	None	.16	.07	.17	.07	.20	.08	.29	.11
	10	.15	.07	.16	.07	.17	.08	.23	.10
	20	.12	.06	.12	.06	.14	.07	.18	.09
	40	.09	.06	.09	.06	.10	.06	.11	.07
	60	.06	.05	.06	.05	.07	.05	.07	.05
	80	.03	.03	.03	.03	.03	.03	.04	.04

[1] Percentage of surface covered by residue in contact with the soil.

[2] *Excellent* soil condition—Highly stable soil aggregates in topsoil with fine tree roots and litter mixed in.

Good—Moderately stable soil aggregates in topsoil or highly stable aggregates in subsoil (topsoil removed during raking), only traces of litter mixed in.

Fair—Highly unstable soil aggregates in topsoil or moderately stable aggregates in subsoil, no litter mixed in.

Poor—No topsoil, highly erodible soil aggregates in subsoil, no litter mixed in.

[3] NC—No live vegetation.

WC—75 percent cover of grass and weeds having an average drop fall height of 20 in. For intermediate percentages of cover, interpolate between columns.

[4] Modify the listed **C** values as follows to account for effects of surface roughness and aging:

First year after treatment: multiply listed **C** values by 0.40 for rough surface (depressions >6 in); by 0.65 for moderately rough; and by 0.90 for smooth (depressions <2 in).

For 1 to 4 years after treatment: multiply listed factors by 0.7.

For 4+ to 8 years: use table 6.

More than 8 years: use table 7.

[5] For first 3 years: use **C** values as listed.

For 3+ to 8 years after treatment: use table 6.

More than 8 years after treatment: use table 7.

meadow, the selected seedbed soil loss ratio is multiplied by a factor from table 5-D. If mulch is applied, a subfactor read from the upper curve of figure 6 is multiplied by the residual subfactor to obtain **C**. When canopy develops, a canopy subfactor from figure 5 is also included.

SUPPORT PRACTICE FACTOR (P)

In general, whenever sloping soil is to be cultivated and exposed to erosive rains, the protection offered by sod or close-growing crops in the system needs to be supported by practices that will slow the runoff water and thus reduce the amount of soil it can carry. The most important of these supporting cropland practices are contour tillage, stripcropping on the contour, and terrace systems. Stabilized waterways for the disposal of excess rainfall are a necessary part of each of these practices.

By definition, factor **P** in the USLE is the ratio of soil loss with a specific support practice to the corresponding loss with up-and-down-slope culture. Improved tillage practices, sod-based rotations, fertility treatments, and greater quantities of crop residues left on the field contribute materially to erosion control and frequently provide the major control in a farmer's field. However, these are considered conservation cropping and management practices, and the benefits derived from them are included in **C**.

Contouring

The practice of tillage and planting on the contour, in general, has been effective in reducing erosion. In limited field studies, the practice provided almost complete protection against erosion from storms of moderate to low intensity, but it provided little or no protection against the occasional severe storms that caused extensive breakovers of the contoured rows. Contouring appears to be the most effective on slopes in the 3- to 8-percent range. As land slope decreases, it approaches equality with contour row slope, and the soil loss ratio approaches 1.0. As slope increases, contour row capacity decreases and the soil loss ratio again approaches 1.0.

Effectiveness of contouring is also influenced by the slope length. When rainfall exceeds infiltration and surface detention in large storms, breakovers of contour rows often result in concentrations of runoff that tend to become progressively greater with increases in slope length. Therefore, on slopes exceeding some critical length the amount of soil moved from a contoured field may approach or exceed that from a field on which each row carries its own runoff water down the slope. At what slope length this could be expected to occur would depend to some extent on gradient, soil properties, management, and storm characteristics.

P Values for Contouring

A joint SEA and SCS workshop group, meeting at Purdue University in 1956, adopted a series of contour **P** values that varied with percent slope. The **P** values were based on available data and field observations supplemented by group judgment. Subsequent experience indicated only a few minor changes. Current recommendations are given in table 13. They are average values for the factor on the specified slopes. Specific-site values may vary with soil texture, type of vegetation, residue management, and rainfall pattern, but data have not become available to make the deviations from averages numerically predictable.

Full contouring benefits are obtained only on fields relatively free from gullies and depressions other than grassed waterways. Effectiveness of this practice is reduced if a field contains numerous small gullies and rills that are not obliterated by normal tillage operations. In such instances, land smoothing should be considered before contouring. Otherwise, a judgment value greater than shown in table 13 should be used when computing the benefits for contouring.

TABLE 13.—**P** *values and slope-length limits for contouring*

Land slope percent	P value	Maximum length[1]
		Feet
1 to 2	0.60	400
3 to 5	.50	300
6 to 8	.50	200
9 to 12	.60	120
13 to 16	.70	80
17 to 20	.80	60
21 to 25	.90	50

[1] Limit may be increased by 25 percent if residue cover after crop seedlings will regularly exceed 50 percent.

Slope-Length Limits

After the 1956 workshop, the SCS prepared reference tables for use with the Corn Belt slope-practice procedure. They included guides for slope-length limits for effective contouring, based largely on judgment. These limits, as modified with later data and observations (*16, 42*), are also given in table 13. Data to establish the precise limits for specific conditions are still not available. However, the **P** values given in table 13 assume slopes short enough for full effectiveness of the practice. Their use for estimating soil loss on unterraced slopes that are longer than the table limits specified is speculative.

Contour Listing

Contour listing, with corn planted in the furrows, has been more effective than surface planting on the contour (*29*). However, the additional effectiveness of the lister ridges applies only from the date of listing until the ridges have been largely obliterated by two corn cultivations. Therefore, it can be more easily credited through **C** than through **P**. This is done by a 50-percent reduction in the soil loss ratios (table 5) that apply to the time interval during which the ridges are intact. The standard **P** value for contouring is applicable in addition to the **C** value reduction.

Potato rows on the contour present a comparable condition from lay-by time until harvest. However, this ridging effect has been already credited in table 5, line 160, and should not be duplicated.

Controlled-Row Grade Ridge Planting

A method of precise contouring has been developed that provides effective conservation on farm fields where the land slope is nearly uniform, either naturally or by land smoothing, and runoff from outside the field can be diverted. The practice uses ridge planting with undiminished channel capacity to carry water maintained throughout the year. It is being studied in Texas (*36*), Arkansas, Mississippi (*8*), and Iowa (*30*). In Texas, the channel cross section, with 40-in row spacing, was nearly 0.5 ft^2, and row grades varied from nearly zero at the upper end to 1 percent at the lower end of a 1,000-ft length. Measured soil loss compared favorably with that from an adjacent terraced watershed. Soil loss measurements in Mississippi and Iowa showed similar effectiveness during the test periods.

Because each furrow functions as an individual terrace, **P** values similar to those for terracing seem appropriate. Slope-length limits for contouring would then not apply, but the length limits would be applicable if the channel capacity were only sufficient for a 2-year design storm.

Contoured-Residue Strips

Contoured strips of heavy crop-residue mulch, resembling contour stripcropping without the sod, may be expected to provide more soil loss reduction than contouring alone. **P** values equal to about 80 percent of those for contouring are recommended if fairly heavy mulch strips remain throughout the year. If the strips are maintained only from harvest until the next seedbed preparation, the credit should be applied to the soil loss ratio for cropstage 4 rather than the **P** value.

Contour Stripcropping

Stripcropping, a practice in which contoured strips of sod are alternated with equal-width strips of row crops or small grain, is more effective than contouring alone. Alternate strips of grain and meadow year after year are possible with a 4-year rotation of corn-wheat with meadow seeding-meadow-meadow. This system has the added advantage of a low rotation **C** value. A stripcropped rotation of corn-corn-wheat-meadow is less effective. Alternate strips of winter grain and row crop were effective on flat slopes in Texas (*14*), but alternate strips of spring-seed grain and corn on moderate to steep slopes have not provided better erosion control than contouring alone.

Observations from stripcrop 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. Thus the stripcrop factor, derived from soil loss measurements at the foot of the slope, accounts for off-the-field soil movement but not for all movement within the field.

P Values, Strip Widths, and Length Limits

Recommended **P** values for contour stripcropping are given in table 14. The system to which each column of factors applies is identified in the table footnotes. The strip widths given in column 5 are essentially those recommended by the 1956 slope-practice workshop and are to be considered approximate maximums. Reasonable adjustments to accommodate the row spacing and row multiple of the planting and harvesting equipment are permissible. Slope-length limit is generally not a critical factor with contour stripcropping except on extremely long or steep slopes. The lengths given in column 6 are judgment values based on field experience and are suggested as guides.

Buffer Stripcropping

This practice consists of narrow protective strips alternated with wide cultivated strips. The location of the protective strips is determined by the width and arrangement of adjoining strips to be cropped in the rotation and by the location of steep, severely eroded areas on slopes. Buffer strips usually occupy the correction areas on sloping land and are seeded to perennial grasses and legumes. This type of stripcropping is not as effective as contour stripcropping (*4*).

TABLE 14.—**P** *values, maximum strip widths, and slope-length limits for contour stripcropping*

Land slope percent	P values[1]			Strip width[2]	Maximum length
	A	B	C		
				Feet	Feet
1 to 2	0.30	0.45	0.60	130	800
3 to 5	.25	.38	.50	100	600
6 to 8	.25	.38	.50	100	400
9 to 12	.30	.45	.60	80	240
13 to 16	.35	.52	.70	80	160
17 to 20	.40	.60	.80	60	120
21 to 25	.45	.68	.90	50	100

[1] **P** values:

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

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

C For alternate strips of row crop and small grain.

[2] Adjust strip-width limit, generally downward, to accommodate widths of farm equipment.

Terracing

The most common type of terrace on gently sloping land is the broadbase, with the channel and ridge cropped the same as the interterrace area. The steep backslope terrace is most common on steeper land. Difficulty in farming point rows associated with contoured terraces led to developing parallel terracing techniques (*16*). Underground outlets, landforming, and variable channel grades help establish parallel terraces. The underground outlets are in the low areas along the terrace line. The ridge is constructed across these areas. Another type of terrace, using a level and broad channel with either open or closed ends, was developed to conserve moisture in dryland farming areas.

Terraces with underground outlets, frequently called impoundment terraces, are highly effective for erosion control. Four-year losses from four such terrace systems in Iowa (*17*) averaged less than 0.4 t/A/year, which was less than 5 percent of the calculated soil movement to the channel. Comparable losses were measured from installations in Nebraska.

Terracing combined with contour farming and other conservation practices is more effective than those practices without the terraces because it positively divides the slope into segments equal to the horizontal terrace interval. The horizontal terrace interval for broadbase terraces is the distance from the center of the ridge to the center of the channel for the terrace below. For steep backslope terraces with the backslope in sod, it is the distance from the point where cultivation begins at the base of the ridge to the base of the frontslope of the terrace below (*44*). With terracing, the slope length is this terrace interval; with stripcropping or contouring alone, it is the entire field slope length.

P Values

Values of **P** for contour farming terraced fields are given in table 15. These values apply to contour farmed broadbase, steep backslope, and level terraces. However, recognize that the erosion control benefits of terraces are much greater than indicated by the **P** values. As pointed out earlier, soil loss per unit area on slopes of 5 percent or steeper is approximately proportional to the square root of slope length. Therefore, dividing a field slope into **n** approximately equal horizontal terrace intervals divides the average soil loss per unit area by the square root of **n**. This important erosion control benefit of terracing is not included in **P** because it is brought into the USLE computation through a reduced **LS** factor obtained by using the horizontal terrace interval as the slope length when entering figure 4 or table 3.

Erosion control between terraces depends on the crop system and other management practices evaluated by **C**. The total soil movement within a contour-farmed terrace interval may be assumed equal to that from the same length of an identical slope that is contoured only. Therefore, if a control level is desired that will maintain soil movement between the terraces within the soil loss tolerance limit, the **P** value for a contour-farmed terraced field should equal the contour factor (col. 2, table 15), and use of these values for farm planning purposes is generally recommended.

With contour stripcropping, the soil deposited in the grass strips is not considered lost because it remains on the field slope. With terraces, most of the deposition occurs in the terrace channels, but research measurements have shown that this deposition may equal 80 percent of the soil moved from the contour-farmed slopes between the terraces (*67*). Use of the contour factor as the **P** value for terracing assumes that all of the eroded soil deposited in the terrace channels is lost from the productive areas of the field. With broadbase terraces, the channels and ridges are cropped the same as

TABLE 15.—**P** *values for contour-farmed terraced fields*[1]

Land slope (percent)	Farm planning		Computing sediment yield[3]	
	Contour factor[2]	Stripcrop factor	Graded channels sod outlets	Steep backslope underground outlets
1 to 2	0.60	0.30	0.12	0.05
3 to 8	.50	.25	.10	.05
9 to 12	.60	.30	.12	.05
13 to 16	.70	.35	.14	.05
17 to 20	.80	.40	.16	.06
21 to 25	.90	.45	.18	.06

[1] Slope length is the horizontal terrace interval. The listed values are for contour farming. No additional contouring factor is used in the computation.

[2] Use these values for control of interterrace erosion within specified soil loss tolerances.

[3] These values include entrapment efficiency and are used for control of offsite sediment within limits and for estimating the field's contribution to watershed sediment yield.

the interterrace slopes, and some of the material deposited in the channels is moved to the ridges in terrace maintenance. The 1956 slope-practice group felt that some of the deposition should be credited as soil saved and recommended use of a terracing practice factor equal to the stripcrop factor (*64*). However, the more conservative values given in column 2 are now commonly used in conservation planning.

When the USLE is used to compute a terraced field's contribution to offsite sediment or watershed gross erosion, the substantial channel deposition must be credited as remaining on the field area. For this purpose, the **P** values given in the last two columns of table 15 are recommended unless an overland flow deposition equation based on transport relationships is used with the USLE.

With widespread use of large multirow equipment, farming with field boundaries across nonparallel terraces is not uncommon in some regions. When terraces are not maintained and overtopping is frequent, **P** = 1 and the slope length is the field slope length. However, if the terraces are periodically maintained so that overtopping occurs only during the most severe storms, **LS** is based on the horizontal terrace interval. If farming across terraces is at an angle that approximates contour farming, **P** values less than 1.0 but greater than the contour factors would be appropriate.

Soil Loss Terrace Spacing

Traditionally, terrace spacing has been based on slope gradient; however, some recent spacing guides have included modifying factors for severity of rainfall and for favorable soil and tillage combinations. A major objective of cropland conservation planning is to hold the productive topsoil in place. Extending this objective to terrace system design suggests limiting slope lengths between terraces sufficiently so that specified erosion tolerances will not be exceeded. Using the USLE in developing spacing guides will make this possible.

The USLE may be written as **LS = T/RKCP,** where **T** is the tolerance limit. If **T/RKP = Z,** then **LS = Z/C,** and **C = Z/LS.** The values **T, R, K** and **P** are constant for a given location and can be obtained from handbook tables and charts as illustrated in the section **Predicting Cropland Soil Losses.** Factor **C** can be selected as the **C** value of the most erosion-vulnerable crop system that a farmer is likely to use on the terraced field. **LS** can be computed by solving the equation as written above and, with the percent slope known, the maximum allowable length can be read from the slope-effect chart, figure 4.

To illustrate the procedure, assume a 6-percent slope at a location where **R** = 175, **K** = 0.32, **T** = 5, **P** = 0.5, and the most erodible crop expected to occur on the field has a **C** value of 0.24. (An assumption that the field will always be in a sod based rotation or that the operator will always make the best possible use of the crop residues would be too speculative to serve as a guide for terrace spacing.) With these assumptions, **Z** = 5/175 (0.32)(0.5) = 0.179 and **LS** = 0.179/0.24, or 0.744. Enter the slope-effect chart, figure 4, on the **LS** scale with a value of 0.744, move horizontally to intersect the 6 percent-slope line and read the corresponding slope length, 120 ft, on the horizontal scale. Add to this value the width of the terrace frontslope and compute the vertical interval: $\left(\frac{120+12}{100}\right)6 = 7.9$ ft. However, the horizontal interval should not exceed the slope-length limit for effectiveness of contouring. From table 13 the length limit for contouring on a 6-percent slope is 200 ft, so the computed terrace interval is satisfactory. A small modification in spacing may be made to adjust to an even multiple of machinery width.

The maximum **C** value that will allow a horizontal terrace spacing equal to the length limit for effective contouring on the given slope can also be determined by using figure 4 and table 13. For the conditions in the illustration above, **C** = 0.179/**LS.** The maximum acceptable length for contouring is 200 ft. From figure 4, the **LS** value for a 200-ft length of 6-percent slope is 0.95. Therefore, the maximum allowable **C** = 0.179/0.95, which is 0.188. With terraces spaced at 200-ft intervals, any cropping and management system with a **C** value of less than 0.188 should provide the level of conservation prescribed by the assumed soil loss tolerance limit of 5 t/A/year.

One additional consideration is important. For a terrace to function satisfactorily, the channel capacity must be sufficient to carry the runoff safely to a stabilized outlet without excessive channel scour or overtopping of the ridge. SCS engineering practice standards specify a capacity sufficient to control the runoff from a 10-year-frequency, 24-hour storm without overtopping. Some SCS practice standards may require a shorter terrace interval than would be indicated by the foregoing procedure.

The discussion of the topographic factor pointed out that the erosion rate increases as slope length increases. Table 4 lists the relative soil losses for successive equal-length increments of a uniform slope divided into 2, 3, 4, or 5 segments. The third column of table 4 shows that if a uniform 6-percent slope were controlled at a tolerance of 5 t average soil loss, the average loss per unit area from the lower third of the slope would exceed the tolerance by about 38 percent. Soil loss from the upper third would be 43 percent less than the tolerance limit. To have an average rate of 5 t from the lower third, the **T** values used in the spacing calculation would need to be 1/1.38 times the 5-t tolerance, or 3.6 t. This is an approach that can be used to calculate terrace spacings for a higher level of conservation.

Effect of Terraces on Amount and Composition of Offsite Sediment

By reducing runoff velocity and inducing deposition of sediment in the channels, terraces have a profound effect on the amount and composition of offsite sediments from cultivated fields. The type of terrace, the channel grade, and the type of outlet influence the magnitude of the effect.

The greatest reduction in sediment is attained with the impoundment type terrace systems that use underground outlets. With the outlets in the lower areas of the field and terrace ridges built across these areas, temporary ponds are created around the risers of the outlet tile. The outlets are designed to drain the impounded runoff in 1 to 2 days. Thus, the ponds provide a maximum stilling effect, and only the smallest and lightest soil particles are carried off the field in the runoff water. The increased time for infiltration also reduces runoff.

Sediments collected from four impoundment terrace systems over 4 years in Iowa (*17*) showed the following percentages of fine materials:

Soil type	< 0.002 mm *Percent*	< 0.008 mm *Percent*
Fayette silt loam	78	91
Sharpsburg silty clay loam	68	96
Floyd loam	31	82
Clarion loam	35	78

Sediment concentrations in the runoff ranged from about 1,300 p/m on the Fayette soil to 6,300 p/m on the Clarion. Average annual sediment from the outlets was less than 800 lb/A for all four systems.

Farm chemical losses in runoff vary with type and formulation, amount, placement, and time of rainfall in relation to time of application, as well as with the usual runoff and erosion factors. Principal chemicals are the fertilizers, insecticides, fungicides, and herbicides. Losses are by solution and by suspension of chemical granules or adsorption on soil particles suspended in the runoff water.

Terracing exerts its greatest influence in reducing offsite pollution from those chemicals that are adsorbed on soil particles. Examples of these are the phosphates, organic nitrogen, and persistent organochlorine insecticides. Reductions in offsite *sediment* by terrace systems with contouring are estimated to range from 82 to 95 percent. However, the reductions in chemical transport are generally not proportional to reductions in soil loss because of an enrichment process that applies to the suspensions. The nutrient content of sediments is often 50 percent greater than that of the soil. Offsite delivery of sediment is also affected by watershed characteristics, particularly size of the drainage area. This reduction is measured by a "delivery ratio" that ranges from 0.33 for an area of one-half square mile to 0.08 for a 200-mi^2 area (*45*).

Terracing has the least effect on offsite pollution from those chemicals transported primarily in solution. Annual runoff reductions by terracing and contour farming, at 21 locations throughout the United States, have been estimated to vary only from 9 to 37 percent (*42*). Examples of farm chemicals transported primarily in solution are the nitrates and some herbicides such as 2,4-D ((2,4-dichlorophenoxy) acetic acid). The predominate transport modes for an extensive list of pesticides are listed in volumes 1 and 2 of "Control of Water Pollution From Cropland" (*42*).

APPLYING THE SOIL LOSS EQUATION

The major purpose of the soil loss prediction procedure is to supply specific and reliable guides for selecting adequate erosion control practices for farm fields and construction areas. The procedure is also useful for computing the upland erosion phase of sediment yield as a step in predicting rates of reservoir sedimentation or stream loading, but the USLE factors are more difficult to evaluate for large mixed watersheds. Specific applications of the soil loss equation are discussed and illustrated below.

Predicting Cropland Soil Losses

The USLE is designed to predict longtime-average soil losses for specified conditions. This may be the average for a rotation or for a particular crop year or cropstage period in the rotation. Where the term "average loss" is used below, it denotes the average for a sufficient number of similar events or time intervals to cancel out the plus and minus effects of short-time fluctuations in uncontrolled variables.

Rotation Averages

To compute the average annual soil loss from a particular field area, the first step is to refer to the charts and tables discussed in the preceding sections and select the values of **R**, **K**, **LS**, **C**, and **P** that apply to the specific conditions on that field. For example, assume a field on Russell silt loam soil in Fountain County, Ind. The dominant slope is about 8 percent with a length of 200 ft. Fertility and crop management on this field are such that crop yields are rarely less than 85 bu corn, 40 bu wheat, or 4 t alfalfa-brome hay. The probability of meadow failure is slight.

Factor **R** is taken from the isoerodent map (fig. 1). Fountain County, in west-central Indiana, lies between isoerodents of 175 and 200. By linear interpolation, **R** = 185. **K** is taken from a table of **K** values that were derived either by direct research measurement or by use of the soil erodibility nomograph (fig. 3). For the Russell silt loam soil, **K** = 0.37. The slope-effect chart, figure 4, shows that an 8 percent slope 200 ft long has an **LS** of 1.41. If the field were continuously in clean-tilled fallow, the average annual soil loss from the dominant slope would equal the product **RKLS**; that is, 185(0.37)(1.41) = 96.5 t/A.

Next, we need to know the effect of the cropping and management system and support practices existing on the field. This effect is represented by factors **C** and **P**. The **C** value for the field may either be derived by the procedure previously presented, using data from tables 5 and 6, or it may be obtained from a centrally prepared **C** value table available from the SCS. For convenience, assume the same crop system and management as were assumed for the problem illustrating the derivation of locality **C** values. From table 8, **C** then equals 0.085. If rows and tillage are in the direction of the land slope, factor **P** = 1.0. The computed average soil loss is then 96.5(0.085)(1.0) = 8.2 t/A/year.

From table 13, contour farming on 8 percent slopes not exceeding 200 ft in length has a **P** value of 0.5. Therefore, if farming were on the contour, the computed average soil loss for the field would be 96.5(0.085)(0.5) = 4.1 t. If the length of 8-percent slope was appreciably greater than 200 ft, the effectiveness of contouring could not be assumed, and the **P** value of 0.5 would not be applied unless the slope length was broken by terraces or diversions. Any change in either the crop sequence or the management practices would likely increase or decrease soil loss. This would be reflected in the USLE solution through a change in the **C** value.

When **C** is used at its average annual value for a rotation that includes a sod crop, as was done in the example given in table 8, the heavier losses experienced during row crop years are diluted by trivial losses in the meadow year(s). For holding longtime-average soil losses below some prescribed tolerance limit, this dilution poses no problem. But from the viewpoint of offsite water quality, it may not be desirable. The USLE may also be used to compute the average soil loss for each crop in the rotation or for a particular cropstage period.

Crop-Year Averages

The subtotals in column 9 of table 8 show that with the assumed management system, **C** for the first-year corn would be 0.130 and for the second-year, 0.138. For the second-year corn, without contouring, the expected average soil loss would equal 185(0.37)(1.41)(0.138), or 13.3 t. If, in the same crop system, the corn residues were plowed down in fall, the **C** value for second-year corn would be 0.29, and the soil loss would average 28 t. On the other hand, no-till planting the second-year corn in a 70-percent cover of shredded cornstalks would reduce the **C** value for this crop to 0.08 and the soil loss to about 8 t. This would also reduce the rotation average for straight row farming to 7 t. Killing the meadow instead of turning it under, and no-till planting, would reduce the **C** value for the first-year corn to 0.01 and the soil loss to less than 1 t. Thus, crop-year **C** values can be helpful for sediment control planning.

Cropstage Averages

Additional information can be obtained by computing the average annual soil loss for each cropstage period. First, the computed cropstage soil losses will show in which portions of the crop year (or rotation cycle) improved management practices would be most beneficial. Second, they provide information on the probable seasonal distribution of sediment yields from the field. When a tabulation like table 8 has been prepared, the values in column 8 will be directly proportional to the cropstage soil losses. They can be converted to tons per acre for a specific field by multiplying them by the product of factors **R**, **K**, **LS**, and **P**.

To estimate the average soil loss for a particular cropstage when such a table has not been prepared, the cropstage soil loss ratio from table 5 is used as **C**. The annual **EI** fraction that is applicable to the selected period is obtained from table 6 and is multiplied by the location's annual erosion index value (fig. 1) to obtain the relevant **R** value. **K**, **LS**, and **P** will usually be assumed to have the same values as for computation of average annual soil losses.

Suppose, for example, that one wishes to predict the average soil loss for the seedbed and establishment periods of corn that is conventionally planted about May 15 on spring plowed soybean land in southwestern Iowa (area No. 13, fig. 9). Suppose also that the corn is on a field for which the combined value of factors **K**, **LS**, and **P** is 0.67 and the fertility and crop management are such that corn planted by May 15 usually develops a 10 percent canopy cover by June 5, 50 percent by June 25, and a final canopy cover of more than 95 percent. Interpolating between values in line 13 of table 6 shows cumulative **EI** percentages of 12, 23, and 43 for these three dates. Therefore, on the average, 11 percent of the annual **EI** would occur in the seedbed period, and 20 percent would occur in the establishment period. From line 109 of table 5, the soil loss ratios for these two cropstage periods under the assumed management are 0.72 and 0.60. From figure 1, the average annual **EI** is 175. The soil loss would be expected to average $0.11(175)(0.72)(0.67) = 9.3$ t/A in the seedbed period and $0.20(175)(0.60)(0.67) = 14$ t in the establishment period. The cropping assumed for this example represents an extremely erodible condition. For second-year corn with good residue management, the applicable soil loss ratios and the predicted soil losses would be much lower.

Individual Storm Soil Losses

The USLE factors derived from tables and charts presented herein compute longtime-average soil losses for specified cover and management on a given field. The USLE is not recommended for prediction of specific soil loss events.

If it is applied to a specific rainstorm, using the storm **EI** for **R** and the relevant cropstage soil loss ratio for **C**, it will estimate the *average* soil loss for a large number of storms of this size occurring on that field and in that cropstage period. However, the soil loss from any one of these events may differ widely from this average because of interactions with variables whose values fluctuate randomly over time (*56*).

When rain falls on relatively dry, freshly tilled soil, most of the water may infiltrate before runoff begins, resulting in a low-average soil loss per unit of **EI** for that storm. When rain falls on presaturated soil, runoff begins quickly, and most of the rain becomes runoff. Such rains usually produce above-average soil loss per **EI** unit. Some rains are accompanied by high winds that increase the impact energy of raindrops; others occur in a fairly calm atmosphere. Some storms begin with a high intensity and seal the surface quickly so that trailing lower intensities encounter a low infiltration rate. In other storms the moderate intensities precede the high ones. In some seasons the soil is cultivated when wet and remains cloddy; in other seasons it is cultivated when soil moisture is ideal for fine pulverization. A claypan or fragipan subsoil may substantially influence permeability in early spring or in a wet growing season and yet have no significant effect on infiltration rates during intense thunderstorms on dry soil.

The soil loss ratios of table 5 are averages for cropstage periods that cover several weeks to several months. Early in a cropstage period, the ratio will usually be higher than the average because the development of cover is gradual. Later in the period it will be lower than average. In a poor growing season the ratio will be above average because cover and water use by transpiration are below normal. In a favorable growing season, the ratio will be below average. Cover effect in a specific year may be substantially influenced by abnormal rainfall. A crop canopy or conservation tillage practice may delay the start of runoff long enough to be 100 percent effective for moderate storms on a given field and yet allow substantial erosion by prolonged runoff periods.

The irregular fluctuations in these and other variables can greatly influence specific-storm soil losses. However, they do not invalidate the USLE for predicting long-term-average soil losses for specific land areas and management conditions. Their positive and negative effects tend to balance over a longtime period, and their average effects are reflected in the factor-evaluation tables and charts.

Two recent research reports are recommended references for those who find it necessary to estimate specific-storm soil losses (*34*, *10*). The authors present modifications of **R** and **LS** that are designed to account for some random effects discussed.

Specific-Year Soil Losses

In any given year, both the annual **EI** and its monthly distribution may differ substantially from the location averages. Therefore, **R** values from figure 1 and **EI** distribution data from table 6 will not correctly reflect specific-year values of these variables. The most accurate procedure is to compute the **EI** value for each storm from a recording-rain gage record for the location and year by the method given in the appendix. The storm values are summed for each cropstage period, and the subtotals are combined with soil loss ratios from table 5 to estimate the soil loss for each cropstage period. The sum of the cropstage soil losses then reflects the effects of possible abnormal **EI** distribution, as well as the corrected **R** value for the specific year. However, the irregular fluctuations in variables discussed in the preceding subsection are often related to abnormalities in rainfall. The plus and minus effects on soil loss may not average out within 1 year but may appreciably bias specific-year soil losses. These biases will not be evaluated by the USLE. Therefore, specific-year estimates of soil loss will be less accurate than USLE estimates of long-term, crop-year averages.

Soil Loss Probabilities

Soil loss probabilities are a function of the combination of the probabilities for annual **EI**, seasonal distribution of the erosive rains, abnormal antecedent soil moisture conditions, favorable or unfavorable conditions for soil tillage and crop development, and other factors. The section on the **Rainfall Erosion Index** pointed out that a location's annual and maximum storm **EI** values tend to follow log-normal frequency distributions and that specific probability values are listed in tables 17 and 18 for 181 key locations. When these probabilities of **EI** are used for **R** in the USLE, the equation will estimate the soil loss that would occur if all the other factors were at their normal levels. However, the seasonal distribution of erosive rains, and the surface conditions in the field, may also be abnormal in years of rainfall extremes. Deriving probable relationships of these variables to extremes in annual **EI** would require longer records than were available.

Stochastic modeling techniques (*66*) are available that could be used to generate synthetic data having the same statistical properties as historical data. Such data could be used to estimate the probable range in specific-year soil losses in a particular rainfall area.

Determining Alternative Land Use and Treatment Combinations

The soil loss prediction procedure supplies the practicing conservationist with concise reference tables from which he can ascertain, for each particular situation encountered, which specific land use and management combinations will provide the desired level of erosion control. A number of possible alternatives are usually indicated. From these, the farmer will be able to make a choice in line with his desires and financial resources.

Management decisions generally influence erosion losses by affecting the factor **C** or **P** in the erosion equation. **L** is modified only by constructing terraces, diversions, or contour furrows with sufficient capacity throughout the year to carry the runoff water from the furrow area above. **R, K,** and **S** are essentially fixed as far as a particular field is concerned.

When erosion is to be limited within a predetermined tolerance, **T,** the term **A** in the equation is replaced by **T,** and the equation is rewritten in the form **CP** = **T/RKLS.** Substituting the site values of the fixed factors in this equation and solving for **CP** give the maximum value that the product **CP** may assume under the specified field conditions. With no supporting practices, **P** = 1, and the most intensive cropping plan that can be safely used on the field is one for which **C** just equals this value. When a supporting practice like contouring or stripcropping is added, the computed value of **T/RKLS** is divided by the practice factor, **P,** to obtain the maximum permissible cover and management factor value. Terracing increases the value of **T/RKLS** by decreasing the value **L.**

A special USLE calculator, originally designed in Tennessee (*41*) and recently updated, enables rapid and systematic calculation of either average annual soil loss or **T/RKLS** for any specific situation.

Many practicing conservationists prefer to use handbook tables. **C**-value tables for specific geographic areas (fig. 9) are centrally prepared by persons who are experienced in the procedures outlined in a preceding section and who obtain the needed data from tables 5 and 6. Values of **T/RKLS** are also centrally computed and arranged in two-way classification as illustrated in table 16 for **R** = 180, **K** = 0.32, and **T** = 5. Similar tables are prepared for other combinations of **R, K,** and **T.**

A conservationist working in the field usually carries a pocket-sized handbook which includes the **R** value(s), **T** and **K** soil values, applicable tables of **T/RKLS** values, and a table of **C** values for the area. These items will provide all the information needed to use this procedure as a guide for selecting conservation practices in each field. Solving the equation or performing field computations rarely will be necessary.

TABLE 16.—*Maximum permissible* **C** *values* (**T/RKLS**) *for* **R** = *180,* **K** = *0.32 and* **T** = *5*

Gradient percent	Values for slope lengths (feet) 50	75	100	150	200	250	300	400
	STRAIGHT ROW							
2	0.53	0.47	0.43	0.38	0.35	0.33	0.31	0.28
4	.29	.24	.22	.18	.16	.15	.14	.12
6	.18	.15	.13	.11	.091	.082	.074	.064
8	.12	.10	.087	.072	.062	.055	.050	.044
10	.090	.073	.063	.052	.045	.040	.037	.032
12	.068	.056	.048	.039	.034	.030	.028	.024
14	.054	.044	.038	.031	.027	.024	.022	.019
16	.043	.035	.030	.025	.022	.019	.018	.015
	CONTOURED[1]							
2	0.89	0.78	0.72	0.64	0.58	0.55	0.52	0.47
4	.57	.49	.43	.37	.33	.30	.28	.25
6	.36	.30	.26	.21	.18	.16	([2])	—
8	.25	.20	.17	.14	.12	.11	—	—
10	.15	.12	.11	.086	([2])	—	—	—
12	.11	.093	.080	.065	—	—	—	—
14	.077	.062	.054	([2])	—	—	—	—
16	.062	.050	.044	—	—	—	—	—

[1] The values for contour farming are T/RKLSP, where P is dependent on percent slope (see table 13).

[2] Omission of values indicates that the slope-lengths exceed the limits for effectiveness of contouring. Use corresponding values from upper half of table.

Example. The first step is to ascertain the soil type, percent slope, and slope length for the field being planned. From his handbook data, the conservationist can then obtain the values of **R, K,** and **T.** To complete the illustration, assume that **R** = 180, **K** = 0.32, **T** = 5, and the field slope is 400 ft long with a nearly uniform gradient of 6 percent. For this combination, the **T/RKLS** table shows a value of 0.064 for straight-row farming with the land slope (table 16). This is the maximum **C** value that will hold the average annual soil loss from that field within the 5-t tolerance limit, if no supporting practices are used. Consulting the **C** value table will show that a **C** as low as 0.064 can be attained only with well-managed, sod-based crop systems, or with no-till planting in residue covers of at least 70 percent.

A logical improvement is to add contouring. Table 13 shows a slope-length limit of 200 ft (250 ft if residue cover after seeding exceeds 50 percent) for contouring on 6-percent slope. Therefore, the **P** value of 0.5 for contouring will not be applicable on the 400-ft slope without terracing. Construction of three, equally spaced terraces across the slope would divide it into four 100-ft slope lengths. Shortening the slope lengths to 100 ft will assure contour effectiveness and will also reduce the site value of **L**. For a 100-ft length of 6-percent slope farmed on the contour, table 16 shows a **T/RKLSP** value of 0.26. Any combination of cropping and management practices having a **C** value less than 0.26 will now be acceptable. Consulting the table of **C** values will show that with the terraces and contouring, the conservationist can recommend a range of possibilities for land use and management. If a system with a **C** value appreciably less than 0.26 is selected, a higher level of conservation will be attained than required by the 5-t tolerance limit.

Had the slope length in the example been only 200 ft, the contour **P** value of 0.5 (table 13) would have been applicable without the terraces. Table 16 shows that this combination would have permitted use of any system having a **C** value less than 0.18.

Thus, by this procedure a conservationist can list all the alternative crop system and management combinations that would control erosion on a field at an acceptable level. Study of this list will show how an erosion control program can be improved and still increase crop yields or decrease labor and fuel costs. In making a selection from this list, practices needed for control of nutrient and pesticide losses in the runoff (*42*) should also be considered.

Construction Sites

Procedures and data have been presented for predicting erosion losses from specific cropland areas and logically determining alternative ways in which the losses from each field may be held below given tolerance limits. These procedures and data can also be adapted to conditions on highway, residential, and commercial developing areas. The USLE will show under which development plan the area will produce the least sediment, and it will also show about how much sediment the developer will need to trap in sediment basins (*46*) during construction to prevent excessive soil movement to streams or reservoirs.

Evaluating the erosion factors for construction site conditions is discussed below. However, those primarily concerned with this particular phase of sediment control should also read the preceding discussions of the USLE factors and the procedures for predicting cropland soil losses.

Factor R. For a construction project extending over several years, the average annual **R** value for the site is obtained directly from figure 1. Probabilities of **EI** values greater than average are given in table 17. Using **EI** probabilities for **R** was discussed in the subsection **Soil Loss Probabilities.**

For construction periods of less than 1 year, the procedure outlined for predicting cropland soil losses for specific cropstage periods is appropriate. The portion of the annual **R** value that is applicable to the construction period is obtained from table 6 as illustrated on p. 41 for cropstage averages.

Factor K. Because the soil surface is often unprotected during construction, this factor assumes even greater importance than for cropland. The soil erodibility nomograph (fig. 3) can be especially helpful for sediment prediction and erosion control planning on construction sites because it can predict the changes in erodibility when various subsoil horizons are exposed in the reshaping process. Some subsoils are substantially more erodible than the original topsoil, and others are less erodible. The planner can usually obtain a detailed description of the successive horizons of his soil from published soil survey data. By using the data for each soil horizon separately to follow the steps of the nomograph solution, the **K** value can be determined after various depths of desurfacing. Soil losses from the successive soil horizons, if exposed on similar slopes, would be directly proportional to the horizon **K** values. Information on the subsoil **K** values not only shows the depths of cut that would result in the most or the least soil erosion but also indicates whether return of stockpiled topsoil on the exposed subsoil would be profitable on the particular site.

When a chemical soil additive is used that stabilizes the soil and makes it less erodible, the **K** value is the nomograph solution times a factor for the effectiveness of the chemical additive.

Factor LS. Within limits, the **LS** value for a given length and steepness of uniform slope can be obtained directly from figure 4 or table 3. When the slope is concave or convex, the figure 4 value needs to be adjusted by the procedure outlined for irregular slopes in the section on **The Topographic Factor.**

Development planning may include measures designed to reduce sediment yield by lowering **LS.** The effect of shortening slope lengths by diversions or stabilized drainageways is credited by entering figure 4 with the reduced slope length. A slope graded to flatten toward the bottom (concave) will lose less soil than an equivalent uniform slope whereas one that steepens toward the bottom (convex) will lose more. Reduction or increase in soil loss can be predicted by the procedure illustrated in the subsection **Irregular Slopes.**

Data are not available to evaluate **LS** on very steep slopes, like 2:1 and 3:1 roadbank slopes, in relation to soil and rainstorm characteristics. The best presently available estimates of **LS** for these slopes can be obtained by the **LS** equation presented earlier. However, values projected by this equation for steep slopes are speculative because the equation was derived from data obtained on slopes of less than 20 percent.

Factor C. Procedures for selecting **C** values for construction sites were given in the **Cover and Management Factor** section.

Factor P. This factor as used for soil conservation planning on cropland would rarely have a counterpart during construction on development areas, and **P** will usually equal 1.0. Erosion-reducing effects of shortening slopes or reducing slope gradients are accounted for through the **LS** factor.

If the lower part of a grass or woodland slope on a development area can be left undisturbed while the upper part is being developed, the procedure outlined for computing the value of **LSC** on irregular slopes is applicable, and sediment deposition on the undisturbed strip must be accounted for separately. For prolonged construction periods, buffer strips of grass, small grain, or high rates of anchored mulch may also be feasible to induce deposition within the area. Such deposition is important for water quality or offsite sediment control, but it should be evaluated from soil-transport factors rather than by a **P** factor.

Alternative plans. When appropriate numerical values of the six erosion factors are combined, their product is the soil loss estimate for the particular area in tons per acre and for the time interval for which **R** was evaluated. With the information supplied by the tables and charts in this handbook, the six factor values can be derived for each feasible alternative plan. Successive solutions of the equation will then provide comparative soil loss estimates to help guide decisions by the developer.

Estimating Upslope Contributions to Watershed Sediment Yield

The importance of predicting watershed sediment yields and identifying the major sediment sources was increased by the Federal Water Pollution Control Act Amendments of 1972, Public Law 92-500. Sources, causes, and potentials of sediment, nutrient, and pesticide losses from cropland, and measures that may be necessary to control these pollutants, are dealt with in depth in a two-volume manual developed by SEA and the Environmental Protection Agency (EPA) (*42*). Volume II, "An Overview," also includes an extensive list of other relevant publications. Only sediment yield prediction will be considered here.

Estimates show that about one-fourth of the amount of sediment moved by flowing water in the United States annually reaches major streams (*42*). The USLE can be used to compute average sheet and rill erosion in the various parts of a watershed, but deposition and channel-type erosion must be estimated by other means. A fully tested equation for sediment transport to use on agricultural land is not now available. One presented by Neibling and Foster (*32*) is perhaps the best now available for use with the USLE. It estimates transport capacity for sand and large silt-sized particles and does not consider the transport of clay particles.

Of the several methods now used for estimating sediment yield, the Gross Erosion-Sediment Delivery Method uses the USLE. A brief description of this method follows. More details are available from the SCS National Engineering Handbook (*45*). The equation is

$$Y = E(DR)/W_s \qquad (6)$$

where **Y** is sediment yield per unit area,
E is the gross erosion,
DR is the sediment delivery ratio, and
W_s is the area of the watershed above the point for which the sediment yield is being computed.

Gross Erosion

Gross erosion is the summation of erosion from all sources within the watershed. It includes sheet and rill erosion from tilled cropland, meadows, pastures, woodlands, construction sites, abandoned acreages, and surface-mined areas; gully erosion from all sources; and erosion from streambeds and streambanks. The relative importance of each of these sources of gross erosion will vary between watersheds.

The USLE can be used to estimate the sediment generated by sheet and rill erosion that is usually, but not always, the major portion of a watershed's gross erosion. Sediment from gully, streambank and streambed erosion, and from uncontrolled roadsides must be added to the USLE estimates. Methods for estimating sediment yields from these sources are discussed in Section 3 of the SCS National Engineering Handbook (*45*).

For small areas like farm fields or construction sites, the six USLE factors can usually be evaluated directly from the information presented in this handbook. For a large heterogeneous watershed, the factors are more difficult to define. Several methods of computing the average slope length and gradient for a large drainage area are available. Using **LS** values based on such averages, together with estimated watershed-average soil and cover factors, simplifies the computing procedure, but the saving in time is at the expense of substantial loss in accuracy. Erosion hazards are highly site specific. The parameters that determine the USLE factor values vary within a large watershed, and the variations are often not interrelated. Combining overall averages in the equation does not reflect the particular way in which the factors are actually combined in different parts of the watershed. Neither does it show which portions of the drainage area are contributing most of the sediment.

A more accurate procedure is to divide the heterogeneous drainage area into subareas for which representative soil type, slope length, gradient, cover, and erosion-control practice factors can be defined. The USLE is then used to compute the sheet and rill erosion on each subarea. For this purpose, eroded soil that is entrapped within the field area by terrace systems is not soil loss. An estimate of the entrapped sediment can be excluded from the USLE soil loss estimates by using values from the last two columns of table 15 as the **P** values. An alternate procedure is to estimate the channel deposition by sediment-transport relationships and subtract this amount from the soil loss computed by using the standard terracing factor (col. 2, table 15) in the USLE. By this procedure, the subarea soil loss computations identify the portions of the drainage area that contribute most of the sediment and also show how much of the sediment derives from tracts that receive heavy applications of agricultural chemicals.

Procedures for computing soil losses from cropped, idle, pasture, range, or wooded areas and from construction or development areas were outlined in the preceding sections. Factor values derived by the prescribed procedures are assumed applicable also for surface-mined areas. However, the effect of mining processes on soil erodibility, **K**, has not been determined. Length and percent slope and deposition within the area also are hard to determine for rugged strip mine spoils. Sometimes nearly all the sediment may be trapped within the bounds of the area. The USLE can be quite useful for predicting the effectiveness of each feasible reclamation plan for such areas.

Sediment Delivery Ratio

Eroded soil materials often move only short distances before a decrease in runoff velocity causes their deposition. They may remain in the fields where they originated or may be deposited on more level slopes that are remote from the stream system. The ratio of sediment delivered at a given location in the stream system to the gross erosion from the drainage area above that location is the sediment delivery ratio for that drainage area. A general equation for computing watershed delivery ratios is not yet available, but the ratios for some specific drainage areas have been computed directly from local data. Helpful guides for estimating this factor for other drainage areas were published by SCS in Section 3 of their National Engineering Handbook (*45*), and most of these guides were also included in a publication by SEA and EPA (*42*). Therefore, the relationships involved will be only briefly summarized here.

Available watershed data indicate that the delivery ratio varies approximately as the 0.2 power of drainage-area size, with representative values of about 0.33 for 0.5 mi^2; 0.18 for 10 mi^2; and 0.10 for 100 mi^2. There were indications that the exponent in this relationship may be as small as 0.1 for very large areas. But the ratio may vary substantially for any given size of drainage area. Other important factors include soil texture, relief, type of erosion, sediment transport system, and areas of deposition within the watershed. Fine soil texture, high channel density, and high stream gradients generally indicate delivery ratios that are above average for the drainage-area size.

A substantial reduction in sediment delivered to a stream may sometimes result in a compensatory increase in channel erosion. Channel erosion produces sediment that is immediately available to the transport system and that may remain in motion as bedload and suspended sediment. The composition of sediment derived from channel erosion will usually differ substantially from that derived from cropland erosion. This is particularly important from the viewpoint of transported chemical pollutants.

With reference to a field-sized area, the delivery ratio can closely approach 1.0 if the runoff drains directly into a lake or stream system with no intervening obstructions or flattening of the land slope. On the other hand, a substantial width of forest litter or dense vegetation below the eroding area may cause deposition of essentially all the sediment except colloidal material. Anything that reduces runoff velocity (such as reduction in gradient, physical obstructions, vegetation, and ponded water) reduces its capacity to transport sediment. When the sediment load exceeds the transport capacity of the runoff, deposition occurs.

From analysis of runoff and soil loss data from small single-cropped watersheds, Williams (*48*) concluded that the need for a sediment delivery ratio could be eliminated by using the watershed runoff times peak rate as the storm **R** value in the USLE.

Accuracy of USLE Predictions

Soil losses computed with the USLE are best available estimates, not absolutes. They will generally be most accurate for medium-textured soils, slope lengths of less than 400 ft, gradients of 3 to 18 percent, and consistent cropping and management systems that have been represented in the erosion plot studies. The farther these limits are exceeded, the greater will be the probability of significant extrapolation error.

An indication of the accuracy of the equation, tables, and charts presented herein was obtained by using them to compute longtime average soil losses for plots in past erosion studies and comparing these with the actually measured losses on each plot. About 53 percent of the differences were less than 1 t/A, 84 percent were less than 2 t, and 5 percent were as much as 4.6 t (*53*). The mean annual soil loss for this 2,300 plot-year sample was 11.3 t. Of those differences that exceeded 1 t/A, 67 percent were from comparisons with plot records whose duration was less than half of a normal 22-year rainfall cycle (*33*). Such short records are subject to bias by cyclical effects and random fluctuations in uncontrolled variables whose effects are averaged in the USLE factor values (*56*). Testing the complete equation against the assembled plot data was statistically valid because the equation for each factor, as a function of several parameters, was independently derived from only selected portions of the data.

The accuracy of a predicted soil loss will depend on how accurately the physical and management conditions on the particular piece of land are described by the parameter values used to enter the factor-evaluation tables and charts. An error in the selection of a factor value will produce an equivalent percentage error in the soil loss estimate. Large-scale averaging of parameter values on mixed drainage areas will usually also reduce accuracy. For reasons previously pointed out and discussed in depth in another publication (*56*), specific-storm or specific-year soil losses and short-term averages may differ substantially from the longtime average predicted by the USLE for the specified physical and management conditions.

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APPENDIX

Estimating Percentages of Canopy and Mulch Covers

"Percent canopy cover" is the percentage of the field area that could not be hit by vertically falling raindrops because of canopy interception. It is the portion of the soil surface that would be covered by shadows if the sun were directly overhead. Because the blades from adjacent rows intertwine does not necessarily indicate 100 percent canopy cover.

"Percent mulch cover" is the percentage of the field area that is covered by pieces of mulch lying on the surface. Researchers in Indiana attempted to relate percent cover to mulch rate by photographing numerous small, equal-sized areas in harvested corn fields. The residues on the photographed areas were carefully picked up, dried, and weighed to measure mulch rates, and the photographs were projected on grids to determine percent cover. The indicated average relation of percent cover to dry weight of well-distributed corn stover mulch is shown by the solid-line curve in figure 10. However, observed differences between samples were appreciable. The average relation of percent cover to dry weight of straw mulch uniformly distributed over research plots is shown by the broken-line curve.

A simple method of estimating percent mulch cover on a field is with a cord, preferably not shorter than 50 ft, that has 100 equally spaced knots or other readily visible markings. The cord is stretched diagonally across several rows, and the knots that contact a piece of mulch are counted. This procedure is repeated at randomly selected spots on the field, and the data are averaged to obtain a representative value for the field.

Probability Values of EI in the United States

The annual and maximum-storm values of **EI** at any given location differ substantially from year to year. The observed ranges and 50 percent, 20 percent and 5 percent probabilities of annual **EI** values from 22-year precipitation records at 181 locations in 44 States are listed in table 17. Other probabilities can be derived by plotting the 50 percent and 5 percent values on log-probability paper and joining the two points by a straight line. Annual maxima storm probabilities for the same locations are given in table 18.

Computing the Erosion Index from Recording-Rain Gage Records

Soil loss prediction by the method presented in this handbook does not require computation of **EI** values by application personnel, but the procedure is included here for the benefit of those who may wish to do so.

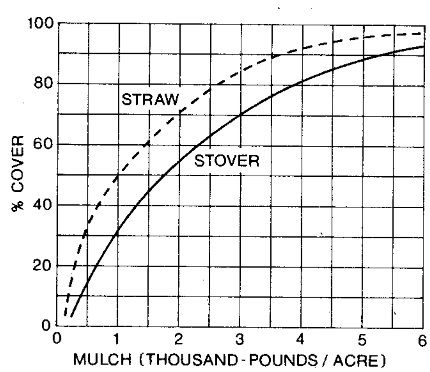

FIGURE 10.—Relation of percent cover to dry weight of uniformly distributed residue mulch.

The kinetic energy of a given amount of rain depends on the sizes and terminal velocities of the raindrops, and these are related to rainfall intensity. The computed energy per inch of rain at each intensity is shown in table 19. The energy of a given storm depends on all the intensities at which the rain occurred and the amount that occurred at each intensity. A recording-rain gage record of the storm will provide this information. Clock time and rain depth are read from the chart at each point where the slope of the pen line changes and are tabulated as shown in the first two columns of the sample computation below. Clock times (col. 1) are subtracted to obtain the time intervals given in column 3, and the depths (col. 2) are subtracted to obtain the incremental amounts tabulated in column 4. The intensity for each increment (col. 5) is the incremental amount times 60, divided by column 3.

Chart readings		For each increment			Energy	
Time	Depth (inch)	Duration (minute)	Amount (inch)	Intensity (in/hr)	Per inch	Total
4:00	0					
:20	0.05	20	0.05	0.15	643	32
:27	.12	7	.07	.60	843	59
:36	.35	9	.23	1.53	977	225
:50	1.05	14	.70	3.00	1074	752
:57	1.20	7	.15	1.29	953	143
5:05	1.25	8	.05	.38	777	39
:15	1.25	20	0	0	0	0
:30	1.30	15	.05	.20	685	34
Totals		90	1.30			1,284

Kinetic energy of the storm = $1{,}284(10^{-2}) = 12.84$

The energy per inch of rain in each interval (col. 6) is obtained by entering table 19 with the intensity given in column 5. The incremented energy amounts (col. 7) are products of columns 4 and 6. The total energy for this 90-minute rain is 1,284 foot-tons per acre. This is multiplied by a constant factor of 10^{-2} to convert the storm energy to the dimensions in which **EI** values are expressed.

The maximum amount of rain falling within 30 consecutive minutes was 1.08 in, from 4:27 to 4:57. I_{30} is twice 1.08, or 2.16 in/h. The storm **EI** value is $12.84(2.16) = 27.7$. When the duration of a storm is less than 30 minutes, I_{30} is twice the amount of the rain.

The **EI** for a specified time is the sum of the computed values for all significant rain periods within that time. The average annual erosion index for a specific locality, as given in figures 1 and 2, is the sum of all the significant storm **EI** values over 20 to 25 years, divided by the number of years. For erosion index calculations, 6 h or more with less than 0.5 in of precipitation was defined as a break between storms. Rains of less than 0.5 in, separated from other showers by 6 h or more, were omitted as insignificant unless the maximum 15-min intensity exceeded 0.95 in/h.

Recent studies showed that the median dropsize of rain does not continue to increase for intensities greater than about 2.5 to 3 in/h (*7, 15*). Therefore, energy per unit of rainfall also does not continue to increase, as was assumed in the derivation of the energy-intensity table published in 1958 (*62*). The value given in table 19 for rain at 3 in/h (7.6 cm/h in table 20) should be used for all greater intensities. Also, analysis of the limited soil loss data available for occasional storms with 30-min intensities greater than 2.5 in/h showed that placing a limit of 2.5 in (6.35 cm)/h on the I_{30} component of **EI** improved prediction accuracy for these storms. Both of these limits were applied in the development of figure 1. They slightly lowered previously computed erosion index values in the Southeast, but average-annual **EI** values for the U.S. mainland other than the Southeast were not significantly affected by the limits because they are rarely exceeded.

Conversion to Metric System

Metric equivalents were not included in the procedures and tables presented in this handbook because direct conversion of each English unit would produce numbers that would be awkward and undesirable. Converting the USLE as a whole is more appropriate. Metric units can then be selected so that each of the interdependent factors will have a metric counterpart whose values will be expressed in numbers that are easy to visualize and to combine in computations.

A convenient unit for measuring cropland soil losses is metric tons per hectare per year. **EI** values of convenient magnitude can be obtained by expressing rainfall energy in metric ton-meters per hectare, expressing intensities in centimeters per hour, and retaining the constant factor of 10^{-2} that has been used consistently for **EI** calculations in English units. Factor **K** will then be in metric tons per hectare per metric **EI** unit. If 22 meters is taken as the basic slope length and 9 percent is retained as the basic slope gradient, the **LS** factor will not be significantly affected. Using these units is recommended and is assumed in the following paragraphs.

The USLE factors will normally be derived directly in these units by procedures outlined below. However, the following conversion factors will facilitate comparisons of the metric factor values with the English values published in this handbook. Factors expressed in the recommended metric units are identified by the subscript, **m**.

Text continues on page 56.

TABLE 17.—*Observed range and 50-, 20-, and 5- percent probability values of erosion index at each of 181 key locations*

Location	Values of erosion index (*EI*)			
	Observed 22-year range	50-percent probability	20-percent probability	5-percent probability
Alabama:				
Birmingham	179-601	354	461	592
Mobile	279-925	673	799	940
Montgomery	164-780	359	482	638
Arkansas:				
Fort Smith	116-818	254	400	614
Little Rock	103-625	308	422	569
Mountain Home	98-441	206	301	432
Texarkana	137-664	325	445	600
California:				
Red Bluff	11-240	54	98	171
San Luis Obispo	5-147	43	70	113
Colorado:				
Akron	8-247	72	129	225
Pueblo	5-291	44	93	189
Springfield	4-246	79	138	233
Connecticut:				
Hartford	65-355	133	188	263
New Haven	66-373	157	222	310
District of Columbia	84-334	183	250	336
Florida:				
Apalachicola	271-944	529	663	820
Jacksonville	283-900	540	693	875
Miami	197-1225	529	784	1136
Georgia:				
Atlanta	116-549	286	377	488
Augusta	148-476	229	308	408
Columbus	215-514	336	400	473
Macon	117-493	282	357	447
Savannah	197-886	412	571	780
Watkinsville[1]	182-544	278	352	441
Illinois:				
Cairo	126-575	231	349	518
Chicago	50-379	140	212	315
Dixon Springs[1]	89-581	225	326	465
Moline	80-369	158	221	303
Rantoul	73-286	152	201	263
Springfield	38-315	154	210	283
Indiana:				
Evansville	104-417	188	263	362
Fort Wayne	60-275	127	183	259
Indianapolis	60-349	166	225	302
South Bend	43-374	137	204	298
Terre Haute	81-413	190	273	389
Iowa:				
Burlington	65-286	162	216	284
Charles City	39-308	140	205	295
Clarinda[1]	75-376	162	220	295
Des Moines	30-319	136	198	284
Dubuque	54-389	175	251	356
Sioux City	56-336	135	205	308
Rockwell City	40-391	137	216	335
Kansas:				
Burlingame	57-447	176	267	398
Coffeyville	66-546	234	339	483
Concordia	38-569	131	241	427
Dodge City	16-421	98	175	303
Goodland	10-166	76	115	171
Hays[1]	66-373	116	182	279
Wichita	42-440	188	292	445
Kentucky:				
Lexington	54-396	178	248	340
Louisville	84-296	168	221	286
Middlesboro	107-301	154	197	248
Louisiana:				
Lake Charles	200-1019	572	786	1063
New Orleans	273-1366	721	1007	1384
Shreveport	143-707	321	445	609
Maine:				
Caribou	26-120	58	79	106
Portland	36-241	91	131	186
Skowhegan	39-149	78	108	148
Maryland:				
Baltimore	50-388	178	263	381
Massachusetts:				
Boston	39-366	99	159	252
Washington	65-229	116	153	198
Michigan:				
Alpena	14-124	57	85	124
Detroit	56-179	100	134	177
East Lansing	35-161	86	121	166
Grand Rapids	33-203	84	123	178
Minnesota:				
Alexandria	33-301	88	147	240
Duluth	7-227	84	127	189
Fosston	22-205	62	108	184
Minneapolis	19-173	94	135	190
Rochester	46-338	142	207	297
Springfield	37-290	96	154	243
Mississippi:				
Meridian	216-820	416	557	737
Oxford	131-570	310	413	543
Vicksburg	165-786	365	493	658
Missouri:				
Columbia	98-419	214	297	406
Kansas City	28-361	170	248	356
McCredie[1]	64-410	189	271	383
Rolla	105-415	209	287	387
Springfield	97-333	199	266	352
St. Joseph	50-359	178	257	366
St. Louis	59-737	168	290	488
Montana:				
Billings	2-82	12	26	50
Great Falls	3-62	13	24	44
Miles City	1-101	21	40	72
Nebraska				
Antioch	18-131	60	86	120
Lincoln	44-289	133	201	299
Lynch	34-217	96	142	205
North Platte	14-236	81	136	224
Scribner	69-312	154	205	269
Valentine	4-169	64	100	153

See footnote at end of table.

TABLE 17.—*Observed range and 50-, 20-, and 5- percent probability values of erosion index at each of 181 key locations*—Continued

Location	Values of erosion index (*EI*)			
	Observed 22-year range	50-percent probability	20-percent probability	5-percent probability
New Hampshire:				
Concord	52-212	91	131	187
New Jersey:				
Atlantic City	71-318	166	229	311
Marlboro[1]	58-331	186	254	343
Trenton	37-382	149	216	308
New Mexico:				
Albuquerque	0-46	10	19	35
Roswell	5-159	41	73	128
New York:				
Albany	40-172	81	114	159
Binghamton	20-151	76	106	146
Buffalo	20-148	66	96	139
Geneva[1]	33-180	73	106	152
Marcellus[1]	24-241	74	112	167
Rochester	22-180	66	101	151
Salamanca	31-202	70	106	157
Syracuse	8-219	83	129	197
North Carolina:				
Asheville	76-238	135	175	223
Charlotte	113-526	229	322	443
Greensboro	102-357	184	244	320
Raleigh	152-569	280	379	506
Wilmington	196-701	358	497	677
North Dakota:				
Bismarck	9-189	43	73	120
Devils Lake	21-171	56	90	142
Fargo	5-213	62	113	200
Williston	4-71	30	45	67
Ohio:				
Cincinnati	66-352	146	211	299
Cleveland	21-186	93	132	185
Columbiana	29-188	96	129	173
Columbus	45-228	113	158	216
Coshocton[1]	72-426	158	235	343
Dayton	56-245	125	175	240
Toledo	32-189	83	120	170
Oklahoma:				
Ardmore	100-678	263	395	582
Cherokee[1]	49-320	167	242	345
Guthrie[1]	69-441	210	316	467
McAlester	105-741	272	411	609
Tulsa	19-584	247	347	478
Oregon:				
Pendleton	2-28	4	8	16
Portland	16-80	40	56	77
Pennsylvania:				
Erie	11-534	96	181	331
Franklin	50-228	97	135	184
Harrisburg	48-232	105	146	199
Philadelphia	72-361	156	210	282
See footnote at end of table.				
Pittsburgh	43-201	111	148	194
Reading	84-308	144	204	285
Scranton	52-198	104	140	188
Puerto Rico:				
San Juan	203-577	345	445	565

Location	Values of erosion index (*EI*)			
	Observed 22-year range	50-percent probability	20-percent probability	5-percent probability
Rhode Island:				
Providence	53-225	119	167	232
South Carolina:				
Charleston	174-1037	387	559	795
Clemson[1]	138-624	280	384	519
Columbia	81-461	213	298	410
Greenville	130-589	249	350	487
South Dakota:				
Aberdeen	19-295	74	129	219
Huron	18-145	60	91	136
Isabel	16-141	48	78	125
Rapid City	10-140	37	64	108
Tennessee:				
Chattanooga	163-468	269	348	445
Knoxville	64-370	173	239	325
Memphis	139-595	272	384	536
Nashville	116-381	198	262	339
Texas:				
Abilene	27-554	146	253	427
Amarillo	33-340	110	184	299
Austin	59-669	270	414	624
Brownsville	46-552	267	386	549
Corpus Christi	124-559	237	330	451
Dallas	93-630	263	396	586
Del Rio	19-405	121	216	374
El Paso	4-85	18	36	67
Houston	176-1171	444	674	1003
Lubbock	17-415	82	158	295
Midland	35-260	82	139	228
Nacogdoches	153-769	401	571	801
San Antonio	77-635	220	353	556
Temple[1]	81-644	261	379	542
Victoria	108-609	265	385	551
Wichita Falls	79-558	196	298	447
Vermont:				
Burlington	33-270	72	114	178
Virginia:				
Blacksburg[1]	81-245	126	168	221
Lynchburg	64-366	164	232	324
Richmond	102-373	208	275	361
Roanoke	78-283	129	176	237
Washington:				
Pullman[1]	1-30	6	12	21
Spokane	1-19	7	11	17
West Virginia:				
Elkins	43-223	118	158	209
Huntington	56-228	127	173	233
Parkersburg	69-303	120	165	226
Wisconsin:				
Green Bay	17-148	77	107	147
LaCrosse[1]	61-385	153	228	331
Madison	38-251	118	171	245
Milwaukee	31-193	93	139	202
Rice Lake	24-334	122	202	327
Wyoming:				
Casper	1-24	9	15	26
Cheyenne	8-66	28	43	66

[1] Computations based on SEA rainfall records. All others are based on Weather Bureau records.

TABLE 18.—*Expected magnitudes of single-storm erosion index values*

Location	Index values normally exceeded once in—				
	year 1	years 2	years 5	years 10	years 20
Alabama:					
Birmingham	54	77	110	140	170
Mobile	97	122	151	172	194
Montgomery	62	86	118	145	172
Arkansas:					
Fort Smith	43	65	101	132	167
Little Rock	41	69	115	158	211
Mountain Home	33	46	68	87	105
Texarkana	51	73	105	132	163
California:					
Red Bluff	13	21	36	49	65
San Luis Obispo	11	15	22	28	34
Colorado:					
Akron	22	36	63	87	118
Pueblo	17	31	60	88	127
Springfield	31	51	84	112	152
Connecticut:					
Hartford	23	33	50	64	79
New Haven	31	47	73	96	122
District of Columbia	39	57	86	108	136
Florida:					
Apalachicola	87	124	180	224	272
Jacksonville	92	123	166	201	236
Miami	93	134	200	253	308
Georgia:					
Atlanta	49	67	92	112	134
Augusta	34	50	74	94	118
Columbus	61	81	108	131	152
Macon	53	72	99	122	146
Savannah	82	128	203	272	358
Watkinsville	52	71	98	120	142
Illinois:					
Cairo	39	63	101	135	173
Chicago	33	49	77	101	129
Dixon Springs	39	56	82	105	130
Moline	39	50	89	116	145
Rantoul	27	39	56	69	82
Springfield	36	52	75	94	117
Indiana:					
Evansville	26	38	56	71	86
Fort Wayne	24	33	45	56	65
Indianapolis	29	41	60	75	90
South Bend	26	41	65	86	111
Terre Haute	42	57	78	96	113
Iowa:					
Burlington	37	48	62	72	81
Charles City	33	47	68	85	103
Clarinda	35	48	66	79	94
Des Moines	31	45	67	86	105
Dubuque	43	63	91	114	140
Rockwell City	31	49	76	101	129
Sioux City	40	58	84	105	131
Kansas:					
Burlingame	37	51	69	83	100
Coffeyville	47	69	101	128	159
Concordia	33	53	86	116	154
Dodge City	31	47	76	97	124
Goodland	26	37	53	67	80
Hays	35	51	76	97	121
Wichita	41	61	93	121	150
Kentucky:					
Lexington	28	46	80	114	151
Louisville	31	43	59	72	85
Middlesboro	28	38	52	63	73
Louisiana:					
New Orleans	104	149	214	270	330
Shreveport	55	73	99	121	141
Maine:					
Caribou	14	20	28	36	44
Portland	16	27	48	66	88
Skowhegan	18	27	40	51	63
Maryland:					
Baltimore	41	59	86	109	133
Massachusetts:					
Boston	17	27	43	57	73
Washington	29	35	41	45	50
Michigan:					
Alpena	14	21	32	41	50
Detroit	21	31	45	56	68
East Lansing	19	26	36	43	51
Grand Rapids	24	28	34	38	42
Minnesota:					
Duluth	21	34	53	72	93
Fosston	17	26	39	51	63
Minneapolis	25	35	51	65	78
Rochester	41	58	85	105	129
Springfield	24	37	60	80	102
Mississippi:					
Meridian	69	92	125	151	176
Oxford	48	64	86	103	120
Vicksburg	57	78	111	136	161
Missouri:					
Columbia	43	58	77	93	107
Kansas City	30	43	63	78	93
McCredie	35	55	89	117	151
Rolla	43	63	91	115	140
Springfield	37	51	70	87	102
St. Joseph	45	62	86	106	126
Montana:					
Great Falls	4	8	14	20	26
Miles City	7	12	21	29	38
Nebraska:					
Antioch	19	26	36	45	52
Lincoln	36	51	74	92	112
Lynch	26	37	54	67	82
North Platte	25	38	59	78	99
Scribner	38	53	76	96	116
Valentine	18	28	45	61	77

TABLE 18.—*Expected magnitudes of single-storm erosion index values*—Continued

Location	Index values normally exceeded once in—				
	year 1	years 2	years 5	years 10	years 20
New Hampshire:					
Concord	18	27	45	62	79
New Jersey:					
Atlantic City	39	55	77	97	117
Marlboro	39	57	85	111	136
Trenton	29	48	76	102	131
New Mexico:					
Albuquerque	4	6	11	15	21
Roswell	10	21	34	45	53
New York:					
Albany	18	26	38	47	56
Binghamton	16	24	36	47	58
Buffalo	15	23	36	49	61
Marcellus	16	24	38	49	62
Rochester	13	22	38	54	75
Salamanca	15	21	32	40	49
Syracuse	15	24	38	51	65
North Carolina:					
Asheville	28	40	58	72	87
Charlottte	41	63	100	131	164
Greensboro	37	51	74	92	113
Raleigh	53	77	110	137	168
Wilmington	59	87	129	167	206
North Dakota:					
Devils Lake	19	27	39	49	59
Fargo	20	31	54	77	103
Williston	11	16	25	33	41
Ohio:					
Cincinnati	27	36	48	59	69
Cleveland	22	35	53	71	86
Columbiana	20	26	35	41	48
Columbus	27	40	60	77	94
Coshocton	27	45	77	108	143
Dayton	21	30	44	57	70
Toledo	16	26	42	57	74
Oklahoma:					
Ardmore	46	71	107	141	179
Cherokee	44	59	80	97	113
Guthrie	47	70	105	134	163
McAlester	54	82	127	165	209
Tulsa	47	69	100	127	154
Oregon:					
Portland	6	9	13	15	18
Pennsylvania:					
Franklin	17	24	35	45	54
Harrisburg	19	25	35	43	51
Philadelphia	28	39	55	69	81
Pittsburgh	23	32	45	57	67
Reading	28	39	55	68	81
Scranton	23	32	44	53	63
Puerto Rico:					
San Juan	57	87	131	169	216
Rhode Island:					
Providence	23	34	52	68	83
South Carolina:					
Charleston	74	106	154	196	240
Clemson	51	73	106	133	163
Columbia	41	59	85	106	132
Greenville	44	65	96	124	153
South Dakota:					
Aberdeen	23	35	55	73	92
Huron	19	27	40	50	61
Isabel	15	24	38	52	67
Rapid City	12	20	34	48	64
Tennessee:					
Chattanooga	34	49	72	93	114
Knoxville	25	41	68	93	122
Memphis	43	55	70	82	91
Nashville	35	49	68	83	99
Texas:					
Abilene	31	49	79	103	138
Amarillo	27	47	80	112	150
Austin	51	80	125	169	218
Brownsville	73	113	181	245	312
Corpus Christi	57	79	114	146	171
Dallas	53	82	126	166	213
Del Rio	44	67	108	144	182
El Paso	6	9	15	19	24
Houston	82	127	208	275	359
Lubbock	17	29	53	77	103
Midland	23	35	52	69	85
Nacogdoches	77	103	138	164	194
San Antonio	57	82	122	155	193
Temple	53	78	123	162	206
Victoria	59	83	116	146	178
Wichita Falls	47	63	86	106	123
Vermont:					
Burlington	15	22	35	47	58
Virginia:					
Blacksburg	23	31	41	48	56
Lynchburg	31	45	66	83	103
Richmond	46	63	86	102	125
Roanoke	23	33	48	61	73
Washington:					
Spokane	3	4	7	8	11
West Virginia:					
Elkins	23	31	42	51	60
Huntington	18	29	49	69	89
Parkersburg	20	31	46	61	76
Wisconsin:					
Green Bay	18	26	38	49	59
LaCrosse	46	67	99	125	154
Madison	29	42	61	77	95
Milwaukee	25	35	50	62	74
Rice Lake	29	45	70	92	119
Wyoming:					
Casper	4	7	9	11	14
Cheyenne	9	14	21	27	34

Note: These conversions are incorrect. Refer to the supplement for corrections.

$$1\ \text{t/ha} = 2.242\ \text{tons per acre} \quad (7)$$
$$1\ \text{t-m/ha/cm} = 0.269\ \text{ft-tons per acre per inch}$$
$$1\ E_m = 0.683\ E$$
$$1\ I_{30m} = 2.54\ I_{30}$$
$$1\ (EI)_m = 1.735\ EI$$
$$1\ K_m = 1.292\ K$$

Factor R. The procedure for computing $(EI)_m$ for a given rain period is similar to that described in the preceding section for computation of **EI**, but the input data will be in different units. If the rain gage chart used for the preceding example had been calibrated in millimeters, the computation would have been as follows:

Chart readings		Storm increments			Energy	
Time	Depth (mm)	Duration (min)	Amount (cm)	Intensity (cm/h)	Per cm	For increment
4:00	0					
:20	1.2	20	0.12	0.36	175	21
:27	3.0	7	.18	1.54	226	41
:36	8.8	9	.58	3.87	263	153
:50	26.6	14	1.78	7.68	289	514
:57	30.4	7	.38	3.26	256	97
5:05	31.7	8	.13	.98	220	29
:15	31.7	10	0	0	0	0
:30	33.0	15	.13	.52	184	24
Totals		90	3.30			879

Kinetic energy of the storm = $879(10^{-2}) = 8.79$

TABLE 19.—*Kinetic energy of rainfall expressed in foot-tons per acre per inch of rain*[1]

Intensity inch per hour	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0	—	254	354	412	453	485	512	534	553	570
0.1	585	599	611	623	633	643	653	661	669	677
.2	685	692	698	705	711	717	722	728	733	738
.3	743	748	752	757	761	765	769	773	777	781
.4	784	788	791	795	798	801	804	807	810	814
.5	816	819	822	825	827	830	833	835	838	840
.6	843	845	847	850	852	854	856	858	861	863
.7	865	867	869	871	873	875	877	878	880	882
.8	884	886	887	889	891	893	894	896	898	899
.9	901	902	904	906	907	909	910	912	913	915
	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
1	916	930	942	954	964	974	984	992	1000	1008
2	1016	1023	1029	1036	1042	1048	1053	1059	1064	1069
3	[2]1074									

[1] Computed by the equation, $E = 916 + 331 \log_{10} I$, where E = kinetic energy in foot-tons per acre per inch of rain, and I = rainfall intensity in inches per hour.

[2] The 1074 value also applies for all intensities greater than 3 in/h (see text).

TABLE 20.—*Kinetic energy of rainfall expressed in metric ton-meters per hectare per centimeter of rain*[1]

Intensity cm/h	.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	0	121	148	163	175	184	191	197	202	206
1	210	214	217	220	223	226	228	231	233	235
2	237	239	241	242	244	246	247	249	250	251
3	253	254	255	256	258	259	260	261	262	263
4	264	265	266	267	268	268	269	270	271	272
5	273	273	274	275	275	276	277	278	278	279
6	280	280	281	281	282	283	283	284	284	285
7	286	286	287	287	288	288	[2]289			

[1] Computed by the equation $E = 210 + 89 \log_{10} I$, where E = kinetic energy in metric-ton meters per hectare per centimeter of rain, and I = rainfall intensity in centimeters per hour.

[2] The 289 value also applies for all intensities greater than 7.6 cm/h.

Values for column 6 are obtained by entering table 20 with the intensities listed in column 5, and their sum, 879, is the kinetic energy (E_m) of the 3.30 cm of rain expressed in metric ton-meters per hectare. The constant factor of 10^{-2} used for the English system should be applied here also so that storm $(EI)_m$ values will usually not exceed 100. The maximum amount of rain in any 30-minute period was 2.74 cm, from 4:27 to 4:57. Therefore $I_{30m} = 2(2.74 = 5.48$ cm/h. $(EI)_m = 8.79(5.48) = 48.17$

The procedure for combining storm **EI** values for local erosion index values was fully described in the preceding section. For predicting average annual soil losses from rainfall and its associated runoff, **R** equals the erosion index. Where runoff from thaw, snowmelt, or irrigation is significant, an R_s factor must be added to the **EI** value as previously discussed.

Where adequate rainfall intensity data are not available, the erosion index cannot be estimated solely from annual precipitation data. It is a function of the sizes and intensities of the individual rainstorms, and these are not closely related to annual precipitation. Therefore a given annual rainfall will indicate only a broad range of possible values of the local erosion index. However, the United States data indicate that the range of likely values can be somewhat narrowed by knowledge of the general climatic conditions in the particular geographic area.

In the U.S. Northern and Northeastern States, the winter precipitation generally comes as snow and low-intensity rains, but erosive intensities occur during the spring and summer. There, the local erosion index values, $(\mathbf{EI})_m$, have ranged from **2P**-52 to 2.6**P**, where **P** is the average annual precipitation expressed in centimeters. In several Northwestern States, where rain intensities rarely exceed 2.5 cm/h, the annual $(\mathbf{EI})_m$ is generally less than **P**, but $\mathbf{R}_s$ values are high. Near the Gulf of Mexico and along the southern half of the Atlantic Coast, the rainfall characteristics are substantially influenced by coastal storms, 24-h rainfall exceeds 10 cm at least once in 2 years, on the average, and erosive rains occur in nearly every month of the year. There, erosion index values range between 4.2**P** and 6.7**P**. Values computed from the few long-term, recording-raingage records available for the islands of Hawaii and Puerto Rico were also within this range. In the large region between the northern and southern extremes mentioned above, the annual $(\mathbf{EI})_m$ values range from 2.5**P** to 4.5**P**. Brief, high-intensity thunderstorms are common in this region during the summer months, but general rains of longer duration also occur.

Where data are adequate to determine 2-year probabilities of 6-hour rainfall, these probabilities may provide more specific estimates of the local erosion index values. In the U.S. data, local erosion index values were approximately equal to the quantity $27.38\ \mathbf{P}^{2.17}$, where $\mathbf{P} =$ the 2-year, 6-hour precipitation in inches. Converted to the recommended metric units, $(\mathbf{EI})_m$ equals approximately $6.28\mathbf{P}^{2.17}$, where **P** is expressed in centimeters. However, this estimating procedure should not be substituted for the standard erosion index calculation procedure where adequate intensity data are available.

Factor K. This factor is the average soil loss in metric tons per hectare per unit of $(\mathbf{EI})_m$, measured on unit plots of the given soil. A unit plot is a 22-m length of uniform 9 percent slope that has been in clean fallow for more than 2 years and is tilled to prevent vegetative growth and surface crusting during the period of soil loss measurement. If a gradient other than 9 percent must be used, the data are adjusted by an **LS** factor available from figure 11. If the soil-erodibility nomograph (fig. 3) is used to evaluate $\mathbf{K}_m$, the **K** value read from the nomograph is multiplied by a conversion factor of 1.292.

The most accurate direct measurement of **K** for a given soil is obtained by measuring soil losses from unit plots under natural rain for at least 5 years, beginning 2 years after the clean-fallow condition was established. This permits averaging the interactions of soil erodibility with antecedent soil moisture, storm size, and other randomly distributed variables. The fallow plots receive the same annual tillage as conventionally tilled row crops.

Using rainfall simulators to evaluate **K** is quicker and less costly, but it requires caution. A one-time simulator test, even though replicated on several plots, measures soil loss from only one storm size and rain intensity, on one set of antecedent conditions, and these may or may not represent natural rainfall patterns. When simulated rainfall is used to evaluate **K**, measuring the soil losses for four or five successive 30-minute periods is helpful so that the segmented data can be rearranged to represent small, intermediate, and large storms beginning at various antecedent soil moisture levels. These can be weighted according to their probability of occurrence in natural rainfall (*58*).

Factor LS. Selecting 22 m as the basic slope length and retaining 9 percent as the basic slope gradient leaves the **LS** values essentially unchanged from those used in the English system of units. For uniform slopes, **LS** may be obtained by entering figure 11 with the field slope length expressed in meters. For concave or convex slopes, the value read from figure 11 should be modified by the procedure given in the subsection **Irregular Slopes.**

Factors C and P. Soil loss ratios (table 5) and **P** values (tables 13, 14, 15) are not affected by the units selected for the other factors. However, in countries where crops and farming techniques are different from those reflected in table 5, measurements of soil loss reductions attainable with feasible changes in crop system, tillage methods, and residue management may merit priority over establishing **EI** and **K** values.

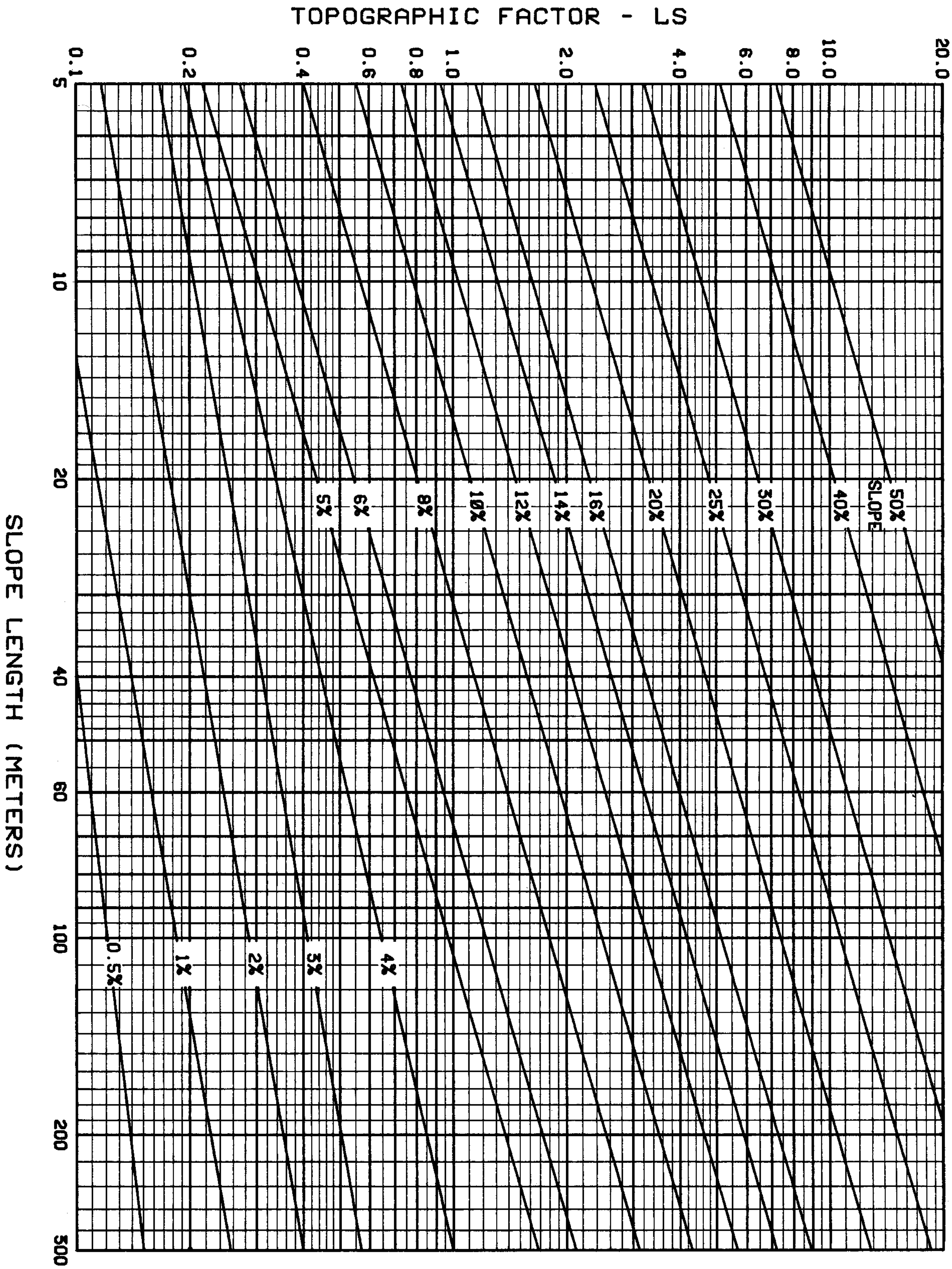

FIGURE 11.—Slope-effect chart for metric system.

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AH-537, PREDICTING RAINFALL EROSION LOSSES— A GUIDE TO CONSERVATION PLANNING

note: ERRATA Jan. 1981

The following corrections and minor additions should be made with pen and ink in existing desk copies of AH-537. Corrected words or numbers have been identified by underlining. Additional footnotes that were added to clarify original content can be inserted in the lower margins of the indicated pages.

Page

4 Insert footnote symbol [4] after the definitions of **R** and **K** in column 1 and add footnote:

[4] The erosion index values in figures 1 and 2 and the EI values used in the text have the dimension 100 (foot-ton inch)/(acre hour). K values in tables 1 and 2 and figure 3 are in tons per acre per EI unit and have the dimensions 0.01 (ton acre hour)/(acre foot-ton inch).

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5 Equation (2) $e = 916 + 331 \log_{10} i$,

where e is kinetic energy in foot-tons per acre-inch and i is intensity in in/h (62). A limit of 3 in/h is imposed on i . . .

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9 column 2. Change footnote number from [4] to [5].

---

18 column 1. Change footnote number from [5] to [6].

---

19 column 1, last sentence. Insert footnote symbol [7] after "The expected effects of mulch and canopy combinations" and add footnote in lower margin:

[7] Figures 6 and 7 and table 5 assume that slope-length limits for full effectiveness of residue mulches at the stated rates are not exceeded. Beyond these limits, the subfactor for mulch effect approaches 1.0. The length limits vary inversely with mulch rate, runoff depth and velocity, but have not been precisely defined by research.

FIGURE 6 and 7. Change the ordinate labels from "SOIL-LOSS RATIO" to SUBFACTOR FOR EFFECT OF COVER.

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23 TABLE 5, line 160. Change 50 percent to 10 percent and reduce the ratio for cropstage 1 from 56 to 28.

---

24 Add to footnote [4]: *See also* footnote [7], page 19.

Change footnote 13 to: Divide the winter-cover period into cropstages for the seeded cover and use lines 132-145.

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32 TABLE 10. Corrected title: *Factor* **C** *for permanent pasture, range, idle land, or grazed woodland*[1]

Change second category of vegetative canopy to: Tall grass, weeds or bushes with average drop fall height of less than 3 ft.[5]

Footnote [1]: The listed C values assume that the vegetation and mulch are randomly distributed over the entire area.

For grazed woodland with high buildup of organic matter in the topsoil under permanent forest conditions, multiply the table values by 0.7.

For areas that have been mechanically disturbed by root plowing, implement traffic or other means, use table 5 or 12.

Footnote [4], G: cover at surface is grass, grasslike plants, or decaying compacted duff. (Delete "or litter at least 2 in deep")

Add footnote [5]: [5] The portion of a grass or weed cover that contacts the soil surface during a rainstorm and interferes with water flow over the soil surface is included in "cover at the surface." The remainder is included in canopy cover. Use table 5-B for nearly complete grass covers.

TABLE 11. 33

Second column heading: Delete "at least 2 in deep."

Footnote [1]: The references to table 6 should be to table 10, and the following may be added: For sites that are mechanically treated following harvest, use table 12.

TABLE 12, footnotes [4] and [5]. The references to tables 6 and 7 should be to tables 10 and 11, respectively. 34

TABLE 13, footnote [1]. Change the word "seedlings" to plantings. 35

TABLE 14, footnote [1]. C For alternate strips of row crop and winter grain. 36

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column 2, line 6. 0.5 should be 0.05 in of precipitation . . . 51

centered heading. Insert footnote symbol [8] after **Conversion to Metric System** and add footnote in lower margin:

[8] See supplement for a recommended metrication of the USLE in the International System of Units (SI), which may be substituted for this section.

TABLES 19 and 20, footnotes. Change E to e and I to i in the energy equations. 56

Below the footnotes for table 20, insert the note: The table values multiplied by 9.81 would equal kilojoules of energy in the SI system.

UNITED STATES DEPARTMENT OF AGRICULTURE

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PREDICTING RAINFALL EROSION LOSSES— A GUIDE TO CONSERVATION PLANNING

Supplement to Agriculture Handbook No. 537

METRICATION OF THE USLE IN THE INTERNATIONAL SYSTEM OF UNITS (SI)

The metric conversion originally presented in this handbook and in prior publications (*53, 60*) is not completely in the International System of Units (SI), which is expected to gain widespread usage. This supplement presents an alternative conversion in which all the Universal Soil Loss Equation (USLE) factors are expressed in standard SI units or approved multiples thereof, and the order of magnitude of each new unit is similar to the old.

Both conversion systems are authentic, and conservationists who have adopted the originally recommended metric units would not improve their USLE accuracy by changing to the new units. For future conversions, however, the revised procedure, which is fully outlined below, is recommended because its use will facilitate standardization of units.

The USLE terms **A, LS, C,** and **P** need no change from the recommendations in the preceding section. Strictly, the **SI** units for mass and area are kilograms and square meters. Because of common use, however, metric ton (a special name for megagram) and hectare (a special name for square hectometer) will be used. Soil loss (**A**) wil be expressed in metric tons per hectare, and factor **K** in metric tons per hectare per metric **EI** unit. Factors **LS, C,** and **P** are dimensionless. **L** is expressed relative to slope lengths measured in meters, but selecting 22 m as the basic slope length and retaining 9 percent as the basic slope gradient leaves the **LS** values essentially unchanged. **C** and **P** are not affected by the units selected for the other factors.

Factor **R** will be in different units than previously recommended. In the **SI** system, energy is measured in joules and rainfall in millimeters. The use of "centi" as a multiple is minimized. Metric **EI** values can be obtained in standard **SI** units by expressing rainfall energy in megajoules (**MJ**) per hectare and maximum 30-minute intensity (I_{30}) in mm/h, but use of cm/h to express I_{30} is more expedient for the following reasons: With I_{30} expressed in mm/h, the metric **EI** values would be 17 times the magnitude of **EI** in U.S. customary units. Annual erosion index values would be in four- or five-digit numbers, which are harder to visualize and compare mentally than the present smaller numbers. Of greater importance, the large metric **EI** values would result in extremely small metric **K** values, ranging downward from a maximum of about 0.09. Absolute differences between **K** values would be so small that many casual users of the USLE would tend to neglect important soil differences as insignificant.

Reducing the magnitude of I_{30} by a factor of 10 alleviates these disadvantages and does not preclude the use of mm as the unit for rainfall amounts and incremental intensities in energy computations. The energy equation or table will also be expressed in MJ/ha per mm of rain. Only I_{30} will be converted to cm as a matter of expedience. This is directly comparable to the U.S. customary procedure of computing energy in ft-tons/acre and dividing by 100 to obtain more convenient magnitudes. The metric **EI** will then equal storm energy in MJ/ha times I_{30} in cm/h.

Assuming use of the metric units specified above, a comparison of U.S. customary and **SI** dimensions for the terms in the USLE is as follows:

Term	*US customary dimensions*	*SI dimensions*	*Symbol*
A	ton/acre	metric ton/hectare	t/ha
R	$\frac{\text{100 foot-ton inch}}{\text{acre hour}}$	$\frac{\text{megajoule centimeter}}{\text{hectare hour}}$	$\frac{\text{MJ cm}}{\text{ha h}}$
K	$\frac{\text{.01 ton acre hour}}{\text{acre foot-ton inch}}$	$\frac{\text{metric ton hectare hour}}{\text{hectare megajoule centimeter}}$	$\frac{\text{t ha h}}{\text{ha MJ cm}}$
L,S,C,P	dimensionless	dimensionless	

The USLE terms will usually be derived directly in the **SI** units by procedures outlined below. However, the following conversion factors will facilitate comparisons of the metric factor values with the U.S. customary values published in this handbook. Terms expressed in metric units are identified by the subscript $_m$.

To convert from:	*multiply by:*	*to obtain:*
A in tons/acre	2.242	A_m in t/ha
E in 100 ft-tons/acre	0.670	E_m in MJ/ha
I_{30} in in/h	2.540	I_{30m} in cm/h
EI in $\frac{\text{100 ft-ton in}}{\text{acre h}}$	1.702	$(EI)_m$ in $\frac{\text{MJ cm}}{\text{ha h}}$
K in $\frac{\text{.01 ton acre h}}{\text{acre ft-ton in}}$	1.313	K_m in $\frac{\text{t ha h}}{\text{MJ ha cm}}$

Page 56 revised

Factor R. The procedure for computing $(\mathbf{EI})_m$ for a given rain period is similar to that described in the preceding section for computing **EI**, but the input data will be in different units. If the raingage chart used for the example on page 51 had been calibrated in millimeters, the computation would have been as follows:

Chart readings		*Storm increments*			*Energy*	
Time	Depth (mm)	Duration (min)	Amount (mm)	Intensity (mm/h)	Per mm of rain (MJ/ha mm)	Increment total (MJ/ha)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
4:00	0					
:20	1	20	1	3	0.161	0.161
:27	3	7	2	17	.226	.452
:36	9	9	6	40	.259	1.554
:50	27	14	18	77	.283	5.094
:57	30	7	3	26	.242	.726
5:05	32	8	2	15	.222	.444
:15	32	10	0	0	0	0
:30	33	15	1	4	.172	.172
Totals		90	33			8.603

Kinetic energy of the storm: 8.60 MJ/ha

Values for column 6 are obtained by entering the revised table 20 with the intensities listed in column 5. The sum of the products of corresponding values from columns 4 and 6 (8.60) is the kinetic energy, E_m, of the 33 mm of rain expressed in megajoules per hectare. The maximum amount of rain in any 30-minute period was 27 mm, from 4:27 to 4:57. Therefore the maximum 30-minute intensity was 2×27, or 54, mm/h, and $I_{30m} = 54/10 = 5.4$ cm/h. $(\mathbf{EI})_m = 8.60 \times 5.4 = 46.4$ (MJ cm)/(ha h).

For the **EI** computations, the rain occurring between two successive periods of 6 hours or more with less than 1.3 mm (0.05 in) of precipitation is considered one storm. Rain showers of less than 12 mm are omitted as insignificant unless they include a 15-minute intensity of at least 25 mm/h. The erosion index at a given location, as mapped in figures 1 and 2, is the average annual total of storm **EI** values over 20 to 25 years. For predicting average annual soil losses from rainfall and its associated runoff, **R** equals the erosion index. Where runoff from thaw, snowmelt, or irrigation is significant, **R** equals the **EI** plus an $\mathbf{R}_s$ value as discussed on page 7.

The erosion index cannot be reliably estimated from annual-rainfall data alone. It is a function of the sizes and intensities of the individual rainstorms, and these have no common relationship to annual rainfall totals. However, later analyses of the U.S. annual erosion index values that had been derived by the above procedure indicated that they were roughly equal to the quantity $27.38\ \mathbf{P}^{2.17}$, where $\mathbf{P}$ = the 2-year, 6-hour rainfall expressed in inches. By direct conversion, the average annual $(\mathbf{EI})_m$ would be roughly estimated by $0.0416\ \mathbf{P}^{2.17}$, where **P** is expressed in mm. This estimating formula is appreciably less accurate than the standard erosion index calculation procedure and should not be substituted for it where intensity data are available.

Factor K. The soil-erodibility factor K is the average soil loss in metric tons per hectare per unit of metric **EI**, measured on unit plots of the given soil. A unit plot (see p. 8) is a 22-m length of uniform 9 percent slope that has been in clean fallow for more than 2 years and is tilled to prevent vegetative growth and surface crusting during the period of soil loss measurement. If a gradient other than 9 percent must be used, the data are adjusted by the appropriate **LS** factor. If the soil-erodibility nomograph (fig. 3) is used to evaluate K_m, the K value read from the nomograph must be multiplied by a conversion factor of 1.313.

The basic slope length used for K and **L** in this handbook is 72.6 ft, which equals 22.134 m. For experimental evaluation of factor **K** in metric units, rounding this to 22.0 m is more convenient and introduces no error when 22.0 m is also used as the basic length for **L**, as in figure 11. The slight reduction in basic length increases factor **L** by 0.3 of 1 percent and decreases factor **K** by the same percentage, so the product of K and **L** is unchanged. For conversion of the U.S. customary K values in this handbook to metric **K** values based on a 22.0 m length, the relatively insignificant potential error is avoided by including an **L**-value of 0.997 in the conversion factor. The **K**-conversion factor of 1.313 given above has been so adjusted.

Factor LS. The preceding paragraph applies here, also. For uniform slopes, **LS** may be obtained by entering figure 11 with the field slope length expressed in meters or it may be computed by the equation

$$LS = (\lambda/22)^m\ (65.41\ \sin^2\theta + 4.56\ \sin\theta + 0.065)$$

where λ = slope length in m; θ = angle of slope; and m = 0.5 if the percent slope is 5 or more, 0.4 on slopes of 3.5 to 4.5 percent, 0.3 on slopes of 1 to 3 percent, and 0.2 on uniform gradients of less than 1 percent. For concave, convex, or mixed-gradient slopes, the value so computed or read from figure 11 should be modified by the procedure outlined on page 16.

Factor C and P. Soil loss ratios (table 5) and **P** values (tables 13, 14, 15) are not affected by the units selected for the other factors and therefore need no conversion.

TABLE 20. (revised).—*Kinetic energy of rainfall at specified intensities, expressed in megajoules per hectare per millimeter of rain*[1]

Intensity (mm/h)	0	1	2	3	4	5	6	7	8	9
0 ..	0	0.119	0.145	0.161	0.172	0.180	0.187	0.193	0.198	0.202
10 ..	.206	.210	.213	.216	.219	.222	.224	.226	.229	.231
20 ..	.233	.234	.236	.238	.240	.241	.242	.244	.245	.247
30 ..	.248	.249	.250	.252	.253	.254	.255	.256	.257	.258
40 ..	.259	.260	.261	.262	.262	.263	.264	.265	.266	.267
50 ..	.267	.268	.269	.270	.270	.271	.272	.272	.273	.274
60 ..	.274	.275	.276	.276	.277	.277	.278	.278	.279	.280
70 ..	.280	.281	.281	.282	.282	.283	.283[2]			

[1] Computed by the equation $e = 0.119 - 0.0873 \log_{10} i$, where e = kinetic energy in megajoules/(hectare millimeter) and i = rainfall intensity in mm/h.

[2] The value of 0.283 also applies for all intensities greater than 76 mm/h.

ESTIMATING FACTOR C FOR AN UNUSUAL CONDITION OR CROP THAT IS NOT LISTED IN TABLES 5 through 5-D of Ag. Handbook No. 537.

W. H. Wischmeier, 11-13-79

Soil-loss ratios can sometimes be closely estimated by comparing characteristic conditions in each cropstage period with conditions associated with a crop and management that is listed in the table. The cropstage ratios may need to be selected from several lines rather than following one line across the table.

Another possible procedure is to multiply-together a number of subfactor values obtained from field observations, guided by the following information.

Benchmark values throughout table 5 were obtained from direct soil-loss measurements under conditions involving various combinations of the subfactors. However, study of the ratios obtained by this method suggested a number of underlying subfactor relationships that can help guide estimation of appropriate ratios for untested conditions or crops. Before using this procedure, please read carefully the background material on pages 18-21 of AH-537.

For each cropstage period, estimate the percentage of surface cover by canopy and the percentage of cover by mulch, using the definitions given on pages 18 & 19 and evaluating the two separately. Include expected volunteer vegetation in the estimates of cover if significant. Then, use the following guides to estimate a subfactor value for each of the listed sub-parameters:

1. Canopy without mulch. Enter Fig. 5 with percent canopy cover, move vertically to drop fall height, and read the subfactor value at the left.

2. Mulch without canopy. Enter Fig. 6 with the percent cover by mulch, move vertically to the line for zero percent canopy (upper curve), and read subfactor value at left.

3. Combination of canopy and mulch. Use the other curves of Fig. 6 or 7, interpolating between the lines.

4. Land-use residual. The greatest residual effect is from sod crops or longterm woodland. Obtain residual sod-effect subfactor from table 5-D. Virgin sod or woodland would be even more effective.

Some residual effect will be apparent on nearly any cropland. For continuous corn with residues removed annually before turnplowing, the residual factor seems to be about 0.82 to 0.86, depending on productivity level. (These are the values given for the SB period in lines 13-16 of table 5.) This is a good starting point from which to move with judgment. This subfactor is in addition to subfactors for residues incorporated or sod-effect when those are also applicable.

(continued, p.2)

5. Residues plowed-down annually by inversion plowing. Credit for this may be approximated by multiplying the number of tons of residue per acre plowed down annually by: 0.12 for periods F, SB and 1; by 0.09 for period 2; and by 0.06 for periods 3 and 4. The residue-incorporated subfactor is 1.0 minus this amount.

6. Residues incorporated in the upper few inches of soil by shallow non-inversion tillage. Estimate effect by multiplying tons of residue so incorporated annually by: 0.20 for periods SB and 1; 0.16 for period 2; 0.12 for period 3; and 0.06 for period 4. Subtract product from 1.0 to obtain subfactor.

7. Random surface roughness. The condition left by inversion plowing and several diskings (with residues removed) has a roughness factor of 1.0. Freshly plowed land would rate a roughness subfactor of from 0.8 to 0.5, depending on amount of residue, soil-moisture at time of plowing, and other conditions. Chiseled or disked land would fall between these extremes.

In all cases, the subfactor becomes larger for each successive cropstage period because of rainfall and tillage effects. It reaches a value of 1.0 no later than the end of cropstage 3 and in some cases appreciably sooner.

8. Detachability. Soil that receives no tillage or traffic gradually becomes less detachable by rainfall. No-till systems with crop residues on the surface seem to merit a detachability subfactor of about 0.7. This is in addition to the mulch factor and may vary with soil texture.

9. Orientation of residues. The mulch-effect curves of figures 6 and 7 are based on fairly uniform, random distribution of the mulch over the field. When residues are concentrated in strips by the harvester, the percent-cover is reduced. However, when the strips are across the slope, they are more effective than the reduced percent-cover would indicate. When the strips are across-slope, they can probably be evaluated as equivalent to the percent cover that they would have provided if they had been fairly uniformly distributed. See figure 10, page 50. However, this does not apply if the strips are up and down slope.

10. High population of close-growing stems (like wheat). More effective than canopy from spreading plants like corn or bushes.

When these guides have been used to estimate the listed subfactors for each cropstage period, the subfactors are multiplied together to compute the soil-loss ratios.

This procedure should not be used for conditions covered by table 5 and its supplements. The relationships given above are only approximate and will provide less accuracy than direct measurements such as used to develop the table.

Slope-length limits for effectiveness of moderate mulch rates and random roughness are of course also applicable with this procedure.