Predicting

RAINFALL-EROSION LOSSES FROM CROPLAND EAST OF THE ROCKY MOUNTAINS

Guide for Selection of Practices for Soil and Water Conservation

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Williams

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PREDICTING RAINFALL-EROSION LOSSES FROM CROPLAND EAST OF THE ROCKY MOUNTAINS

Guide for Selection of Practices for Soil and Water Conservation

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PURPOSE OF HANDBOOK

Scientific farm 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 on cropland. Since 1930, 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 efforts can be realized only when the findings are rapidly converted to sound practice on the numerous farms throughout the country. Specific guidelines are needed to help select the control practices best suited to the particular needs of each farm.

The soil-loss prediction procedure presented in this handbook provides such guidelines. It is a technique whereby all pertinent research information is methodically combined to provide design data for conservation plans.

The empirical soil-loss equation underlying this technique is applicable in any location where numerical values of the equation's factors are known or can be determined. Research has supplied information from which at least approximate values of these factors can be derived for any location in the major agricultural areas of the United States. Tables and charts make this information readily available for field use.

Research is continuing to obtain more complete and more precise information on the interrelations of topography, soil, and management practices. Additional knowledge gained can be readily brought into the present prediction procedure. Experience has shown, however, that the factor values reported herein are sufficiently accurate to provide very valuable guidelines for conservation farm planning and to aid in estimating gross erosion from watersheds.

The soil-loss equation in its present form is the result of more than 20 years of development and has had many contributors.

HISTORY OF SOIL-LOSS EQUATIONS

Development of equations for calculating field soil loss began about 1940 in the Corn Belt States. The soil-loss estimating procedure developed in that region between 1940 and 1956 has been generally referred to as the slope-practice method. Zingg (*28*) [1] published an equation in 1940 relating soil-loss rate to length and percentage of slope. In the following year, Smith (*12*) added crop and conservation-practice factors and the concept of a specified soil-loss limit, to develop a graphical method for determining conservation practices needed on the Shelby and associated soils of the Midwest. Browning and coworkers (*1*) added soil erodibility and management factors and prepared a set of tables to simplify field use of the equation in Iowa. Other advances and adaptations of the procedure in the Corn Belt were made by Smith and Whitt (*13, 14*) and by Van Doren and Bartelli (*19*). Research scientists and operations personnel in the North Central States worked together in developing the slope-practice method for use throughout the Corn Belt States.

In 1946, a nationwide committee on soil-loss prediction met in Ohio for the purpose of adapting the Corn Belt equation to other cropland areas with erosion problems. This committee reappraised the Corn Belt factor values and added a rainfall factor (*9*). The resulting formula, generally known as the Musgrave equation, has been widely used for estimating gross erosion from watersheds in flood abatement programs. A graphical solution of the equation was published in 1952 by Lloyd and Eley (*5*) and used by the Soil Conservation Service in the Northeastern States.

[1] Italic numbers in parentheses refer to Literature Cited, p. 44.

Years of field experience by the Soil Conservation Service in the Corn Belt and the Northeastern States proved the value of soil-loss prediction as a tool to help guide conservation farm planning. Extension of the usefulness of these equations to new areas was seriously hampered by the lack of procedures and basic information for adjusting measured factor values for differences in rainfall distribution, types of rainstorms expected, localized farming methods, length of growing season, and other variables.

An improved soil-loss equation developed in the latter part of the 1950's (*18, 26*) overcame many of the limitations of the earlier equations. The improved equation was developed at the Runoff and Soil-Loss Data Center of the Agricultural Research Service, established at Purdue University in 1954. Most of the basic runoff and soil-loss data obtained in studies in the United States since 1930 were assembled at this location for summarization and further analyses.[2] These analyses resulted in several major improvements that were incorporated in the new soil-loss equation: (1) an improved rainfall-erosion index (*21*); (2) a method of evaluating cropping-management effects on the basis of local climatic conditions (*22*); (3) a quantitative soil-erodibility factor; and (4) a method of accounting for effects of interrelations of such variables as productivity level, crop sequence, and residue management.

These developments freed the equation from some of the generalizations and the geographic and climatic restrictions inherent in earlier models. Because of its general applicability, the improved equation presented in this handbook has been referred to in some of the literature as the "universal" soil-loss equation (*10, 16, 17, 18, 26*).

SOIL-LOSS TOLERANCES

The term "soil-loss tolerance" is used to denote the maximum rate of soil erosion that will permit a high level of crop productivity to be sustained economically and indefinitely. This rate has usually been expressed in terms of average soil loss per acre per year. Knowledge of the expected rate of soil erosion for each of various alternative cropping systems and management plans on any particular field may be obtained by use of the erosion equation. When these predicted losses can be compared with a soil-loss tolerance for that field, very specific guidelines are provided 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 various satisfactory alternatives indicated by the soil-loss prediction procedure, the farmer may then select the land use and management combination best suited to his particular farm enterprise.

Establishment of tolerances for specific soils and topography has been largely a matter of collective judgment. Both physical and economic factors are considered. For the soils in the United States, the maximum soil-loss rates thus determined range from 1 to 5 tons per acre per year, depending upon soil properties, soil depth, topography, and prior erosion. A deep, medium-textured, moderately permeable soil that has subsoil characteristics favorable for plant growth has a tolerance of 5 tons per acre. Tolerances for soils with a shallow root zone, or with a high percentage of shale at the surface, are usually quite low.

Soil-loss tolerances for the major soil types were subjectively evaluated at regional Soil-Loss Prediction Workshops, and lists were distributed in the workshop reports.[3]

[2] Data used to develop the present equation and supporting tables and charts were contributed by personnel on 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.; 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.; Knoxville and Greeneville, Tenn.; Temple and Tyler, Tex.; Blacksburg, Va.; Pullman, Wash.; LaCrosse, Madison, and Owen, Wis.; and Mayaguez, P.R. Rainfall data for development of the iso-erodent map and erosion-index distribution curves were supplied by the U.S. Weather Bureau, National Records Center.

[3] ARS-SCS Soil Loss Prediction Workshop Reports:

1959. Soil loss estimation in Tennessee. Knoxville, Tenn.
1960. Soil loss estimation in the Southeast. Athens, Ga.
1961. Soil loss prediction, North Dakota, Nebraska, and Kansas. Lincoln, Nebr.
1961. Soil loss prediction for Arkansas, Louisiana, Mississippi, Oklahoma, and Texas. Little Rock, Ark.
1962. Soil loss prediction for the North Central States. Chicago, Ill.
1962. Soil loss prediction for the Northeastern States. New York, N.Y.

These reports are mimeographed, but may be available either from the Agricultural Research Service or the Soil Conservation Service.

THE SOIL-LOSS EQUATION

The Equation Model

The soil-loss equation is

$$A=R\ K\ L\ S\ C\ P$$

where *A* is the computed soil loss per unit area.

R, the rainfall factor, is the number of erosion-index units in a normal year's rain. The erosion index is a measure of the erosive force of specific rainfall.

K, the soil-erodibility factor, is the erosion rate per unit of erosion index for a specific soil in cultivated continuous fallow, on a 9-percent slope 72.6 feet long. The reasons for selection of these conditions as unit values is explained in the detailed discussion of this factor.

L, the slope-length factor, is the ratio of soil loss from the field slope length to that from a 72.6-foot length on the same soil type and gradient.

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

C, the cropping-management factor, is the ratio of soil loss from a field with specified cropping and management to that from the fallow condition on which the factor *K* is evaluated.

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

Numerical values for each of the six factors have been determined from research data. These values differ from one field or locality to another. The approximate numerical values for any particular field may be obtained from the figures and tables presented herein.

The subsection entitled "Predicting Field Soil Loss," page 38, illustrates how to select appropriate values from the figures and tables. The reader who has had no prior experience with the soil-loss equation may wish first to read that section. After he has referred to the tables and figures and located the values used in the example, he will be able to understand the intervening detailed discussions of the equation's factors.

In actual practice, the equation is usually not solved in selecting practices for each farm field. In many locations, persons experienced in the use of the equation have prepared reference tables that provide the information needed for the specific locality.

The soil-loss prediction procedure can be more intelligently used 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 ready-reference table or chart from which locational values of that factor may be obtained. Limitations of the data available for evaluation of some of the factors are also pointed out.

The Rainfall Factor (*R*)

One major difference between the universal soil-loss equation and its predecessors is in the manner and precision with which locational differences in rainfall are brought into the soil-loss computations. The Corn Belt slope-practice equation was based on an overall average of the severity and distribution of the rainfall that occurred on the plot studies in that region. This average rainfall effect was reflected in an 8-ton base soil-loss rate for a 3-year rotation of corn, oats, and meadow. The Musgrave equation assumed that the erosivity of annual rainfall varied as the 1.75 power of the 2-year maximum 30-minute rainfall. This relation was based on limited data taken in Wisconsin in the 1930's. Research since 1946 has not supported the accuracy of this term as an indicator of annual rainfall erosivity. Furthermore, its use as a rainfall factor allowed no consideration of effects of locational differences in the number of erosive rainstorms and in their expected distribution within the year.

Rills and sediment deposits observed after an unusually intense storm could lead to the conclusion that the significant soil erosion is associated with only a few rare storms. However, more than 30 years of measurements in many States have shown that such is not the case (*24*). The data showed that a rainfall factor used to estimate average annual soil loss must include the cumulative effects of the many moderate-size storms, as well as the effects of the occasional very severe ones.

The rainfall factor in the soil-loss equation is the rainfall erosion index reported by Wischmeier in 1959 (*21*). Locational values of this factor were published in 1962 in the form of an iso-erodent map (*23*).

The Rainfall Erosion Index

Exploratory analyses of the large volume of soil loss and rainfall data assembled at the Runoff and Soil Loss Data Center brought out a very helpful relation between soil loss and a single rainstorm parameter. The research data show that when factors other than rainfall are held constant, storm soil losses from cultivated fields are directly proportional to the product value of two rainstorm characteristics: total kinetic energy of the storm times its maximum 30-minute intensity (*EI*). This product variate is an interaction term that reflects the combined potential of raindrop impact and turbulence of runoff to transport dislodged soil particles from the field. The value of this statistic for any particular rainstorm can be computed from a recording-raingage record with the help of a rainfall energy table published in 1958 (*25*).

The sum of the computed storm *EI* values for a given time period is a numerical measure of the erosivity of all the rainfall within that period. The rainfall erosion index at a particular location is the longtime-average yearly total of the storm *EI* values. The storm *EI* values reflect the interrelations of significant rainstorm characteristics. Summing these values to compute the erosion index adds the effect of frequency of erosive storms within the year.

Iso-Erodent Map

Locational values of the rainfall factor, *R*, may be taken directly from the iso-erodent map reproduced in figure 1. The lines joining points with the same erosion-index value (which implies equally erosive average annual rainfall) are called iso-erodents. The average number of erosion-index units per year along each iso-erodent is the value of *R* in the erosion equation. Points lying between the indicated iso-erodents may be approximated by linear interpolation.

To develop the map, the locational value of the erosion index was computed from rainfall data for each of about 2,000 locations fairly evenly distributed over the 37 States. The iso-erodents were then plotted as indicated by these values (*23*).

Iso-erodents in the mountainous States west of the 104th meridian were not included because of the sporadic rainfall pattern of the mountains. In this area, one weather station may average fewer than 10 inches of rain per year, whereas another station less than 100 miles away averages more than 25 inches. Locational erosion-index values are probably equally sporadic, but are not directly proportional to rain amounts. A very large number of locational rain-intensity records would be required to establish iso-erodents in the mountainous States. In the scattered agricultural areas where rainfall is sufficient to pose an erosion hazard, locational values of the erosion index can be computed from rainfall records within those specific areas, but a few spot values of the index should not be considered representative of a large geographic area.

The iso-erodent map shows that erosion-index values in the 37 States range from 50 to 600. The erosion index measures only the effect of rainfall when separated from all other factors that influence erosion. 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. This potential difference is, however, partially offset by differences in soil, topography, vegetal 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 establishment of meadows and good cover provided by other crops is often limited to only a relatively short period. Hence, serious soil-erosion hazards exist in semiarid regions as well as in humid.

In areas such as the Pacific Northwest, where snowmelt causes a large part of the field erosion, the practical value of the rainfall-erosion equation in its present form has not been established.

Probability Values of the Erosion Index

When the erosion equation is used to estimate average annual soil loss, the value of the factor *R* must equal the *average annual* value of the erosion index at that location as obtained from the iso-erodent map. If desired, however, some specific probability value of the erosion index, other than annual averages, may be substituted for *R* in the equation. For example, the quantity of soil loss that will be exceeded 1 year in 5, on the average, may be estimated by assigning to *R* the 20-percent probability of the erosion index.

The 50-percent, 20-percent, and 5-percent probability values of the index at 181 key locations are shown in appendix table 11.

To approximate the amount of soil loss from a single storm that will probably be exceeded once in 1, 2, 5, 10, or 20 years, the factor *R* may be assigned a value selected from appendix table 12. For this purpose, however, the value of *C* should be determined as indicated under "Individual-Storm Soil Losses."

The 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 on any area may be influenced more by land slope, rainstorm characteristics, cover, and management than by properties of the soil itself. The total rate of soil loss is designated by the symbol *A* in the equation. But some soils erode more readily than others even when slope, rainfall, cover, and management are the same. This difference, due to properties of the soil itself, is referred to as the soil erodibility.

Soil properties that influence erodibility by water are (1) those that affect the infiltration rate, permeability, and total water capacity, and (2) those that resist the dispersion, splashing, abrasion, and transporting forces of the rainfall and runoff. A number of attempts have been made to determine criteria for scientific classification of soils according to erodibility (*4, 6, 7, 11, 16*). Generally, however, soil classifications used for erosion prediction have been largely subjective and have been only relative rankings.

The relative erodibility of different soils is difficult to judge from field observations. Even a soil with a relatively low erodibility factor may show signs of serious erosion when the soil occurs on long or steep slopes or in localities having 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 the Factor *K*

The soil-erodibility factor, *K*, in the soil-loss equation is a quantitative value, experimentally determined. For a particular soil, it is the rate of erosion per unit of erosion index from *unit* plots on that soil.

A *unit* plot is 72.6 feet 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 a period of at least 2 years or until prior crop residues have decomposed. 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 vegetal growth or serious surface crusting. When all of these conditions are met, each of the factors *L*, *S*, *C*, and *P* has a value of 1.0 and *K* equals A/EI.

The conditions listed above were selected as unit values in the soil-loss equation because they represent the predominant slope length and the median gradient on which past erosion measurements in the United States have been made, and the designated management provides the surface condition least influenced by differences in climate and local cropping systems.

Direct measurements of *K* on well replicated unit plots as described should reflect the combined effects of all the variables that significantly influence the ease with which a soil is eroded by rainfall and runoff. 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 9-percent slope by means of the slope factor.

Values of *K*

Values of *K* determined for 23 major soils on which erosion plot studies 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 per location and requiring a minimum of adjustment for management effects (*10*).

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 fine 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 row-crop data.

Other soils on which valuable erosion studies have been conducted (see footnote 2, p. 2) were not included in the table because of uncertainties involved in adjustments of the data for effects of cropping and management. Short periods of record from plots cropped to rotations that provide good canopy or residue protection most of the time cannot presently serve for authentic evaluation of *K*, even though the studies were well designed and provided valuable data for evaluation of other factors in the equation.

Soil-erodibility values for numerous other soils have been approximated by considering a soil's characteristics and tempering the estimate of its erodibility against the established values for the 23 soils listed in table 1. Such estimated values for all the major soils in the several major geographic regions were prepared at joint ARS–SCS Regional Soil-Loss Prediction Workshops.[4]

[4] See footnote 3, p. 2.

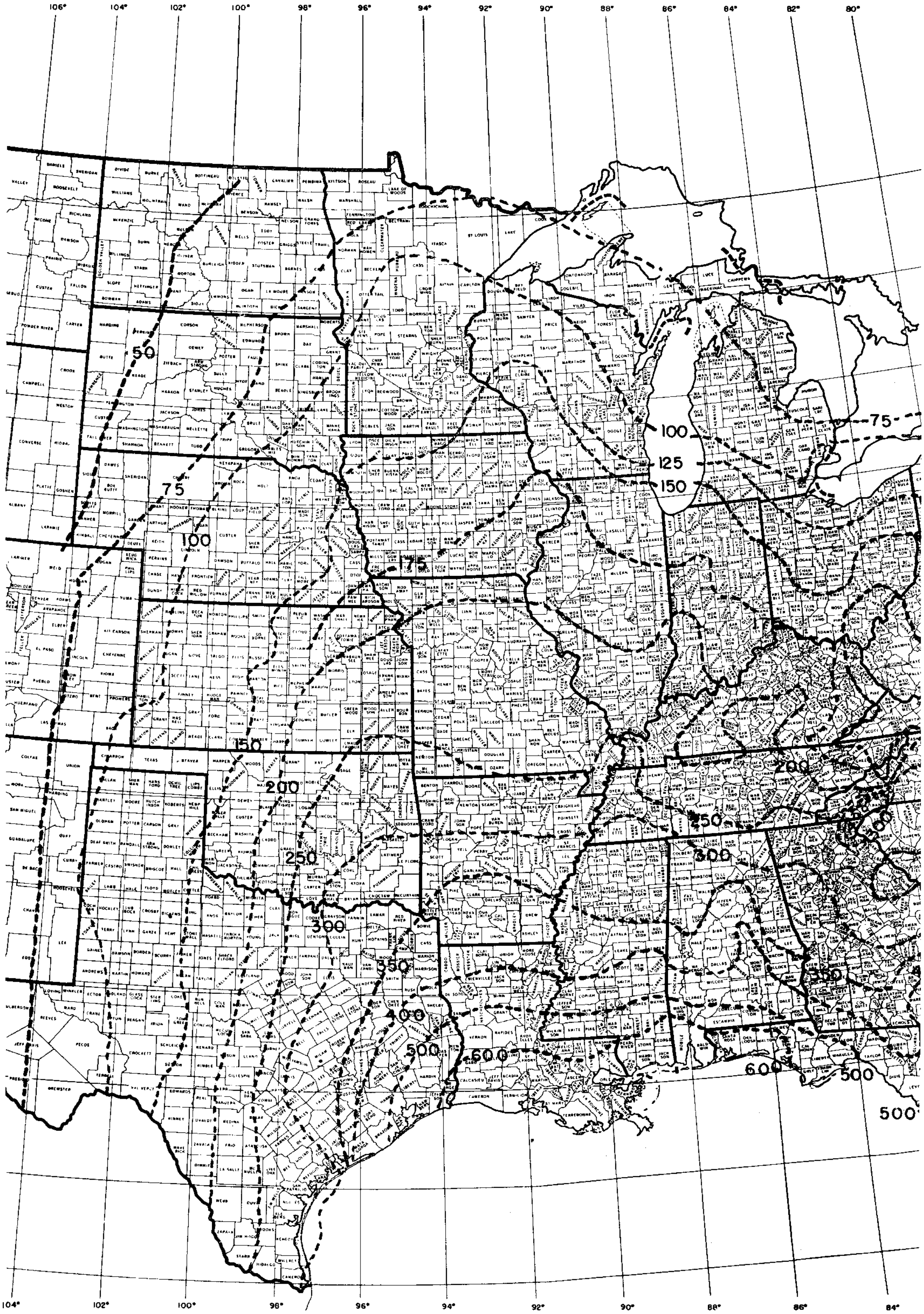
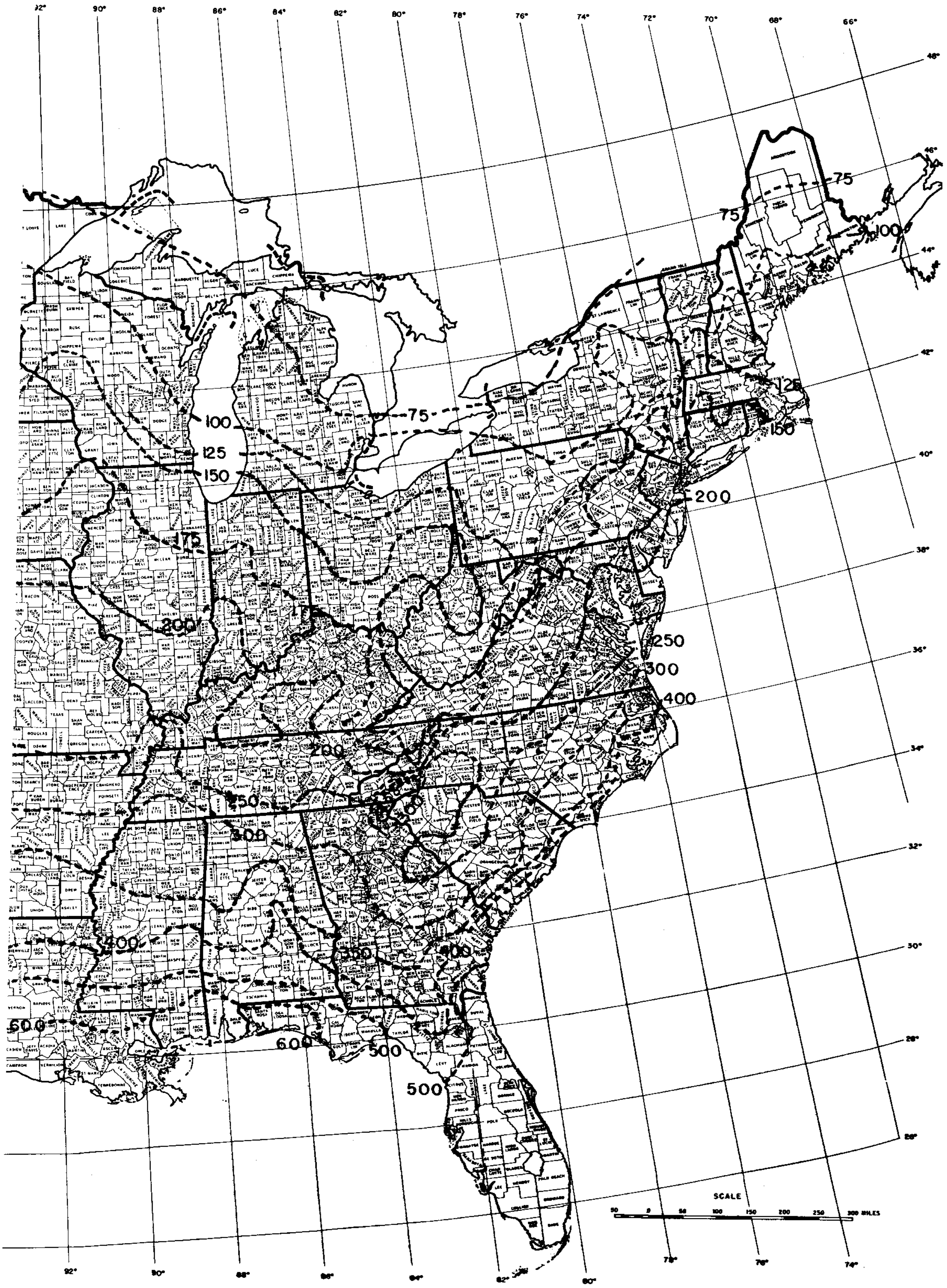


FIGURE 1.—Average annual



values of the rainfall factor, *R*.

Increased research efforts, begun in 1961 at several locations, are designed to identify and evaluate the various soil properties that influence erodibility. Additional benchmark values are also being obtained by direct measurement of *K* on unit plots.

Factors for Slope Length (*L*) and Gradient (*S*)

The rate of soil erosion by water is very much affected by both slope length and gradient (percent slope). The two effects have been evaluated separately in research and are represented in the erosion equation by *L* and *S*, respectively. In field application of the equation, however, it is convenient to consider the two as a single topographic factor, *LS*.

The Slope-Effect Chart

The factor *LS* is the expected ratio of soil loss per unit area on a field slope to corresponding loss from the basic 9-percent slope, 72.6 feet long. This ratio, for specific combinations of slope length and gradient, may usually be taken directly from the slope-effect chart (fig. 2). For example, a 10-percent slope, 360 feet long, would have an *LS* ratio of 2.6.

When the equation is used as a guide for selection of practices on an area where several slopes are combined into a single field, the slope characteristics of the most erosive significant segment of the field should be used for figure 2. Use of field averages on such slope complexes would underestimate soil movement on significant parts of the field.

The slope-effect chart assumes essentially uniform slopes. Field slopes are often either convex (steepening substantially toward the lower end) or concave (flattening toward the lower end). The effect of convexity or concavity of slopes on soil-erosion rates has not been fully evaluated. However, limited data indicate that use of the *average* gradient of the entire slope length would substantially underestimate soil loss from the con-

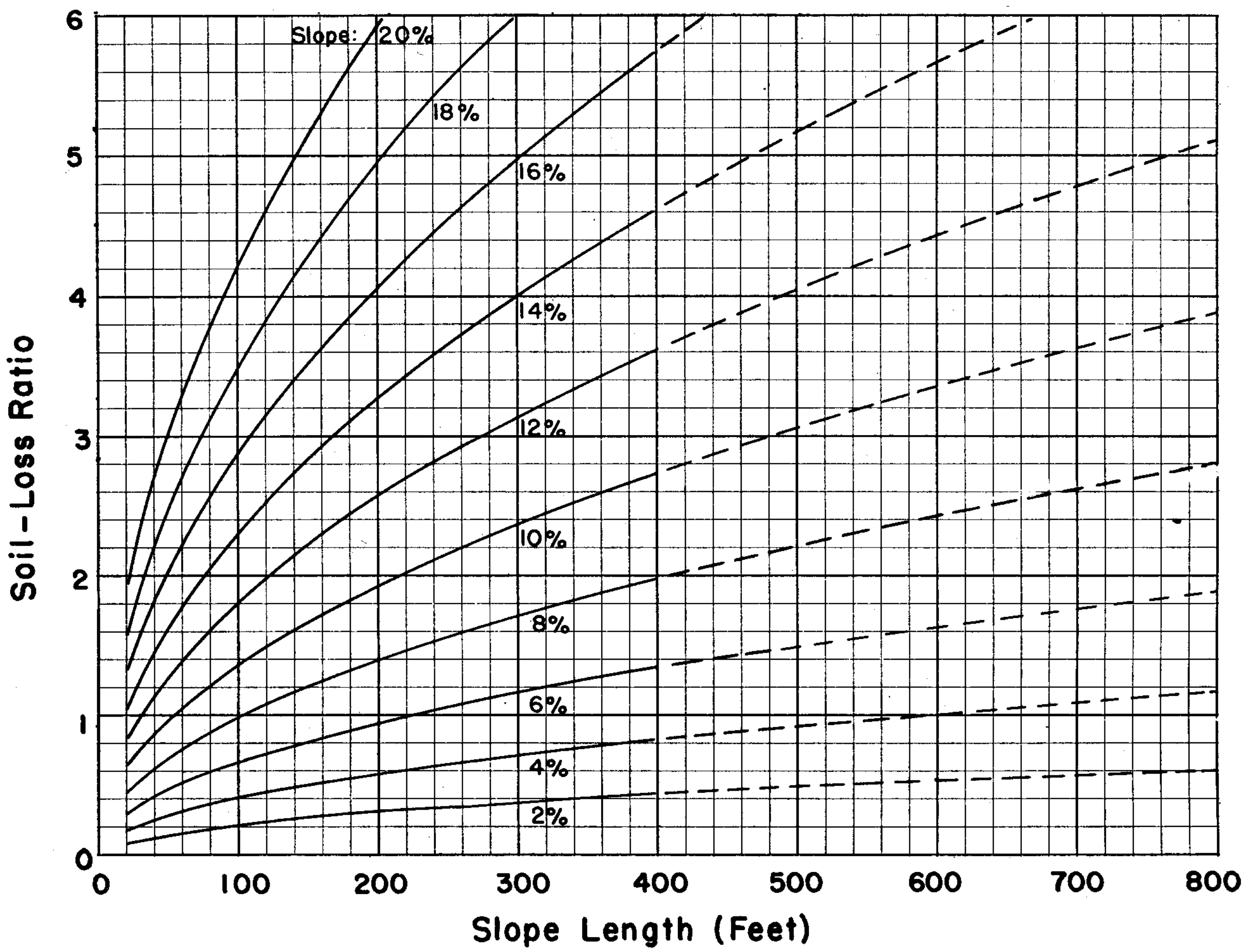


FIGURE 2.—Slope-effect chart (topographic factor, *LS*).

vex slopes and would overestimate the loss from concave slopes. When the lower end of the slope is steeper than the upper end, the gradient of the steeper segment should be used with the overall slope length to enter the slope-effect chart. On a concave slope, deposition may occur on the lower end of the field. In such cases, the appropriate length and gradient are those of that segment of the slope that is above the point where it flattens enough for deposition to occur.

The broken-line portions of the curves on the chart were extrapolated to provide the best estimates now available for slopes longer than those measured in plot studies. Subsequent investigations on slopes longer than 300 feet may show need for revision of these segments of the curves.

Values of LS for slope percentages not shown on the chart may be computed by solving the following equation:

$$LS=\sqrt{\lambda}(0.0076+0.0053s+0.00076s^2)$$

where λ is the field slope length in feet, and s is the gradient expressed as slope percent.

Slope Length

Slope length is defined as the distance from the point of origin of overland flow to either of the following, whichever is limiting for the major part of the area under consideration: (1) the point where the slope decreases to the extent that deposition begins or (2) the point where runoff enters a well-defined channel that may be part of a drainage network or a constructed channel such as a terrace or diversion (*15*).

Numerous plot studies have shown that the soil loss per unit area is proportional to some power of slope length. Since the factor L is the ratio of field soil loss to that from a 72.6-foot slope, the value of L may be expressed as $\left(\frac{\lambda}{72.6}\right)^m$, where λ is field slope length in feet and the exponent m is determined from field data. The magnitude of the exponent m in this expression is not the same for all locations or for all conditions at a given location. (*27*). Its average value in past investigations under natural rainfall has been about 0.5. This is the value used for development of the slope-effect chart (fig. 2).

The value of m is significantly influenced by the interaction of slope length with gradient and may also be influenced by soil properties, type of vegetation, and management practices. On slopes steeper than 10 percent, a value of 0.6 for m is recommended. A value of 0.3 appears applicable to the very long slopes of less than one-half percent gradient encountered in the furrow-irrigated sections of the High Plains of western Texas. Data from gently sloping Houston clay and Mansic clay loam soils that were frequently dry and deeply cracked showed a decrease in runoff with increased slope length and indicated a value of m=0.3 for these particular soils. Other than for these special cases, use of the 0.5-power relation reflected in figure 2 is presently recommended. However, further research investigation may soon provide a basis for recommending other deviations from this overall average.

Figure 3 provides a graphical method for determining the value of LS when conditions indicate that a length exponent other than 0.5 is applicable. For example, assume a 600-foot slope length on Houston clay with 4-percent gradient and an exponent of 0.3. Entering figure 2 with the 260 found in figure 3, the LS value for the assumed situation is about 0.68. A 600-foot slope length under conditions where the applicable exponent is 0.4 is shown to be equivalent to a 390-foot length under conditions where the exponent is 0.5.

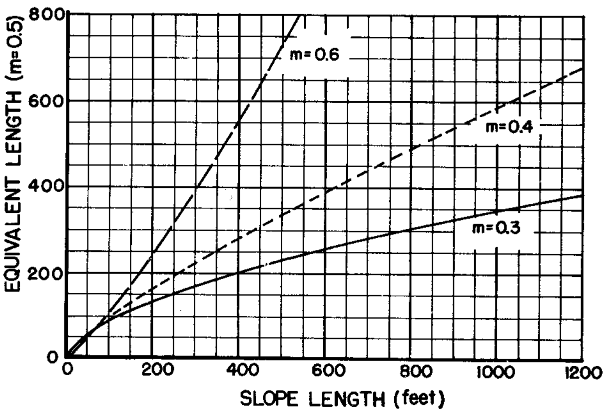


FIGURE 3.—Equivalent slope lengths for use of slope-effect chart when the value of the pertinent length-exponent is not 0.5.

Slope Gradient

A. W. Zingg, in 1940, concluded that soil loss varies as the 1.4 power of percent slope (*28*). In 1946, the Musgrave Committee (*9*) recommended use of the 1.35 power of percent slope. Based on analyses of the data assembled at the Runoff and Soil-Loss Data Center Smith and Wischmeier (*15*) in 1957 proposed the relation:

$$S=\frac{0.43+0.30s+0.043s^2}{6.613}$$

where s is the gradient expressed as percent slope and S is the slope factor in the erosion equation. The latter relation was used to derive figure 2.

The relation of soil loss to gradient is influenced by density of vegetal cover and by soil particle size. However, research data are presently not adequate to determine the specific conditions under which deviations from the expressed average relation would be significant.

The Cropping-Management Factor (*C*)

The effects of cropping and management variables cannot be evaluated independently because of the many interre ations involved. Almost any crop can be grown continuously, or it can be grown in any one of numerous rotations. The sequences of crops within a system can be varied. 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 they can be allowed to remain as left by the harvesting operation. Seedbeds can be left rough, with much available capacity for surface storage of rainfall, or they can be left smooth. Different combinations of these variables are likely to have different effects on soil loss.

In addition, the effectiveness of crop-residue management will depend on how much residue there is. This, in turn, depends on rainfall distribution, on the fertility level, and on various management decisions made by the farmer. Similarly, the erosion-control effectiveness of meadow sod turned under before corn or other rowcrops depends on the type and quality of the meadow and on the length of time elapsed since the sod was turned under.

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 or management practice provides the least protection.

Definition of Factor *C*

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

The loss that would occur on a particular field if it were continuously in fallow condition is computed by the four-factor product, *RKLS*, in the erosion 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. The factor *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. In order to derive the appropriate *C* values for a given locality, it is necessary to know how the erosive rainfall in that locality is likely to be distributed through the 12 months of the year. It is also necessary to know how much erosion-control protection the growing plants, the prior-crop residues, and various tillage operations will provide at the time when erosive rains are likely to occur. A procedure has been developed for deriving locational values of the factor *C* on the basis of available weather records and research data that reflect effects of crops and management. The cropping and weather data needed for this purpose appear in ready-reference form in the subsections entitled "Soil-Loss Ratios" and "Erosion-Index Distribution Curves."

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

Crop Stage Periods

The five crop stage periods that are used for computation of locational *C* values are defined as follows:

Period F.—*Rough fallow.* Turn plowing to seeding.

Period 1.—*Seedling.* Seedbed preparation to 1 month after planting.

Period 2.—*Establishment.* From 1 to 2 months after spring or summer seeding. For fall-seeded grain, period 2 includes the winter months, ending about May 1 in the Northern States, April 15 in the Central States, and April 1 in the Southern States.

Period 3.—*Growing and maturing crop.* End of period 2 to crop harvest.

Period 4.—*Residue or stubble.* Crop harvest to plowing or new seeding. (When meadow was established in small grain, grain period 4 was assumed to extend 2 months beyond the grain harvest date. After that time, the vegetation was classified as established meadow.)

Some adjustment in length of periods 1 through 3 may be necessary for vegetable crops.

Effects of Cropping System and Management on Soil Loss

About 10,000 plot-years of runoff and soil-loss data assembled from 47 research stations in 24 States (*20*) were analyzed to obtain empirical measurements of the effects of cropping system and management on soil loss within each crop-stage period. Several significant factor relations that became apparent from the analyses provide background information for interpretation of the soil-loss ratio table.

Erosion From Fallow Soil.—The rate at which fallow soil eroded depended on cropping history and the nature and quantity of residues turned under as well as on inherent characteristics of the soil itself. Brief periods of fallow in a rotation were not comparable in erodibility to continuous clean-tilled fallow on similar soil and slope. Plant residues incorporated in fallow soil were very effective in reducing both runoff and erosion. Effects of cropping history are a part of the factor *C* in the erosion equation.

Productivity Level and Soil Loss.—In general, soil losses decreased as crop yields increased. Since good grain yields are usually associated with good stands and good forage growth, the canopy cover is better and more residues are returned to the soil. Both help to decrease erosion losses. However, the added erosion-reducing benefit of each additional unit of crop yield becomes less as yields become higher.

Crop-Residue Management.—The soil-loss reduction resulting from prior crop residues left on the field depended on the type and quantity of residues produced and the method of handling. Residues were most effective when left at the surface. But after several years of turning heavy crop residues under with a moldboard plow before row-crop seeding, both runoff and soil loss from the row crop were much less than from similar plots from which cornstalks and grain straw were removed at harvesttime. The effectiveness of incorporated residues was greatest during the fallow and seedling periods.

Erosion From Row Crop After Meadow.—Specific-year erosion losses from corn after meadow ranged from 14 to 68 percent of corresponding losses from continuous corn on adjacent plots. Mixtures of grass and legume were more effective than legumes alone. In general, the effectiveness of grass-and-legume meadow sod plowed under before corn in reducing soil loss from the corn was directly proportional to meadow yields. Its erosion-control effectiveness was greatest during the rough fallow and corn-seedling periods and decreased as the corn year moved along. The total reduction in soil loss effected by the meadow depended, therefore, largely upon the stage of development of the corn when the erosive rains occurred. The length of the period during which the turned sod remained effective in reducing erosion was also directly related to meadow yields.

Effect of Length of Meadow Periods.—Direct comparisons of corn after first, second, and third years of meadow were very limited, and the data were too sporadic for overall differences to be statistically significant. When second-year meadow was allowed to deteriorate under poor management, it was less effective than 1 year of meadow. When succeeding meadows were more productive than first-year, they were usually more effective in reducing erosion from corn after the meadow. The effectiveness of virgin sod and of long periods of continuous alfalfa in which grass became well established was longer lasting than that of 1 or 2 years of rotation meadow.

Grass-and-legume catch crops established in spring-seeded small grain and plowed under at corn planting time in the following year effected significant reduction in soil erosion during the corn seedling period, but their effectiveness was shorter lived than that of a full year of meadow.

Winter-Cover Seedings.—The erosion control attained with winter-cover seedings depended upon time and method of seeding, time of plowing, rainfall distribution, and type of cover seeded. Covers such as vetch and ryegrass seeded between the corn or cotton rows before harvest and turned under in April were effective in reducing erosion not only in the winter months but also during the seedling and establishment periods of the following crop. Small grain alone seeded in corn or cotton residues and plowed under in spring was of some value during the winter period but showed no residual erosion-reducing effect after the next year's corn or cotton planting. Very limited data indicated crimson clover alone to be of doubtful value as a winter cover, but when it was combined with a quick-starting grass, effective protection was provided. Small grain or vetch seeded in the fall on plowed cottonland and turned under in spring for another cotton seeding lost about 20 percent more soil than adjacent plots with undisturbed cotton residues on the surface.

Soil-Loss Ratios

Humid Areas.—An empirical measure of the erosion-control effectiveness of each crop, grown in various sequences, was obtained from the assembled plot data. Ratios of soil losses from the cropped plots to corresponding losses from continuous fallow were computed. This ratio was computed for each of the five crop-stage periods previously defined, for each particular crop, in various combinations of crop sequence and productivity level.

A 10-column, 100-line table of the computed soil-loss ratios was published in 1960 by Wischmeier (*22*). This table was not as comprehensive as would be desirable from an application viewpoint. Some combinations of conditions encountered in field soil-loss estimation in various parts of the United States were omitted from the table, because not enough research data were available to make sound evaluations of these particular combinations. Nevertheless, the table was comprehensive enough to test the validity and value of the new procedure for deriving rotation *C* values on a locational basis. It also provided a broad set of benchmark values from which other ratios could be estimated by subjective comparisons.

Table 2 is an expansion of the previously published soil-loss ratio table. It lists, for each crop-stage period, the expected ratio of soil loss from the designated crop and practice combination to corresponding loss from the base fallow condition. The table is entered on the basis of crop, crop sequence, residue management, and crop productivity level, in that order. The soil-loss ratio for each crop-stage period is taken from the seven columns at the right. Three columns are needed for corn-period 4, in order to reflect effects of different ways of managing the field during that period. Suggestions for estimating soil-loss ratios under some of the conditions not directly listed in this table are shown in table 3.

TABLE 2.—*Ratio of soil loss from cropland to corresponding loss from continuous fallow*

Line No.	Cover, sequence, and management [1]	Productivity [2]		Soil-loss ratio for crop-stage period [3]						
		Hay yield	Corn yield	F	1	2	3 [4]	4L	4R	4L+WC
	CORN IN ROTATION									
	1st-year C after gr & lg hay:	*Tons*	*Bu.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
1	Spg TP, conv till	3–5	75+	8	25	17	10	15	35	10
2	Do	2–3	75+	10	28	19	12	18	40	11
3	Do	2–3	60–74	12	29	23	14	20	43	13
4	Do	1–2	60–74	15	30	27	15	22	45	13
5	Do	1–2	40–59	15	32	30	19	30	50	15
6	Do	<1	40–59	23	40	38	25	35	60	18
7	Do	<1	20–35	23	40	43	30	45	65	23
8	Spg TP, min till	3–5	75+	---	8	8	6	15	35	10
9	Do	2–3	75+	---	10	10	7	18	40	10
10	Do	2–3	60–74	---	12	12	8	20	43	13
11	Do	1–2	60–74	---	15	15	9	22	45	13
12	Do	1–2	40–59	---	15	15	11	30	50	15
	2d-year C after gr & lg hay:									
13	RdL, spg TP, conv till	3–5	75+	25	48	37	20	24	---	14
14	Do	2–3	75+	32	51	41	22	26	---	15
15	Do	2–3	60–74	35	54	45	24	28	---	15
16	Do	1–2	40–59	42	57	49	28	42	---	21
17	Do	<1	40–59	46	62	54	30	50	---	25
18	Do	<1	20–35	55	66	60	35	65	---	33
19	RdL, spg TP, min till	3–5	75+	---	25	25	12	24	60	14
20	Do	2–3	75+	---	32	32	13	26	60	15
21	Do	2–3	60–74	---	35	35	14	28	65	15
22	Do	1–2	40–59	---	42	42	17	42	70	21
23	Do	<1	40–59	---	46	46	18	50	75	25
24	RdL, WC in prec C, conv till	3–5	75+	18	35	30	20	24	60	14
25	Do	2–3	75+	20	37	33	22	26	60	15
26	Do	2–3	60–74	21	39	36	24	28	65	15
27	Do	1–2	40–59	25	42	40	28	42	70	21
28	Do	<1	40–59	28	45	44	30	50	75	25
29	Do	<1	20–35	33	48	49	35	65	80	33
30	RdR, WC in prec C, conv till	3–5	75+	30	52	40	22	---	60	35
31	Do	2–3	60–74	35	55	45	24	---	65	35
32	Do	1–2	40–59	42	60	53	30	---	75	35
33	RdR, no WC, conv till	3–5	75+	55	62	47	22	---	60	---
34	Do	2–3	60–74	60	65	51	24	---	65	---
35	Do	1–2	40–59	65	72	57	30	---	70	---
	3d or 4th year C after gr & lg hay, or 2d-year C after SG, red cl, or sw cl:									
36	RdL, conv till	3–5	75+	36	63	50	26	30	---	---
37	Do	2–3	60–74	45	66	54	29	40	---	---
38	Do	1–2	40–59	55	70	58	32	50	---	---
39	Do	<1	20–35	70	76	64	38	65	---	---
40	RdL, min till	3–5	75+	---	36	36	16	30	---	---
41	Do	2–3	60–74	---	45	45	17	40	---	---
42	Do	1–2	40–59	---	55	55	19	50	---	---
43	RdL + WC in prec C	3–5	75+	22	46	41	26	30	---	15
44	Do	2–3	60–74	26	48	44	29	40	---	20
45	Do	1–2	40–59	33	51	47	32	50	---	25

See footnotes at end of table.

TABLE 2.—*Ratio of soil loss from cropland to corresponding loss from continuous fallow*—Continued

Line No.	Cover, sequence, and management [1]	Productivity [2]		Soil-loss ratio for crop-stage period [3]						
		Hay yield	Corn yield	F	1	2	3 [4]	4L	4R	4L+WC
	CORN IN ROTATION—continued	*Tons*	*Bu.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
46	RdL+WC in prec C	<1	20–35	42	56	52	38	65	----	33
47	RdR, conv till	3–5	75+	70	78	54	27	----	62	----
48	Do	2–3	60–74	75	80	60	30	----	70	----
49	Do	1–2	40–59	75	80	70	35	----	75	----
50	RdR, 8 tons manure added	----	60–74	60	70	52	28	----	62	----
51	1st-year C after cl hay	2	40–55	21	35	32	25	35	60	----
52	1st-year C after sw cl	---	40–55	23	45	38	28	35	60	----
53	1st-year C after lesp hay	1–2	60–70	55	70	55	30	40	65	----
54	Do	1–2	40–55	55	70	60	32	50	75	----
55	C after 1 year cot after gr & lg hay	2–3	60–70	30	58	46	24	28	65	----
56	Do	1–2	40–59	35	65	54	29	42	70	----
	Corn in meadowless systems:									
57	After SG w/intercrop, spg TP	----	75+	22	37	35	22	27	----	----
58	Do	----	60–70	25	40	38	24	30	----	----
59	Do	----	40–55	30	45	42	30	40	----	----
60	After SG, no intercrop, RdL	----	----	(5)	(5)	(5)	(5)	(5)	----	----
	COTTON IN ROTATION									
61	1st-year cot after gr & lg hay	3–5	HP	8	25	30	20	22	----	15
62	Do	2–3	HP	10	30	35	25	25	----	16
63	Do	1–2	HP	15	34	40	30	30	----	18
64	Do	1–2	MP	15	34	45	35	33	----	20
65	Do	<1	MP	23	40	54	45	42	----	23
	2d-year cot after gr & lg hay:									
66	RdL, no WC seeding	3–5	HP	30	54	56	38	38	----	20
67	Do	2–3	HP	34	58	62	44	40	----	20
68	Do	1–2	MP	40	65	68	46	42	----	22
69	Do	<1	MP	45	70	70	50	48	----	25
70	RdL+WC in prec cot	3–5	HP	20	40	46	38	38	----	20
71	Do	2–3	HP	23	42	50	44	40	----	20
72	Do	1–2	MP	23	47	55	46	42	----	22
73	Do	<1	MP	27	51	57	50	48	----	25
	Cot after cot, 3d or more year after M:									
74	RdL, no WC seeding	----	HP	42	70	70	48	42	----	22
75	Do	----	MP	45	80	80	52	48	----	25
76	RdL+WC in prec cot	----	HP	32	51	57	48	42	----	22
77	Do	----	MP	35	58	65	52	48	----	25
78	Cot after 1 year C (RdL) after M	3–5	75+	25	48	49	32	38	----	20
79	Do	2–3	60–75	32	51	51	35	40	----	20
80	Do	1–2	40–59	35	54	56	38	45	----	23
81	Cot after 1 year C, C RdR	2–3	40–59	60	65	63	40	48	----	25
82	Cot after 2 years C (RdL) after M	3–5	75+	36	63	62	39	45	----	23
83	Do	2–3	60–75	45	66	68	45	48	----	25
84	Do	1–2	40–59	55	70	73	50	48	----	25
85	Cot in cot (V)–C (crot) system	----	HP	28	40	45	35	----	----	22
86	Cot in cot-O-lesp seed, RdL	----	HP	23	34	40	30	----	----	----
87	Do	----	MP	25	40	45	37	----	----	----
88	Cot in cot-SG-sw cl	----	MP	25	45	48	35	----	----	----
	SMALL GRAIN IN ROTATION									
	With meadow seeding:									
	In disked row-crop residue—									
89	After 1 year C after M	3–5	75+	----	20	12	2	2	----	----
90	Do	2–3	60–74	----	30	18	3	2	----	----
91	Do	1–2	40–59	----	41	25	4–15	2	----	----
92	Do	<1	25–39	----	60	36	5–15	3	----	----
93	After 2d or 3d year C after M	3–5	75+	----	32	19	5	3	----	----
94	Do	2–3	60–74	----	40	24	5	3	----	----
95	Do	1–2	40–59	----	58	35	5–15	3	----	----
96	Do	<1	25–39	----	75	45	6–15	3	----	----
97	After 1 or more C after SG	----	----	----	(6)	(6)	(6)	(6)	----	----

See footnotes at end of table.

TABLE 2.—*Ratio of soil loss from cropland to corresponding loss from continuous fallow*—Continued

Line No.	Cover, sequence, and management [1]	Productivity [2]		Soil-loss ratio for crop-stage period [3]						
		Hay yield	Corn yield	F	1	2	3 [4]	4L	4R	4L+WC
	SMALL GRAIN IN ROTATION—continued									
	With meadow seeding—Continued									
	In disked row-crop residue—Con.	*Tons*	*Bu.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
98	After 1st-year cot after M	2–3			35	25	5–15	3		
99	After 2d-year cot after M	2–3			50	35	5–15	3		
100	In cot middles after sw cl or lesp				30	22	10–15	3		
	On disked row-crop stubble, RdR—									
101	After 1 year C after M	2–3	60+		50	40	5–15	3		
102	Do	1–2	40–59		80	45	7–15	3		
103	After 2 years C after M	2–3	60+		80	50	6–15	3		
104	After C, 3d year after M				92	55	7–15	3		
	On plowed seedbed, RdL—									
105	After 1 year C or SG after M	3–5	75+	25	45	30	5	3		
106	Do	2–5	60–74	35	51	34	5	3		
107	Do	1–2	40–59	42	60	40	7	4		
108	After 2 years C or SG after M	3–5	75+	36	60	40	5	3		
109	Do	2–3	40–59	55	70	45	7	4		
	On plowed seedbed, RdR—									
110	After 1 year C or SG after M	3–5	75+	55	60	40	5	3		
111	Do	2–3	60–74	60	65	42	6	3		
112	Do	1–2	40–59	65	70	45	7	4		
113	After 2 years C after M	2–3	60–74	65	70	45	7	4		
	Without meadow seeding:									
114	Sequences and yields of lines 89–90			(7)	(7)	(7)	8	8	16	
115	Sequences and yields of lines 91–99, 101, 105, 106, 108–110			(7)	(7)	(7)	10	10	20	
116	Sequences and yields of lines 102–104, 107, 111-113			(7)	(7)	(7)	12	12	25	
	DOUBLE-CROPPED ROTATIONS									
117	Wheat (grain) and lesp (hay)				25	25	5	5		
118	Wheat and lesp, both grazed				25	25	12	6		
119	Spg oats (hay) and lesp (hay) [8]				50	18	5	5		
	ESTABLISHED MEADOWS [9]									
120	Grass and legume mix	3+						0.4		
121	Do	2						.6		
122	Do	1						1.0		
123	Alfalfa	2.5+						2.0		
124	Lespedeza							2.0		
125	Red clover							1.5		
126	Sericea, 2d year							2.0		
127	Sericea, after 2d year							1.0		
128	Sweetclover							2.5		

[1] Symbols: C, corn; conv till, conventional tillage; cot, cotton; crot, crotolaria; gr & lg, grass and legume; lesp, lespedeza; M, grass and legume meadow, at least 1 full year; min till, minimum tillage; O, oats; prec, preceding; RdL, residue of prior crop left; RdR, residue of prior crop removed; spg, spring; SG, small grain; sw cl, sweetclover; TP, turn plow; V, vetch; WC, grass or grass-and-legume winter cover seeded early.

[2] For cotton, HP=high crop productivity; MP=moderate crop productivity.

Small-grain cover is assumed commensurate with the indicated productivity level of corn or cotton.

[3] Crop-stage periods are as defined on p. 10. Period 4 ratios are taken from column 4L when crop residues remain on field but without winter cover seeding; from column 4R when corn stover, straw, and similar residues are removed; and from column 4L+WC when early-seeded grass and legume winter cover is established in addition to leaving crop residues.

[4] Where two period 3 values appear, the first is for high-yielding grain and the second is for grain yielding less than 30 bushels of oats or 15 bushels of wheat per acre.

[5] Use data from lines 36 to 42, selecting line on basis of productivity level.

[6] Use data from lines 93 to 96, selecting line on basis of productivity level.

[7] Use data from lines 89 to 113.

[8] Ratio for winter months is 12 percent.

[9] Ratios shown are the yearly averages.

TABLE 3.—*Suggestions for approximating soil-loss ratios for cropping and management combinations not listed in table 2*

Cover, sequence, and management	Soil loss ratios
Corn:	
After fall turnplowing in northern half of United States.	To compensate for effect of freezing and thawing and for high early-spring soil moisture content, add 7 to each period-F and period-1 value in lines 1 to 7, 13 to 18, 33 to 39, and 47 to 50 of table 2.
After 2 or more full years of meadow.	Table 2 assumed at least 1 full year of established grass-and-legume meadow. Additional credit for 2-year meadows may be considered if meadows are high yielding and are not permitted to deteriorate: Reduce by 10 percent the values for periods F, 1, 2, 3 and 4L in lines 13, 14, 15, 33, 34, 66, 67, 78, and 79.
With small-grain seeding for winter cover.	Small grain turned early in spring does not significantly reduce soil loss from following corn crop. Select lines from table 2 that do not specify WC seeding and substitute small-grain periods 1 and 2 for corn period 4L or 4R.
Grain sorghum	Same as ratios for corn in similar rotations where canopy cover and quantities of residue are comparable. Under irrigation, the values for grain sorghum may equal those for high-yielding corn.
Meadow:	
New	When seeded without a nurse crop, use values listed for spring-seeded small grain. The lengths of periods 1 and 2 should be adjusted if necessary so that cover in each period will be comparable to corresponding grain periods.
Established	Apply values of lines 120 to 128.
Peanuts	For comparable crop sequence, values in lines 5, 6, 16, 17, 27, 28, 32, 35, 38, 45, 49, 52, and 56 are recommended.
Potatoes:	
After potatoes or truck crop	In similar crop sequence, select values from periods F, 1, 2, and 4 of lines 18, 29, 39, 46. For period 3, use values from line 16, 17, 27, 28, 38, or 45.
After grass-and-legume hay yielding more than 2 tons per acre.	Select values for periods F to 3 from lines 1, 3, 5, 7 on basis of hay yield; period 4 from line 7.
After corn or small grain	Select values for periods F to 3 on basis of preceding crop and yield; period 4 from line 7.
Soybeans:	
After grass-and-legume hay or after corn.	Use values for comparable corn rotations: Periods F to 3 from lines 3 to 7, 15 to 18, 26 to 29, 37 to 39, 48, 49; period 4 from lines 7, 18, 29, 39.
After soybeans	Select lines representing corn residues equivalent to soybean residues: Lines 15 to 18, 37 to 39.
Late-planted	Select values from comparable crop sequences in lines 5, 6, 16, 17, 27, 28, 32, 35, 38, 45, 49.
Sweet corn	Do.
Truck crops	For low-residue truck crops after grass-and-legume hay or high-residue crops, select periods F and 1 values from comparable corn rotations; periods 2, 3, and 4 values from lines 7, 18, 29, 39, 46. For second or more year of truck crop, use values from line 39 or 46 for all periods.

Other combinations of crops and management variables are being included in studies as rapidly as possible. Rainfall simulators have been developed to decrease the time required to obtain data. In the meantime, the data in table 2 will be helpful for estimating the effectiveness of covers or management practices that have not been measured directly. Such estimates are facilitated by the fact that the table values are given for each crop-stage period separately. Cover and surface conditions as they occur in each crop-stage period of an untested crop or with a new tillage practice may usually be compared with the conditions reflected in one of the lines of soil-loss ratio table. This procedure is illustrated in table 3, which suggests a number of specific comparisons.

Semiarid Areas.—Water erosion is a serious problem also in most semiarid regions. Inadequate moisture and periodic droughts reduce the periods when growing plants provide good soil cover and limit the total quantities of plant residues produced. Erosive rainstorms are not uncommon, and they are concentrated within the season when cropland is least protected. Because of the difficulty of establishing meadows and the competition for available soil moisture, sod-based rotations are often impractical.

Proper management of available residues offers one of the most important opportunities for a higher level of soil and moisture conservation. However, accurate soil-loss ratios for stubble mulching and summer fallowing practices on the western Plains are not yet available from research data. The ratios given in table 4 are approximations based on observations of experi-

TABLE 4.—*Approximations of soil-loss ratios for crop-stage periods and number of tillage operations with stubble mulching and summer fallowing in western Plains areas*

Cover, sequence, and management	Residue on surface at seeding time	Soil-loss ratios for crop-stage period—				
		1	2	3	4L	4R
Small grain without meadow seeding:	*Pounds*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
After small grain	200–500	70	45	6	10	20
Do	500–1, 000	42	25	6	10	20
Do	1, 000–1, 500	25	17	6	10	20
Do	1, 500–2, 000	15	10	6	10	20
After summer fallow of—						
Small-grain residues	0–200	90	55	6	10	20
Do	200–500	70	45	6	10	20
Do	500–1, 000	42	25	6	10	20
Do	1, 000–1, 500	25	17	6	10	20
Do	1, 500–2, 000	15	10	6	10	20
Row crop residues	0–200	90	55	6	10	20
Do	200–500	85	50	6	10	20
Do	500–1, 000	70	45	6	10	20
Do	1, 000–1, 500	50	35	6	10	20
Do	1, 500–2, 000	40	30	6	10	20
Do	2, 000–2, 500	30	25	6	10	20
		Soil-loss ratios for following number of tillage operations after grain harvest—				
		1	2	3	4	5
Summer fallow:						
After small grain	0–200	53	60	70	80	90
Do	200–500	25	49	55	63	70
Do	500–1, 000	25	29	34	39	42
Do	1, 000–1, 500	10	14	19	22	25
Do	1, 500–2, 000	4	6	8	11	13
After row crop	0–200	68	72	80	85	90
Do	200–500	50	55	63	75	85
Do	500–1, 000	50	55	60	65	70
Do	1, 000–1, 500	26	35	40	45	50
Do	1, 500–2, 000	20	25	30	35	40
Do	2, 000–2, 500	15	20	25	28	30

enced field personnel,[5] guided by very limited data on the erosion-control effectiveness of various amounts of surface mulch and by the experimentally determined values of table 2. These approximations appear to be consistent with present knowledge of erosion research and runoff and will provide valuable guides until more precise evaluations can be obtained through additional research.

Erosion-Index Distribution Curves

The rainfall factor, *R*, in the erosion equation does not completely describe the effects of locational differences in rainfall pattern on soil erosion. On cropped fields, rainstorm distribution within the year is also important. The erosion-control effectiveness of a cropping system on some particular field depends, in part, on how the year's erosive rainfall is distributed among the five crop-stage periods of each crop included in the system. Therefore, expected monthly distribution of erosive rainfall at a particular location is an element in deriving the applicable value of the cropping-management factor, *C*.

It was previously pointed out that a location's erosion index is computed by summing *EI* values of individual storms. Thus, the monthly distribution of the erosion index can also be determined from long-time rainfall data. This was done for all the station rainfall records abstracted for development of the iso-erodent map.

On the basis of monthly distribution of the erosion index, the 37 States of figure 1 were

[5] The authors are indebted to D. G. Craig, W. A. Hays, J. J. Pierre, and J. W. Turelle, Soil Conservation Service, for substantial contributions toward expanding the scope and usability of the soil-loss ratio data from which table 2 was derived. Table 4 was taken from unpublished material developed by J. W. Turelle and D. G. Craig, in cooperation with the Agricultural Research Service's runoff and soil loss data center.

divided into 33 geographic areas shown in figure 4. For practical purposes, its monthly distribution may be considered uniform throughout any one of these areas but different from monthly distribution in any of the other 32 areas. Actually, the changes in distribution are usually gradual transitions from one area to another rather than abrupt changes at the area boundaries. Therefore, wide differences between average distributions within two adjacent areas are often not apparent. However, at some part of the distribution curve, the difference is sufficient to affect C-value derivations for some cropping systems. For widely separated geographic areas, differences in the erosion-index distributions are much more apparent.

The erosion-index distribution curve applicable in each of the 33 subareas of figure 4 is shown in figures 5 to 21, respectively. The numbers of the plotted curves in these figures correspond with the area numbers shown on the key map, figure 4. Average monthly erosion-index values were expressed as percentages of average annual values and plotted cumulatively against time. Thus, the percentage of the annual erosion index that is to be expected within any particular crop stage period may be found by reading the curve at the last and first date of the period and subtracting.

Procedure for Deriving Rotation *C*-Values for a Particular Locality

To compute the value of C for any particular rotation on a given field, one needs first to determine the most likely seeding and harvest dates

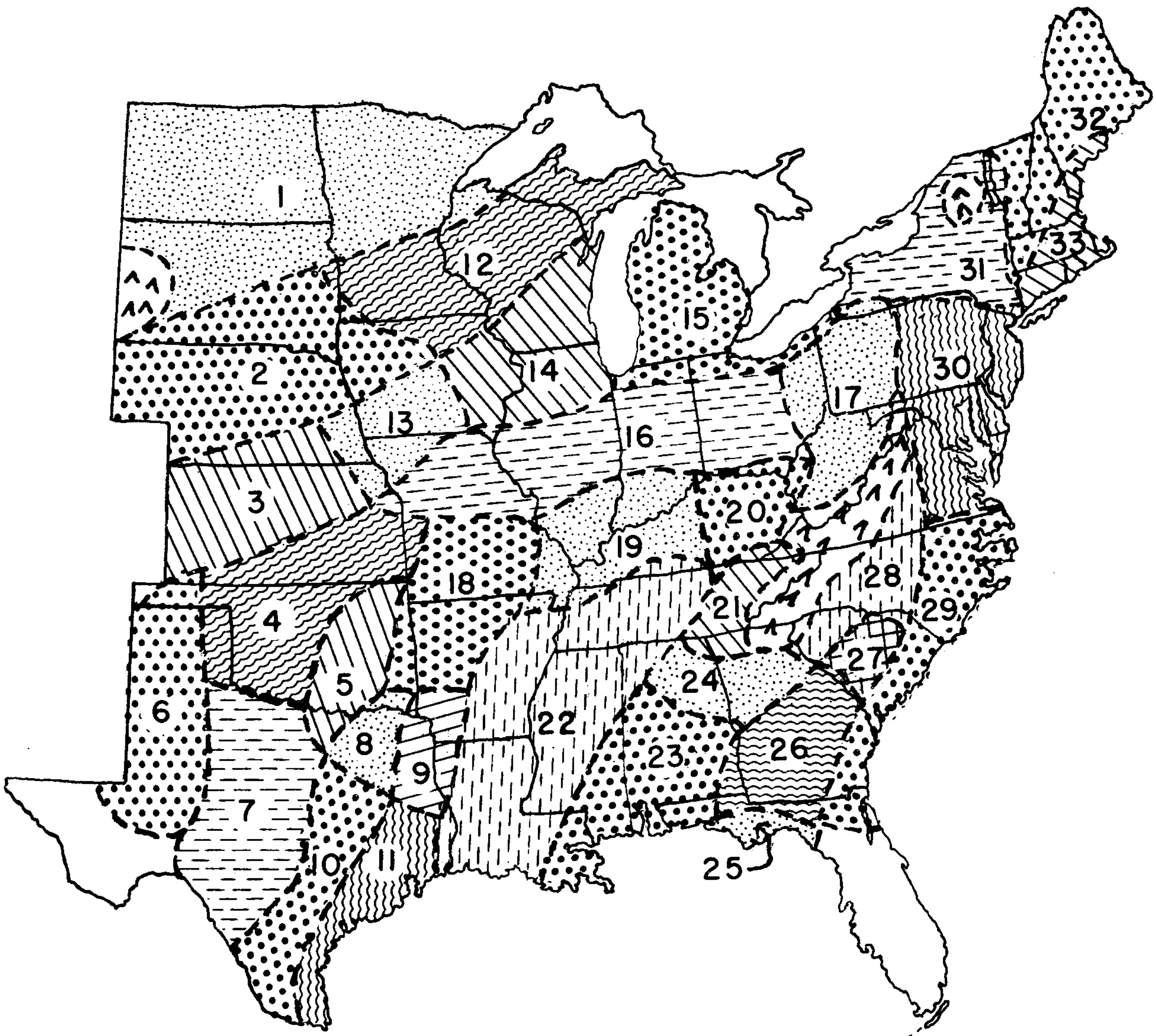
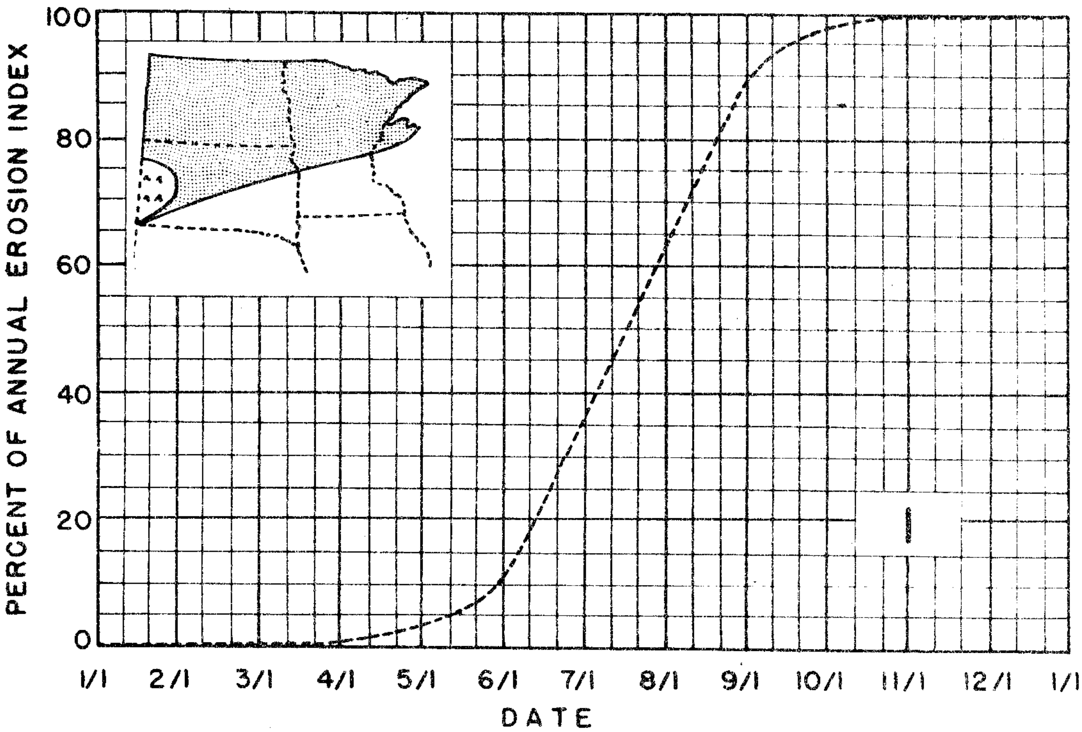


FIGURE 4.—Key map for selection of applicable erosion-index distribution curve.



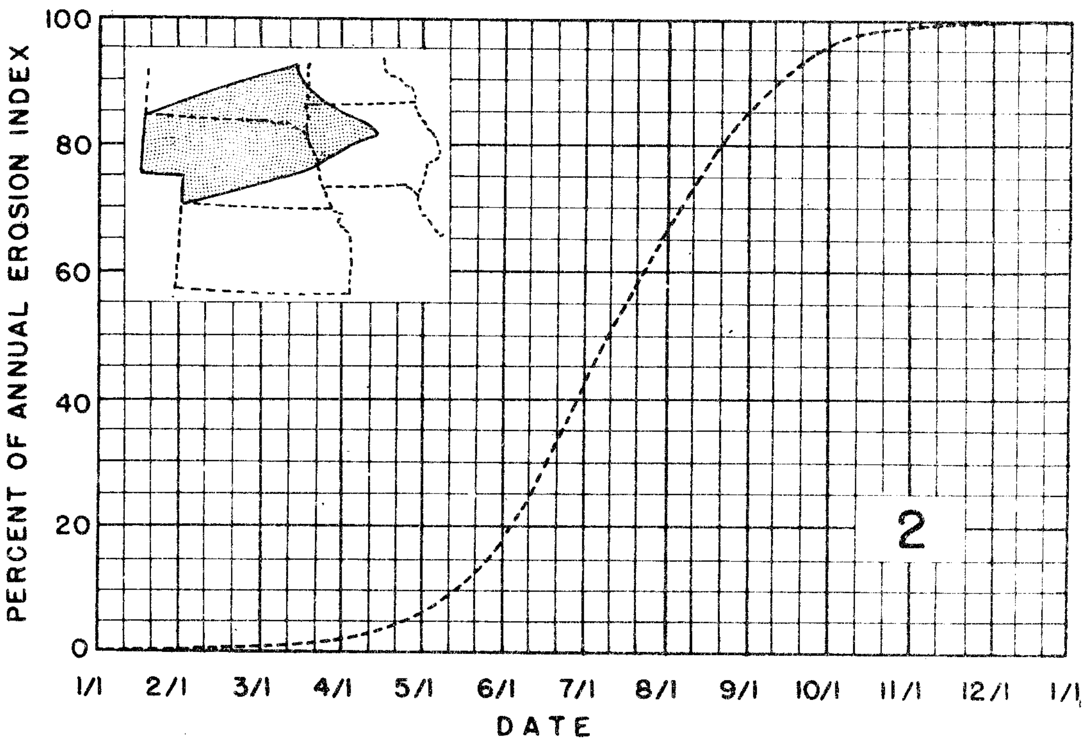
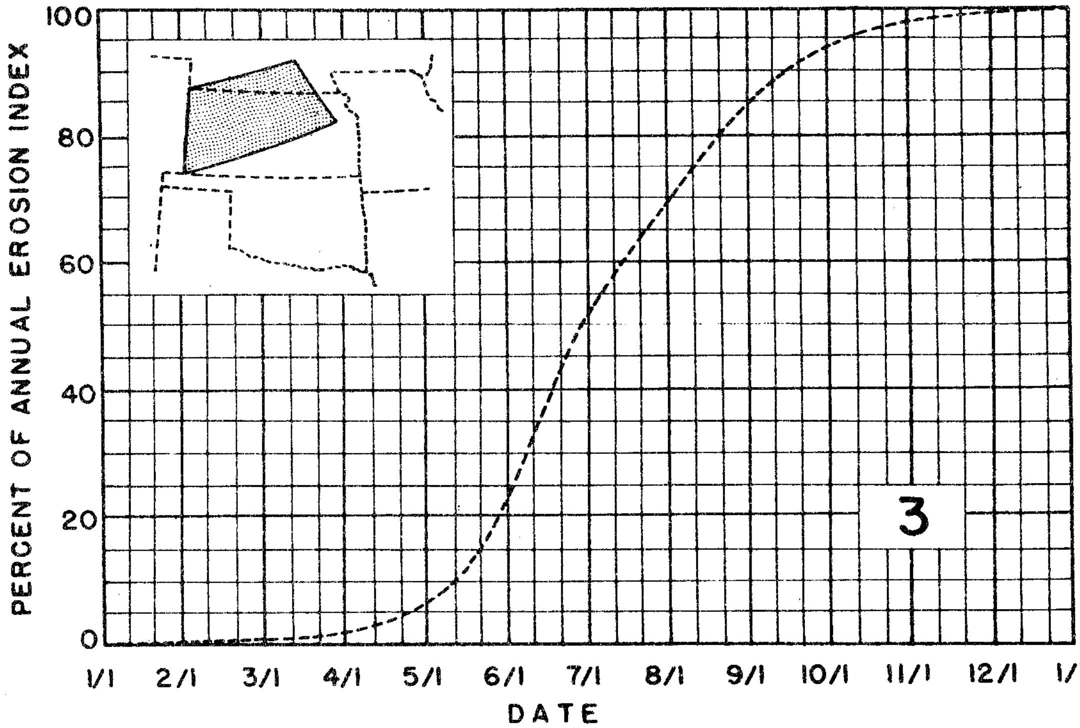


FIGURE 5.—Erosion-index distribution curves 1 and 2: the Dakotas and parts of Minnesota, Nebraska, and Iowa.



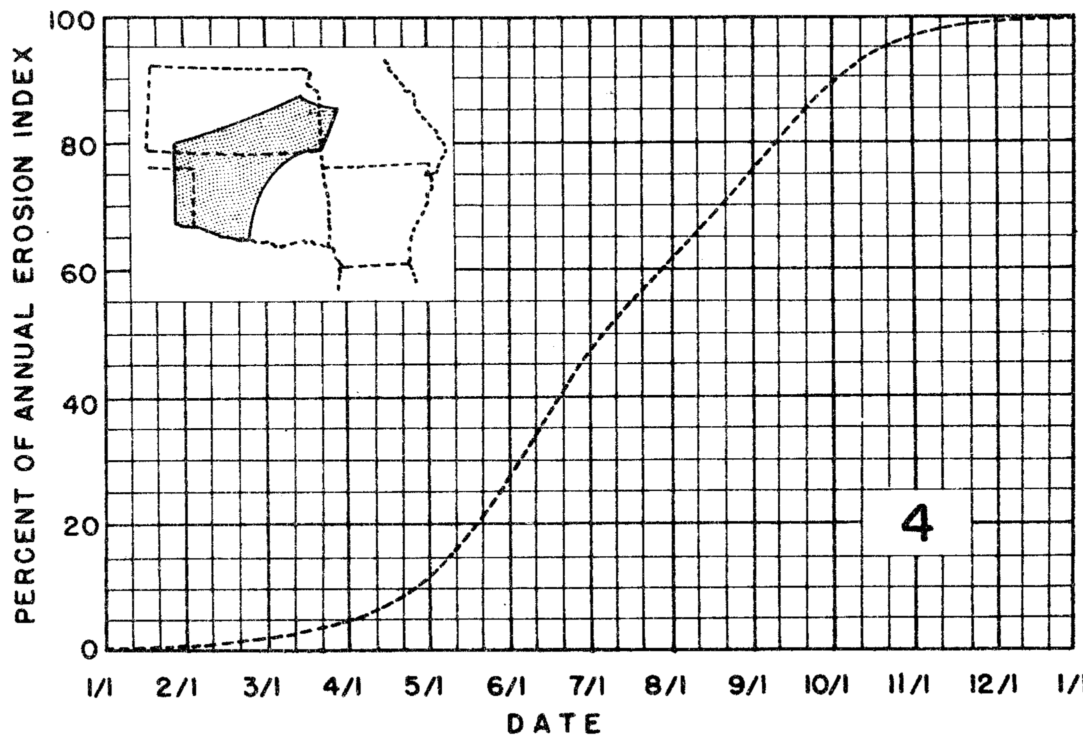
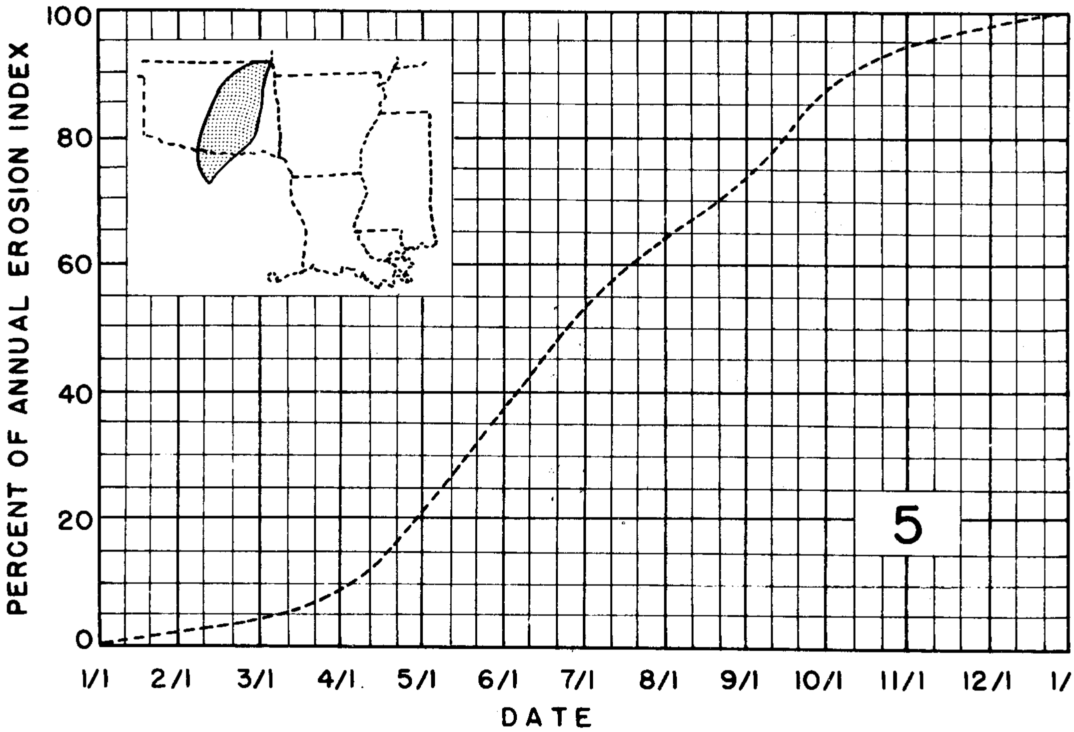


FIGURE 6.—Erosion-index distribution curves 3 and 4: parts of Nebraska, Kansas, and Oklahoma.



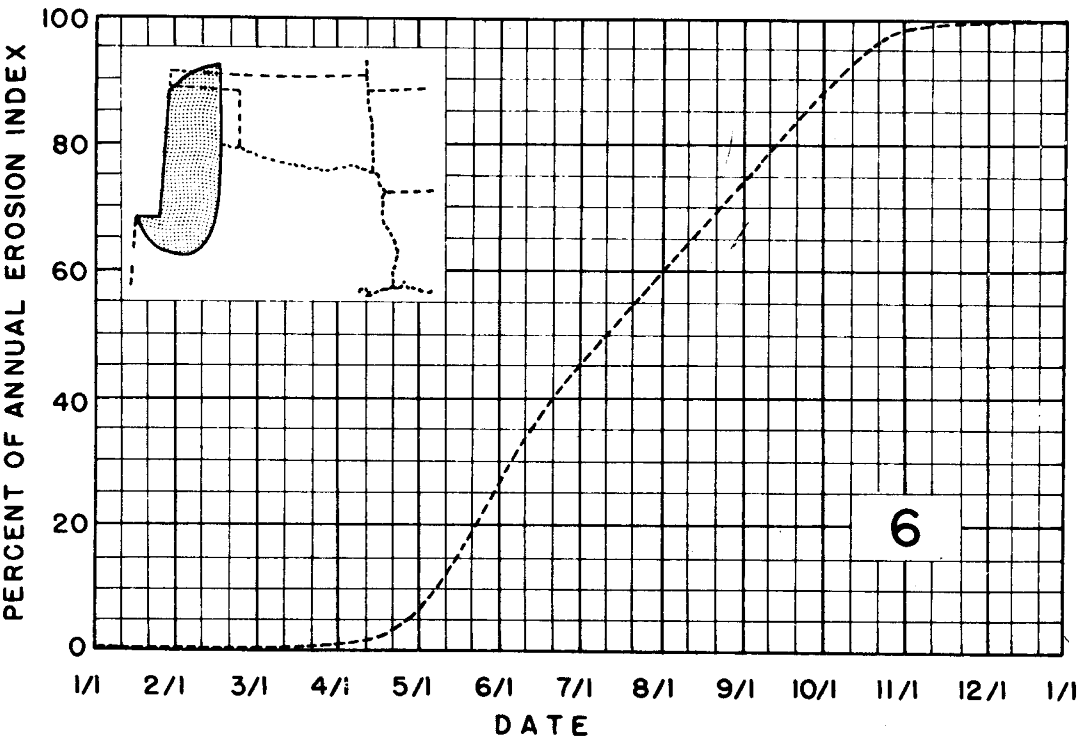
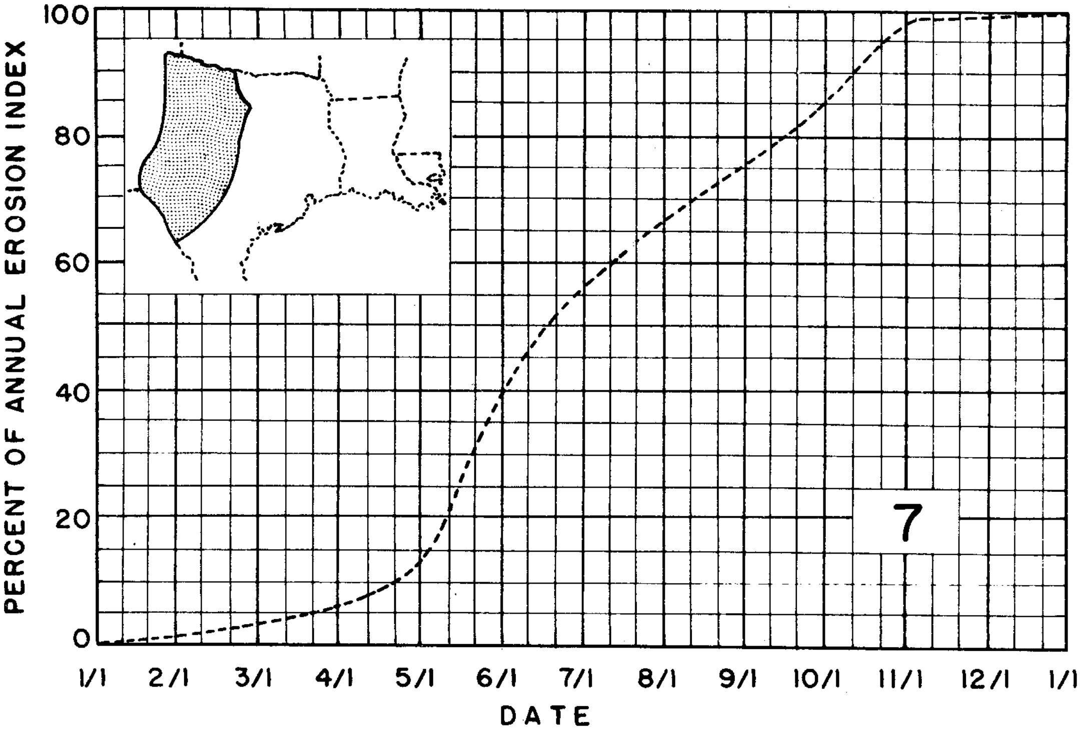


FIGURE 7.—Erosion-index distribution curves 5 and 6: parts of Oklahoma and Texas.



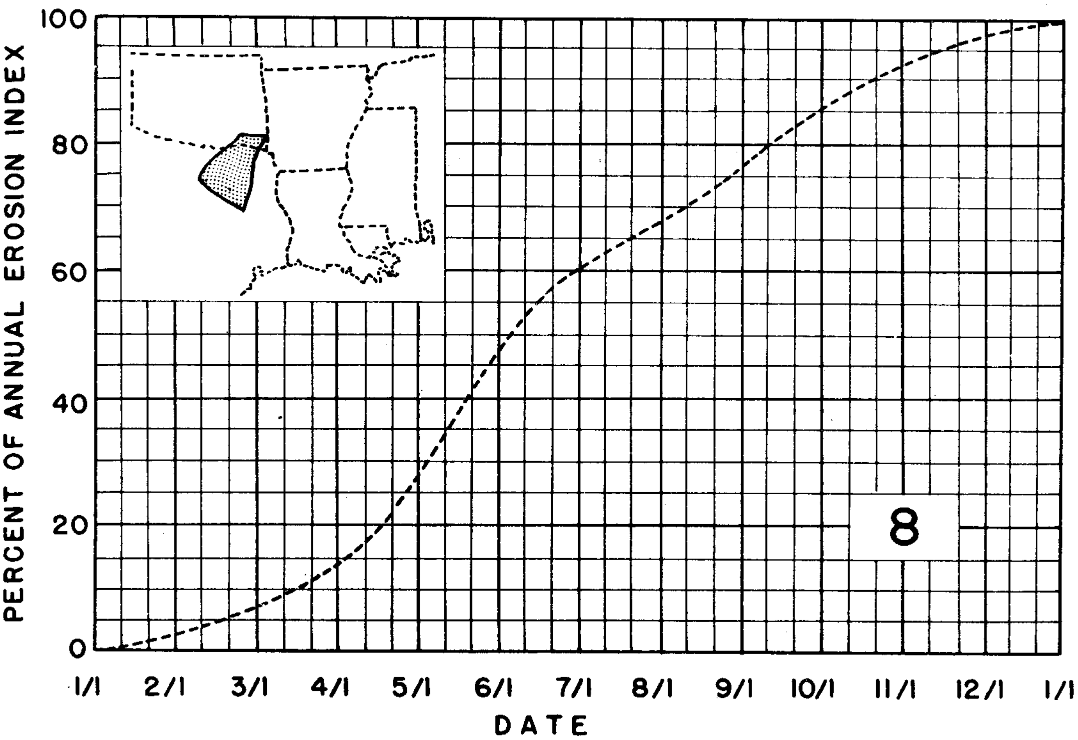
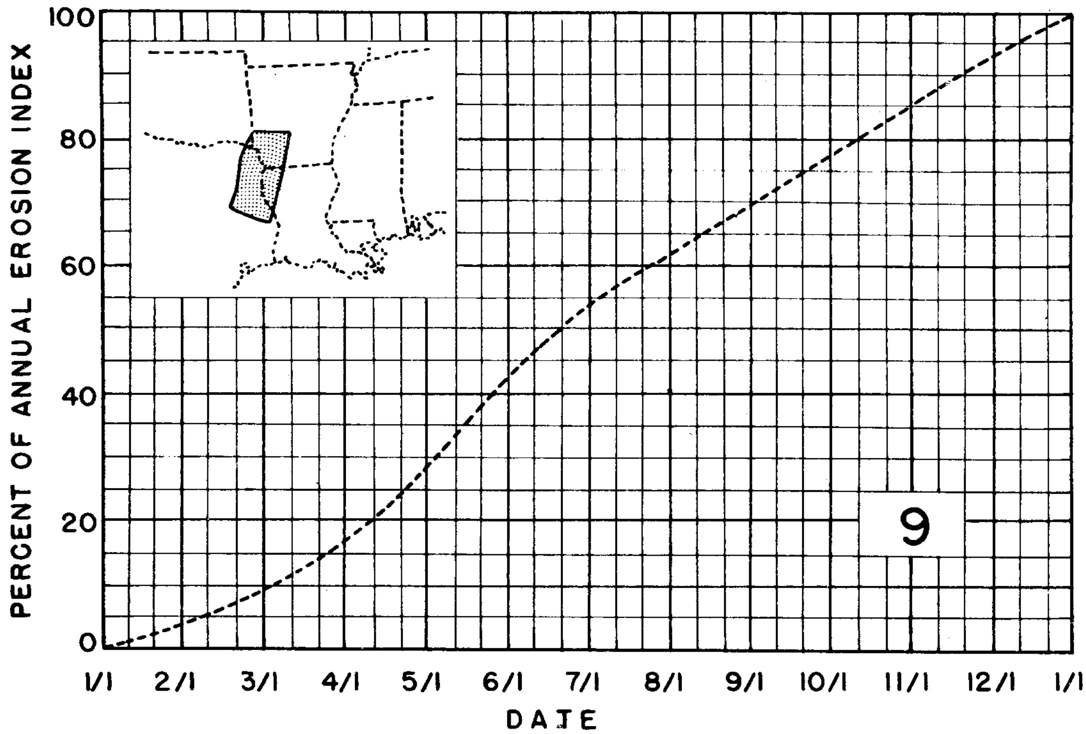


FIGURE 8.—Erosion-index distribution curves 7 and 8: parts of Texas.



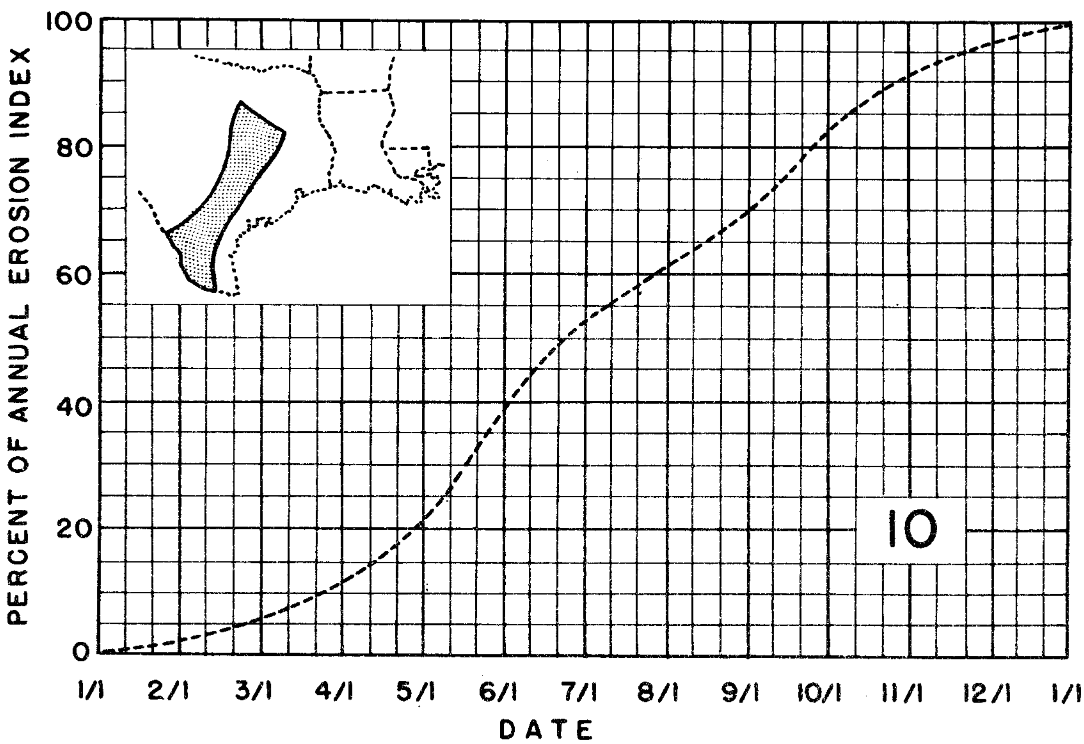
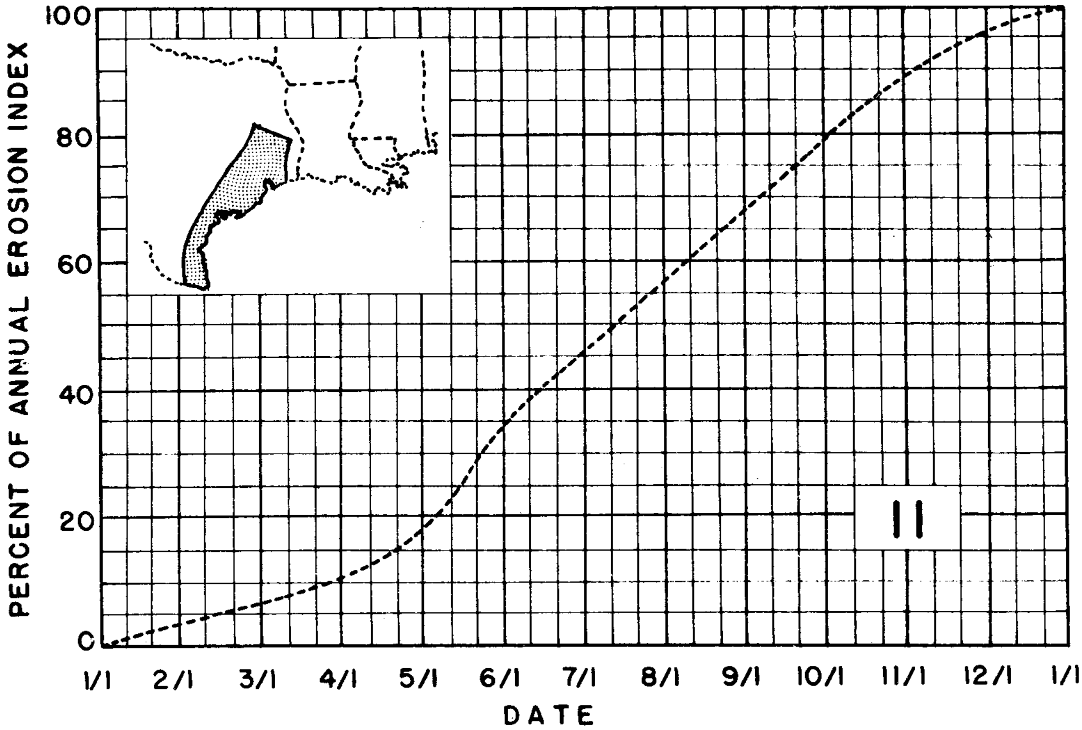


FIGURE 9.—Erosion-index distribution curves 9 and 10: parts of Texas, Arkansas, and Louisiana.



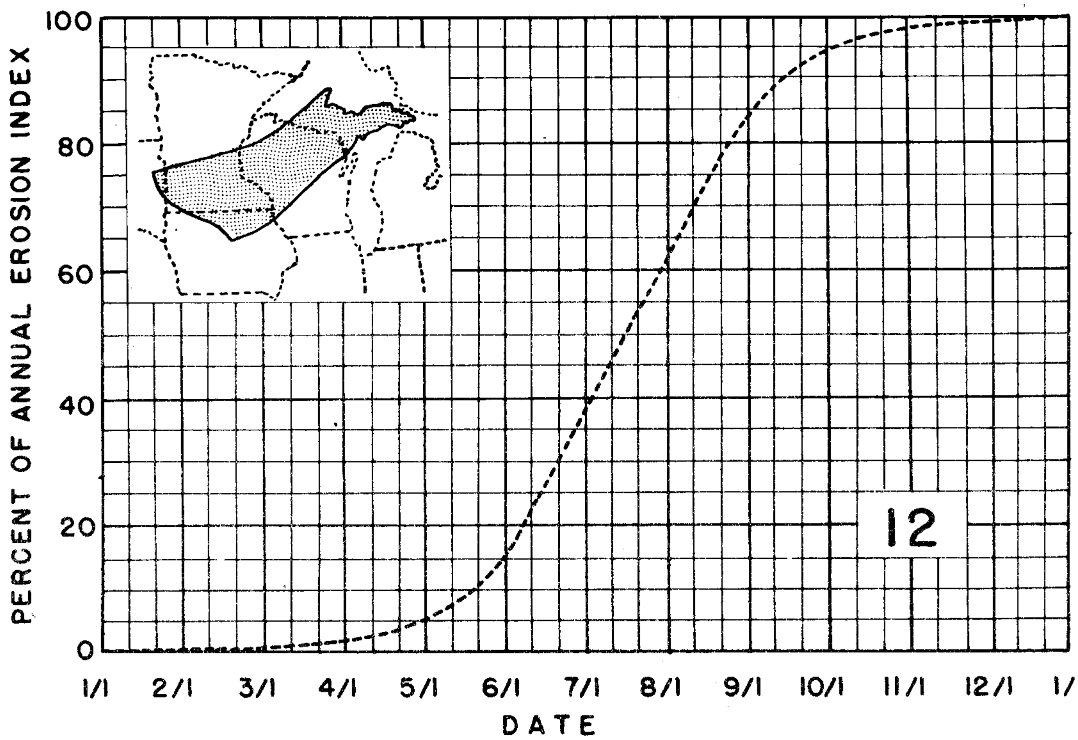
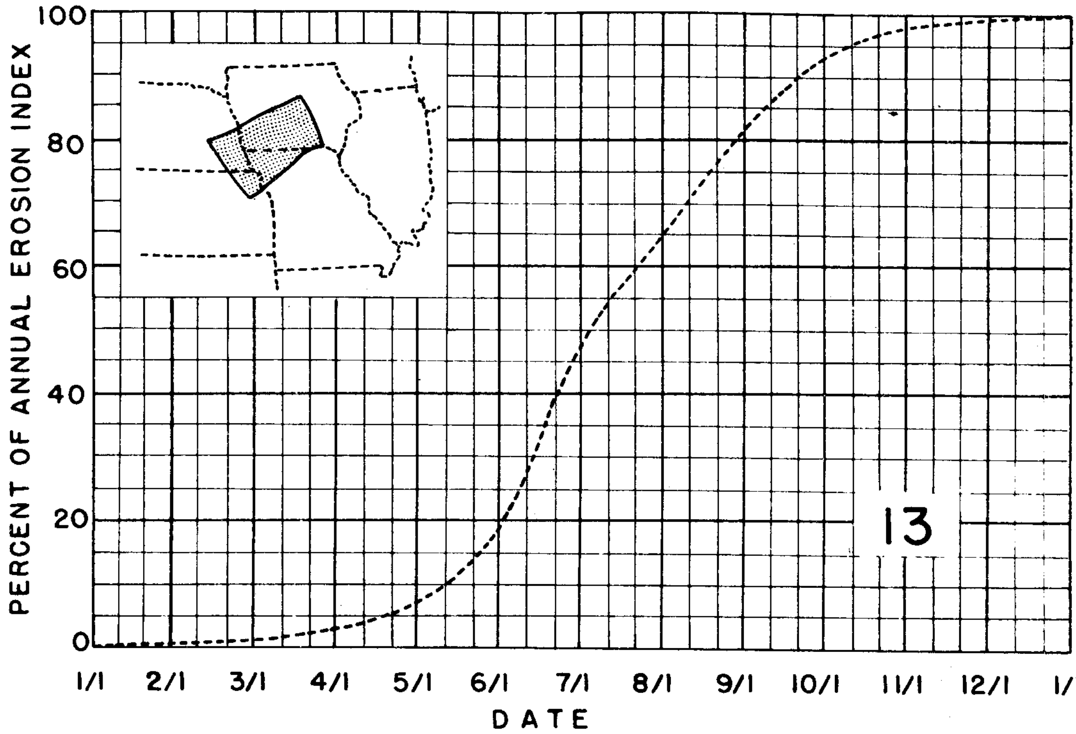


FIGURE 10.—Erosion-index distribution curves 11 and 12: parts of Texas, Minnesota, Iowa, Wisconsin, and Michigan.



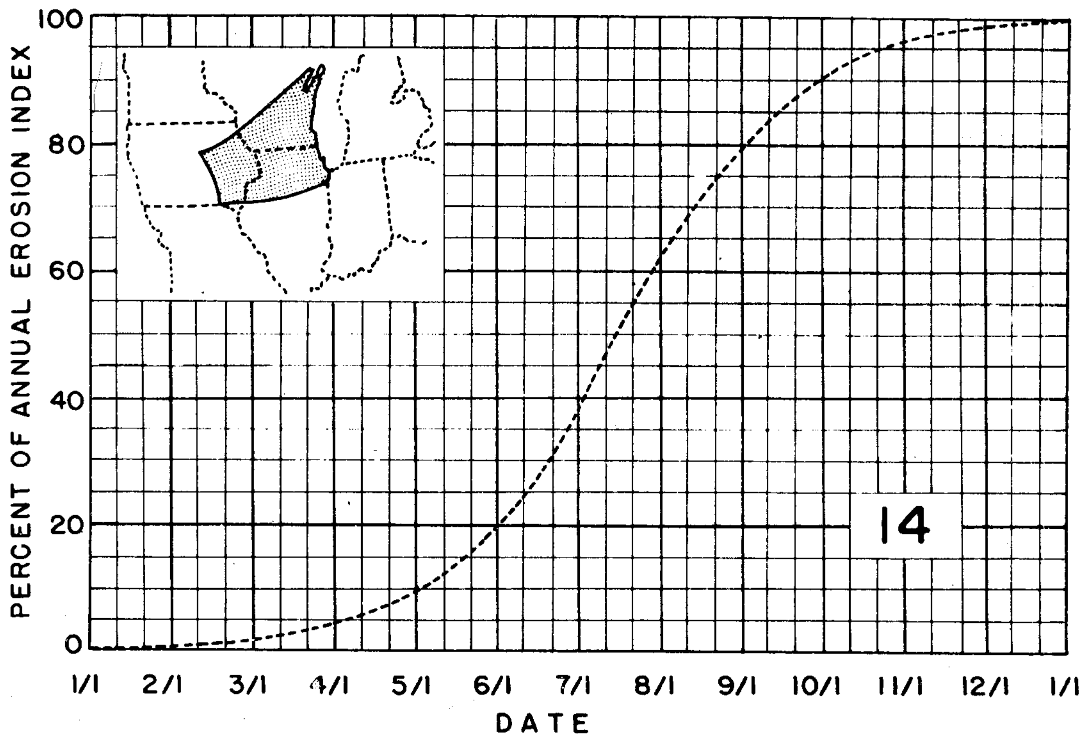
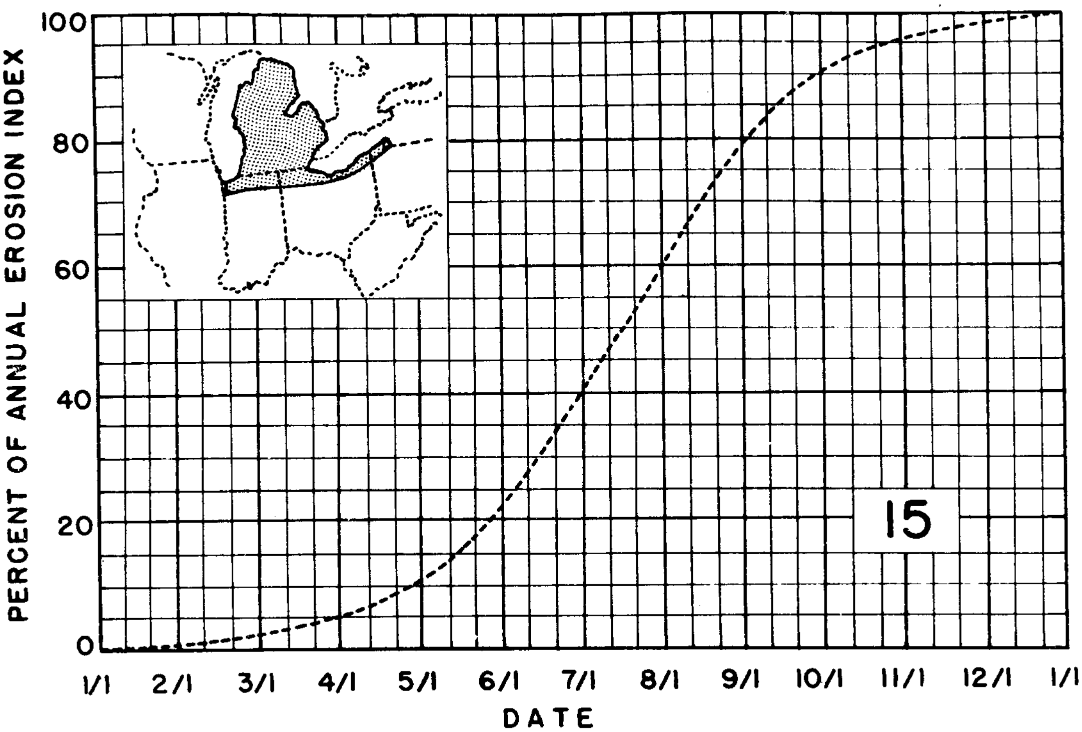


FIGURE 11.—Erosion-index distribution curves 13 and 14: parts of Nebraska, Kansas, Missouri, Iowa, Illinois, and Wisconsin.



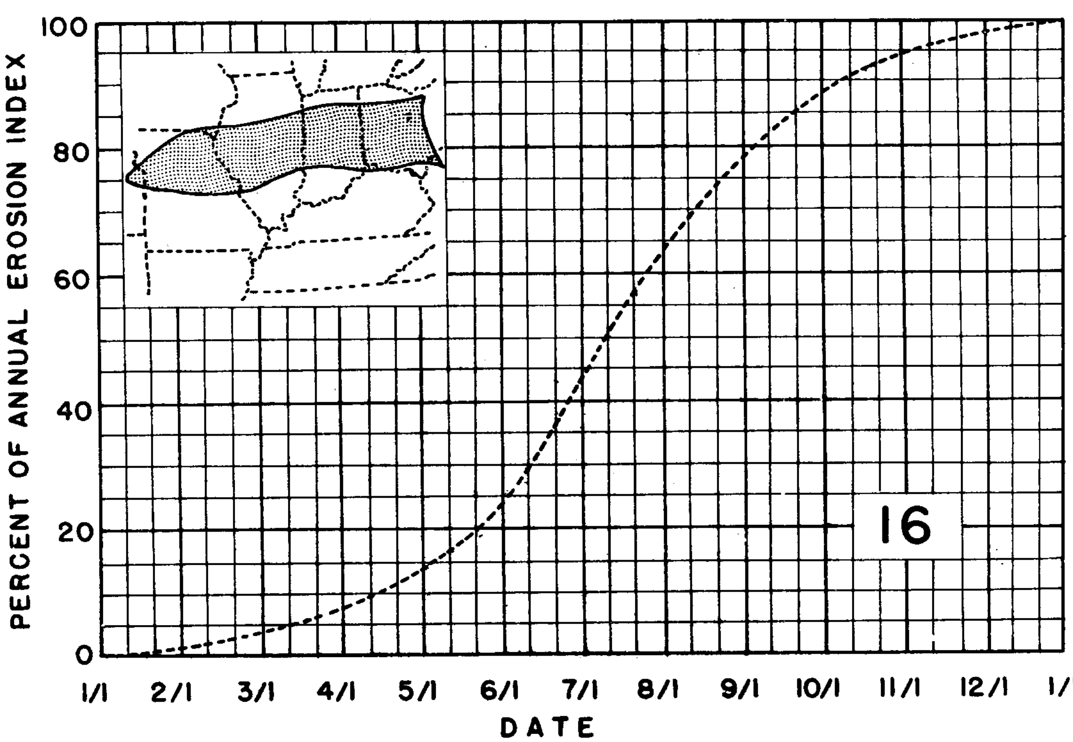
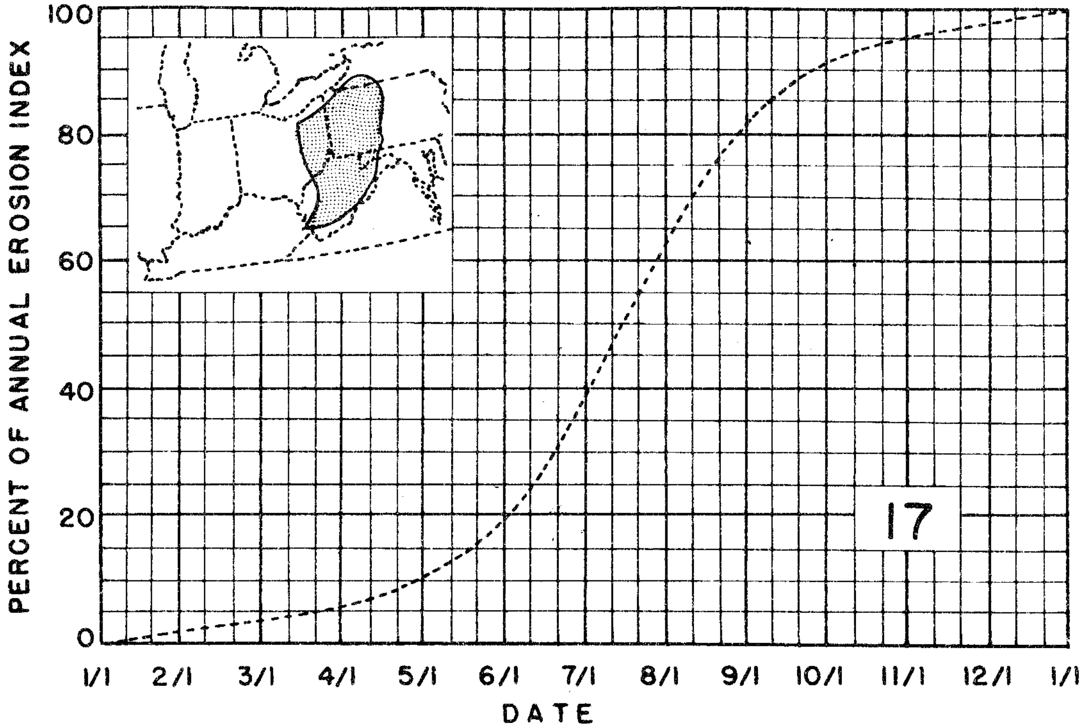


FIGURE 12.—Erosion-index distribution curves 15 and 16: parts of Michigan, Missouri, Illinois, Indiana, and Ohio.



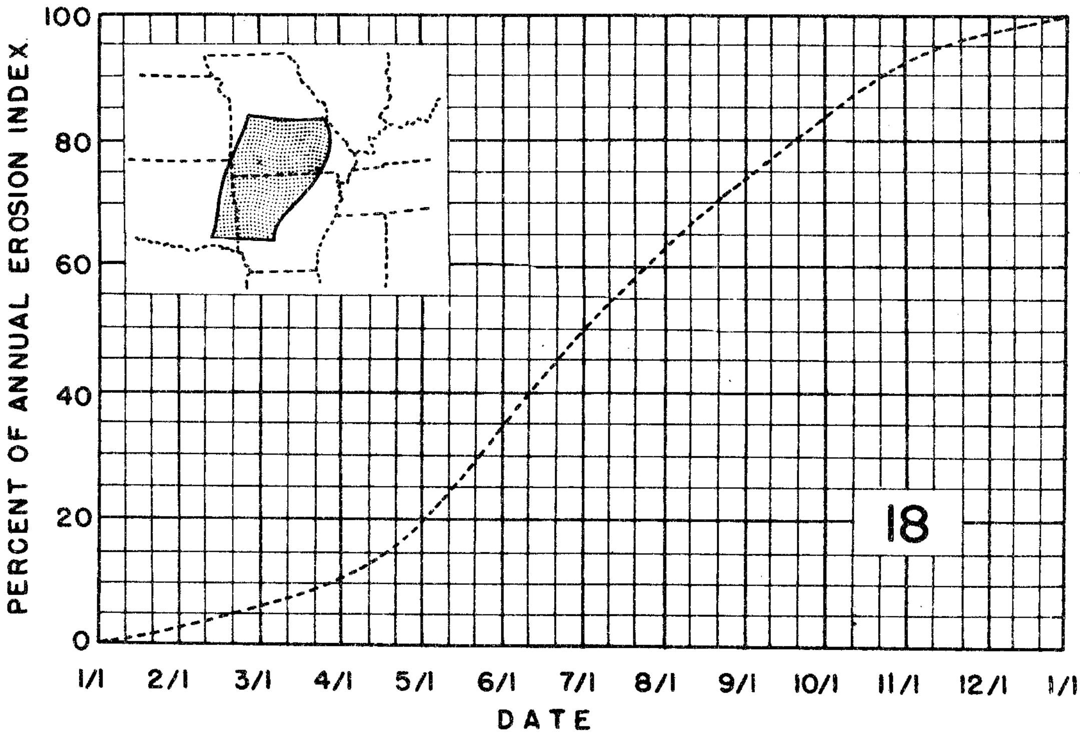
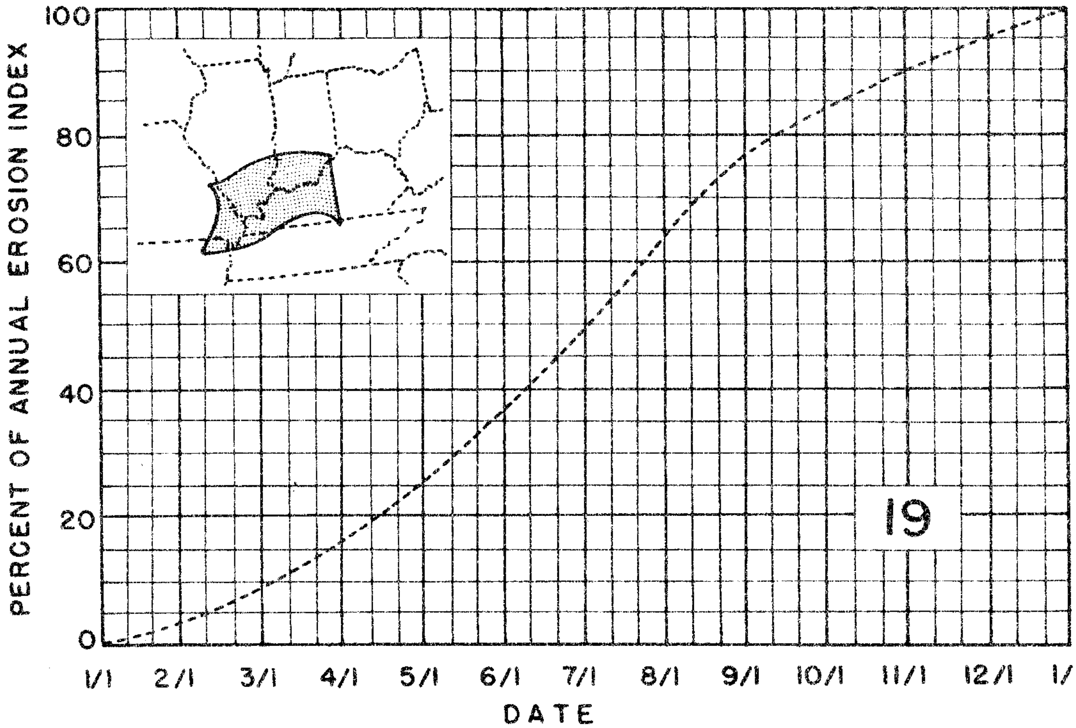


FIGURE 13.—Erosion-index distribution curves 17 and 18: parts of Ohio, Pennsylvania, West Virginia, Missouri, and Arkansas.



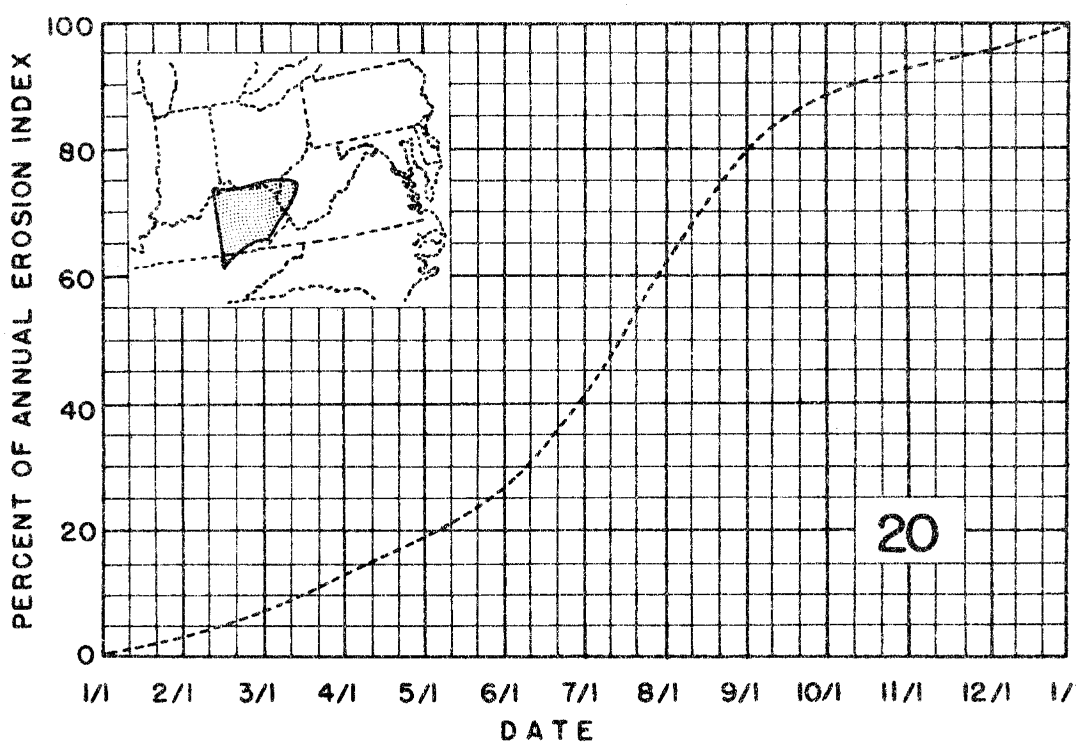
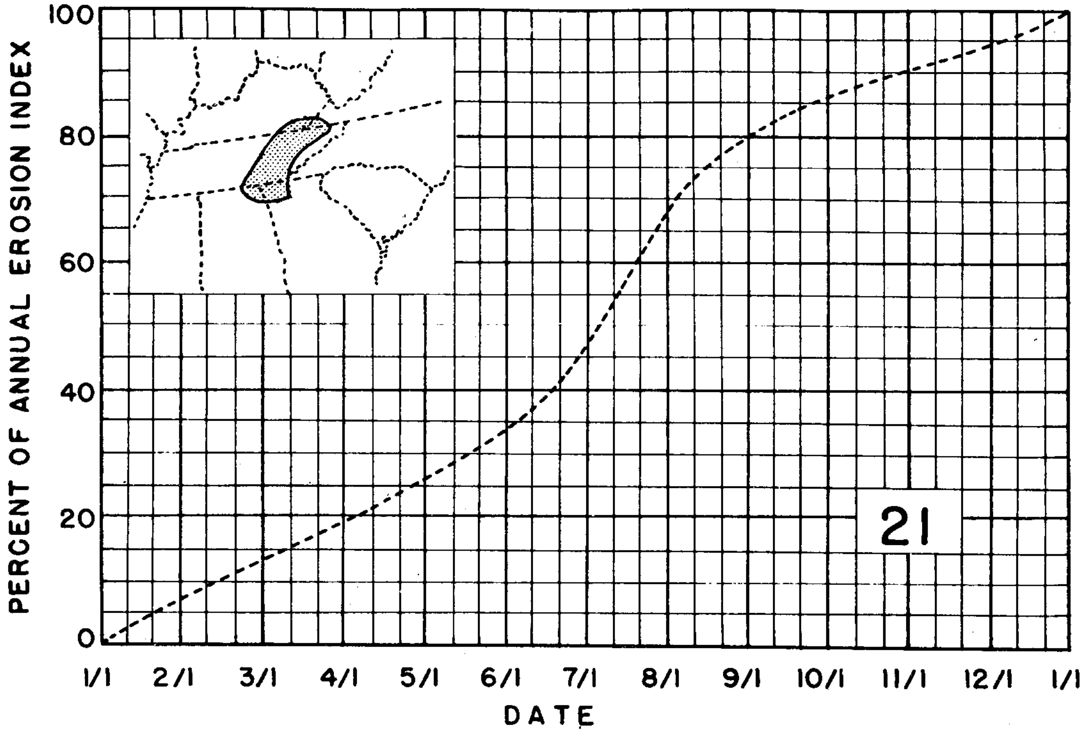


FIGURE 14.—Erosion-index distribution curves 19 and 20: parts of Missouri, Illinois, Indiana, and Kentucky.



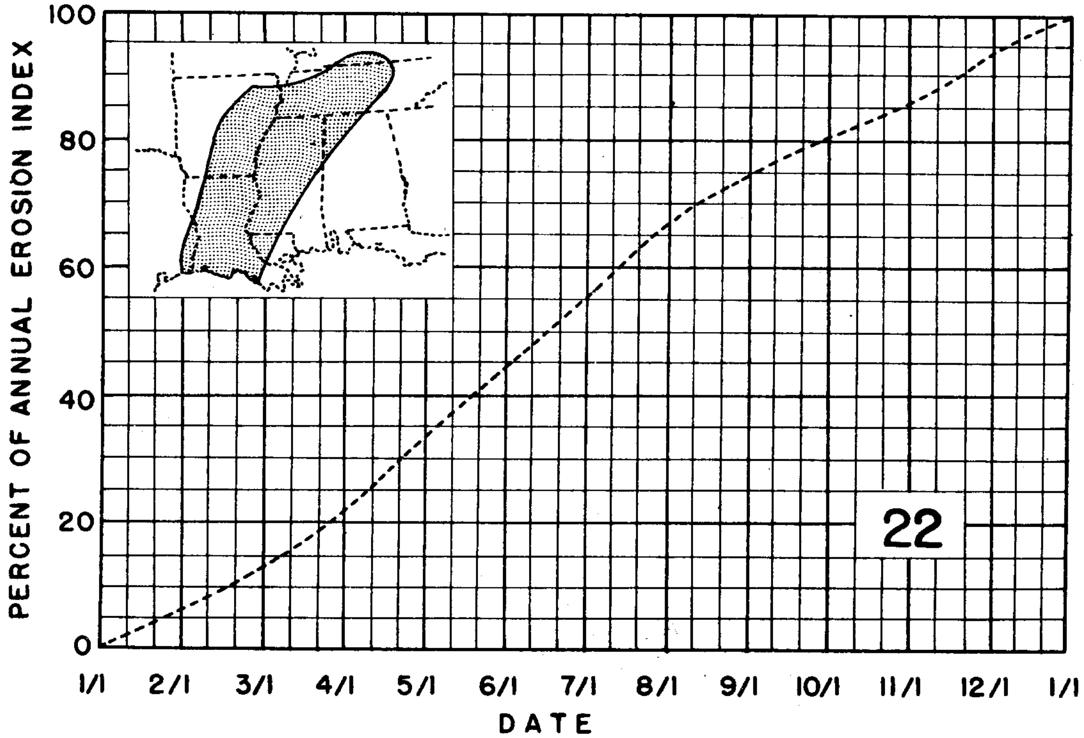
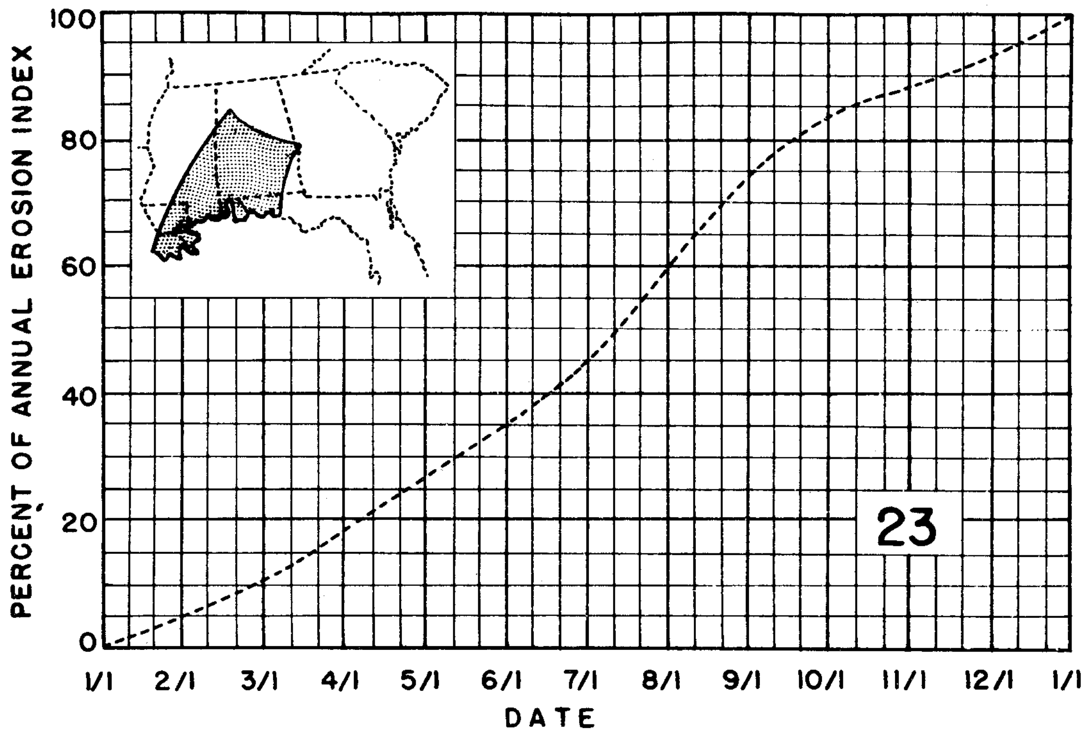


FIGURE 15.—Erosion-index distribution curves 21 and 22: parts of Tennessee, Arkansas, Louisiana, Mississippi, and Alabama.



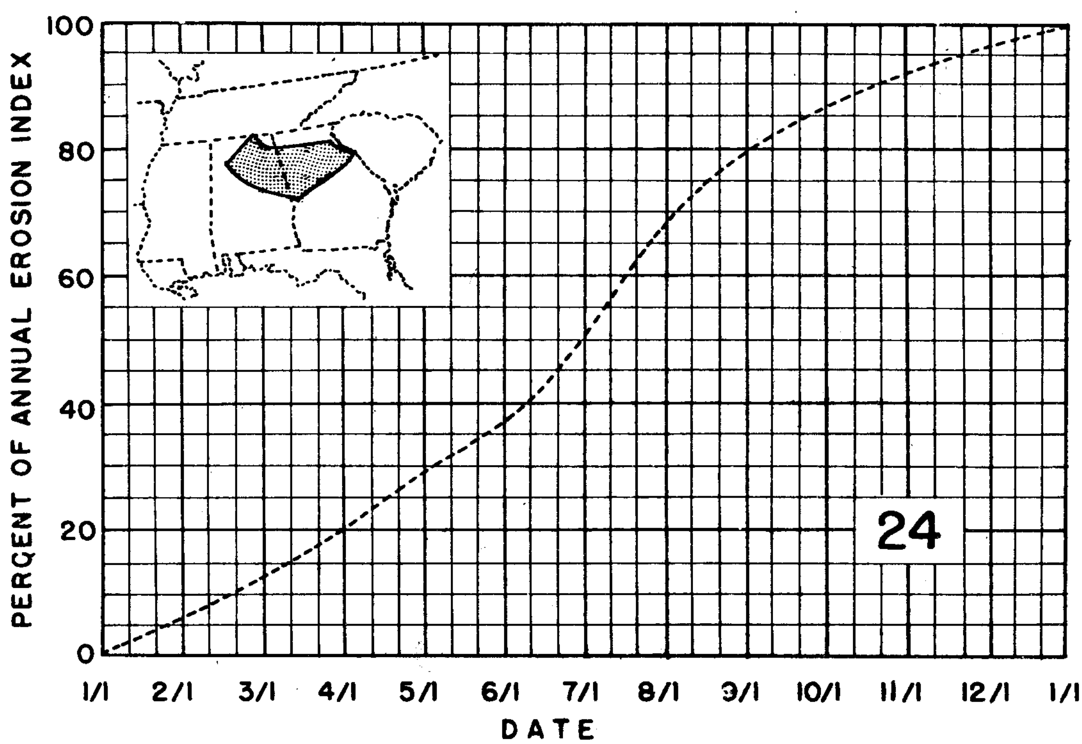
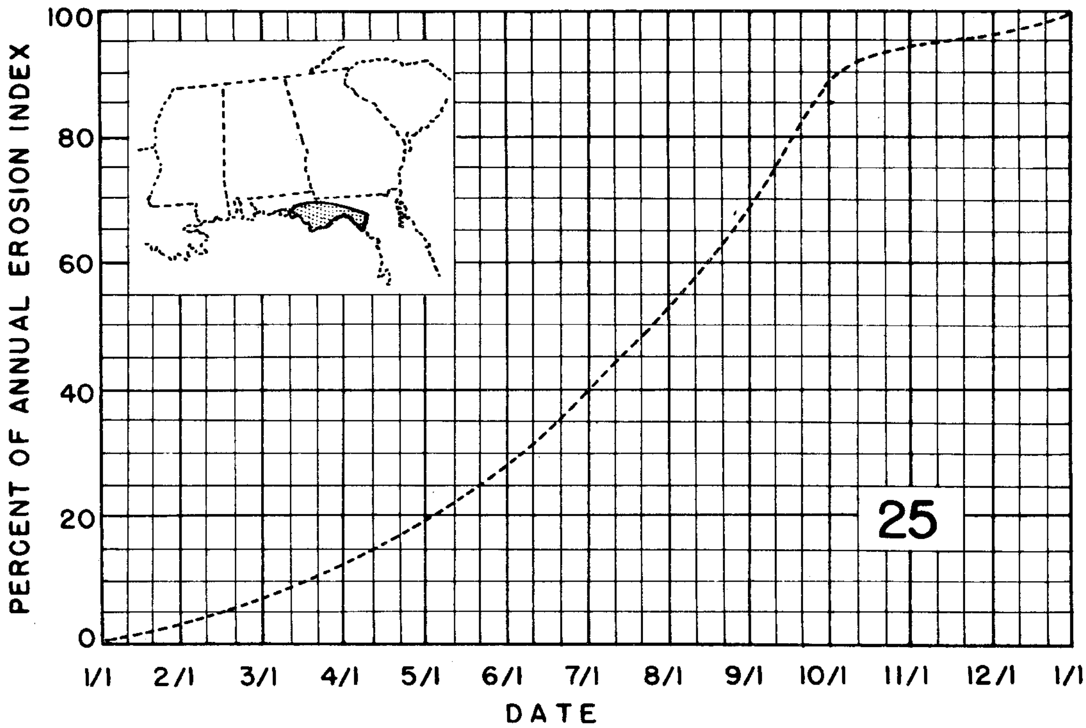


FIGURE 16.—Erosion-index distribution curves 23 and 24: parts of Mississippi, Alabama, Florida, and Georgia.



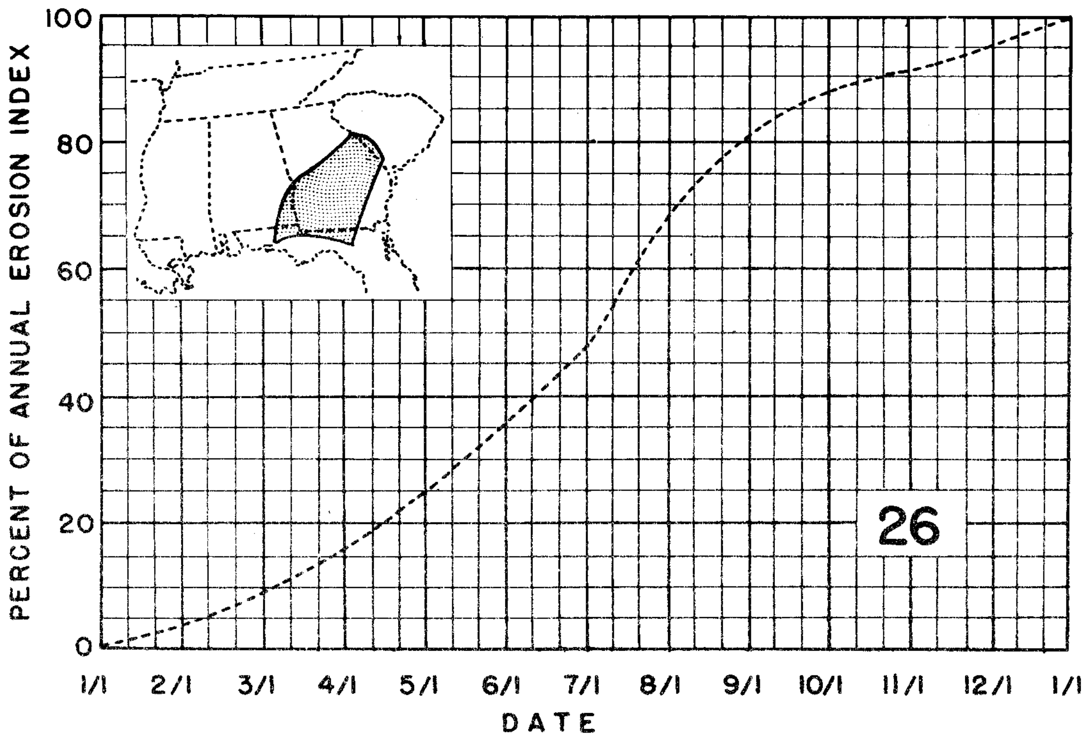
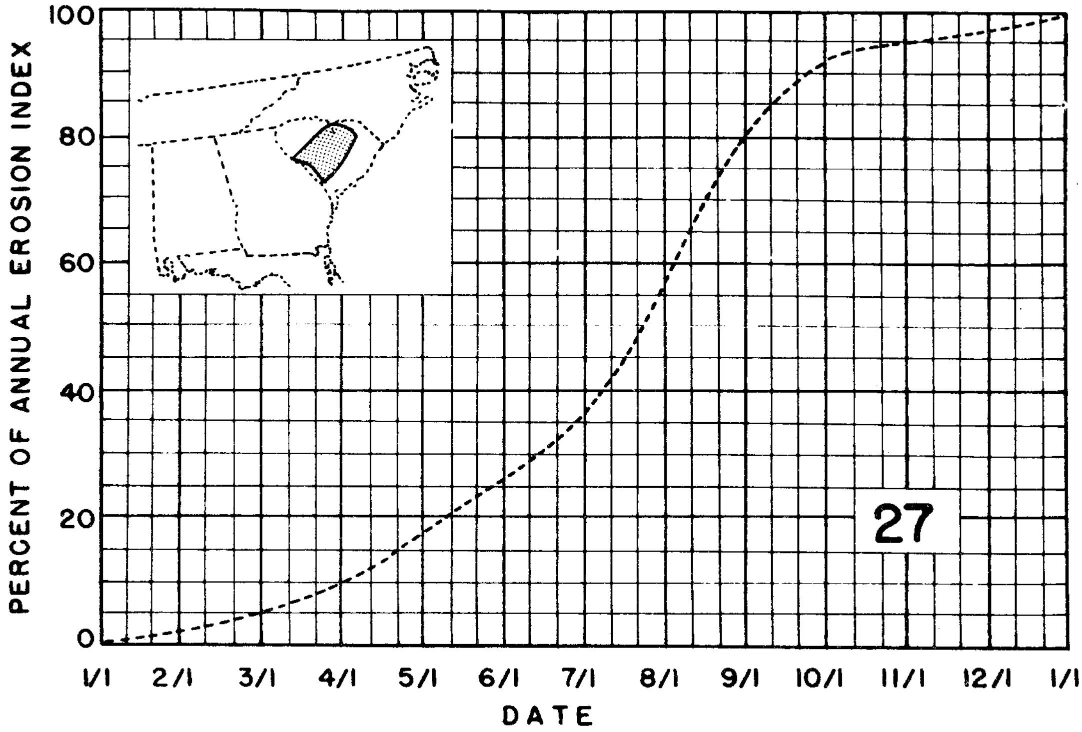


FIGURE 17.—Erosion-index distribution curves 25 and 26: parts of Florida and Georgia.



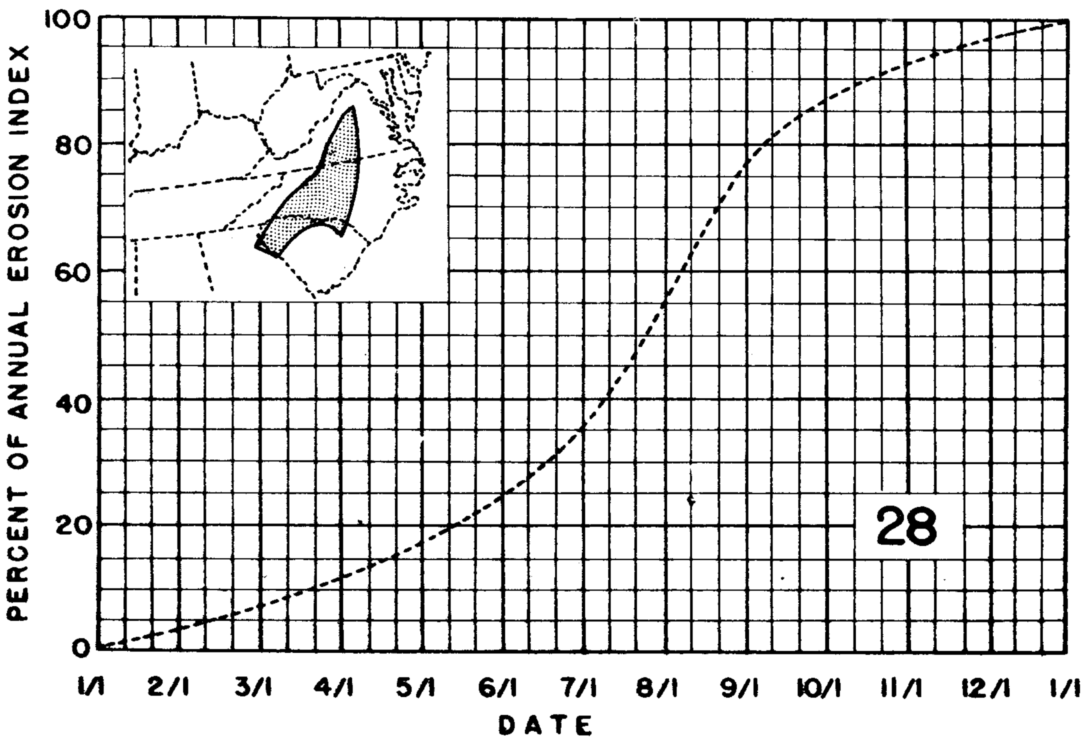
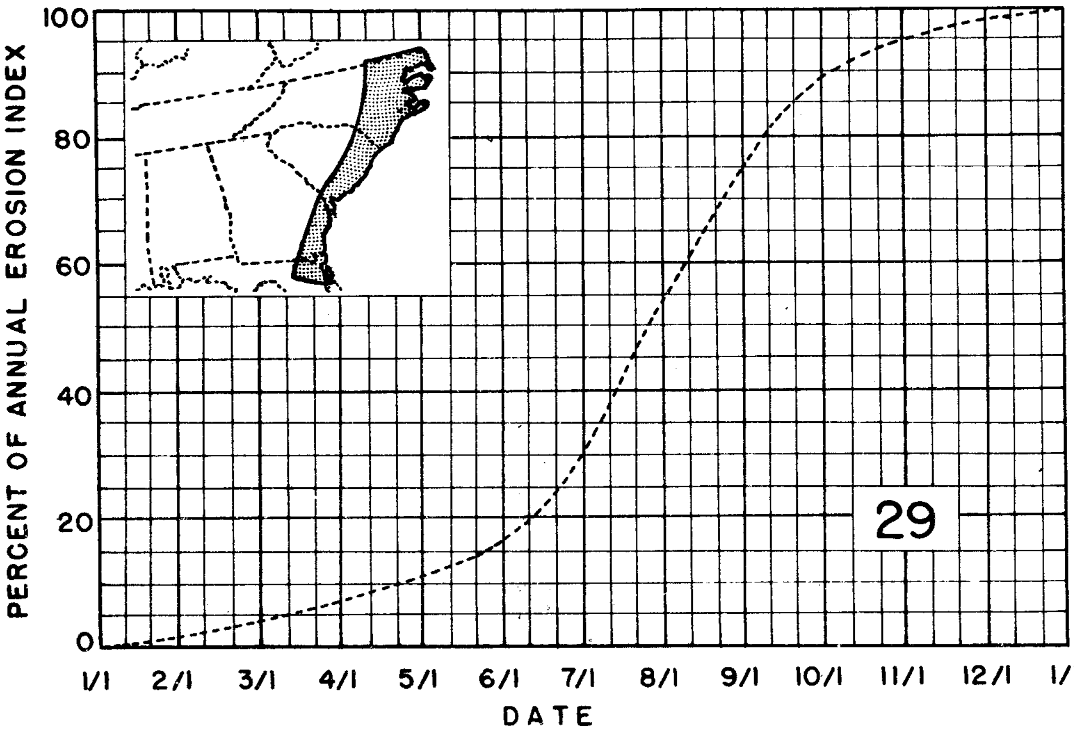


FIGURE 18.—Erosion-index distribution curves 27 and 28: parts of South Carolina, North Carolina, and Virginia.



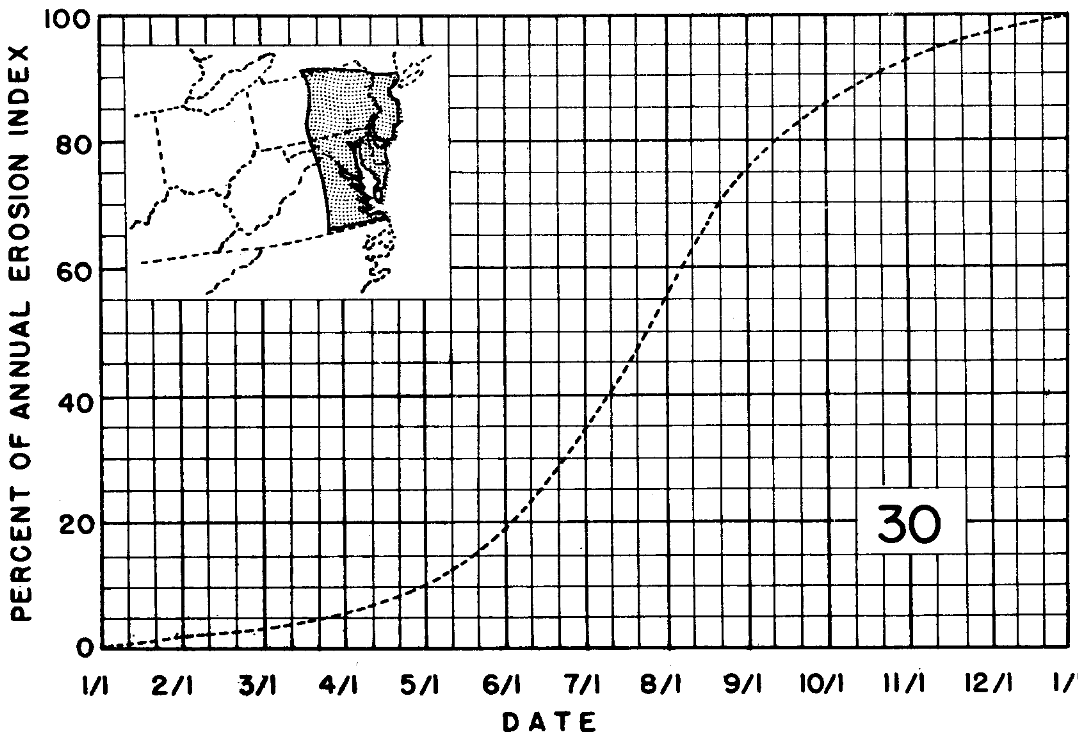
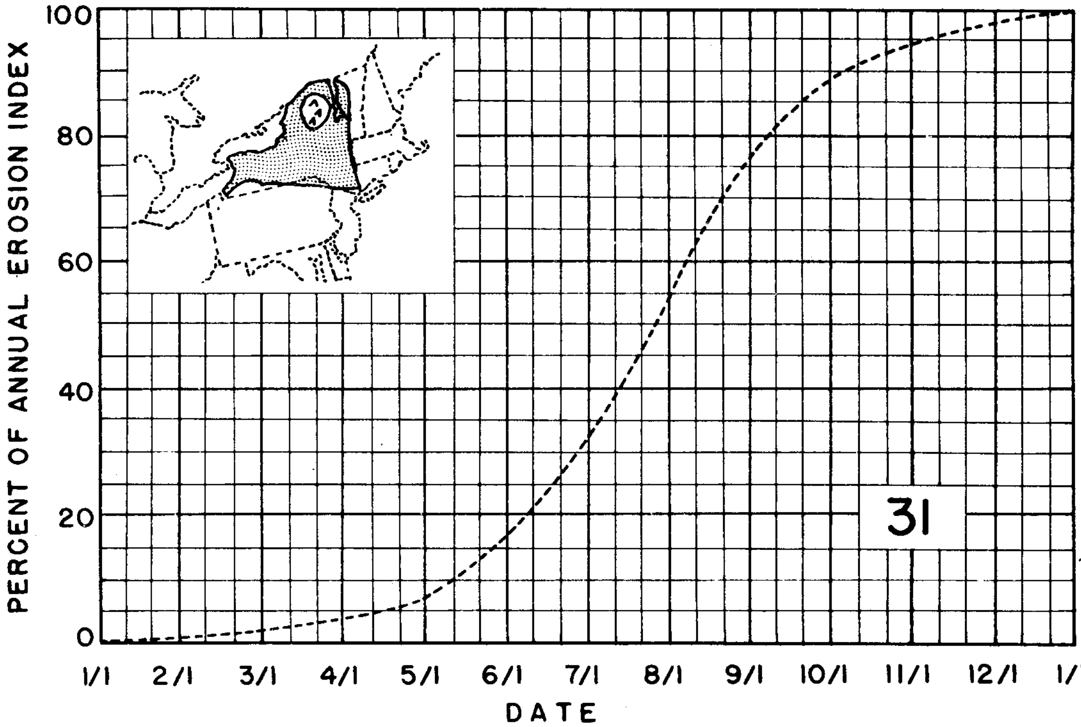


FIGURE 19.—Erosion-index distribution curves 29 and 30: Atlantic coast from New Jersey to Florida.



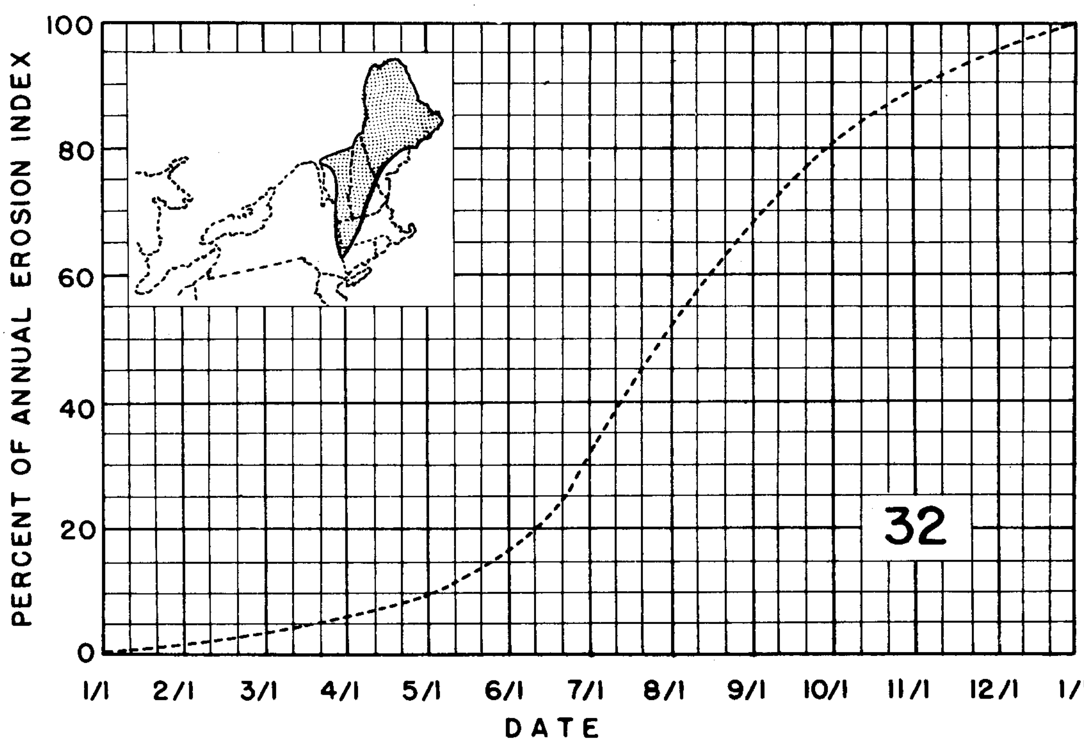


FIGURE 20.—Erosion-index distribution curves 31 and 32: New York and parts of Maine, New Hampshire, Vermont, and Massachusetts.

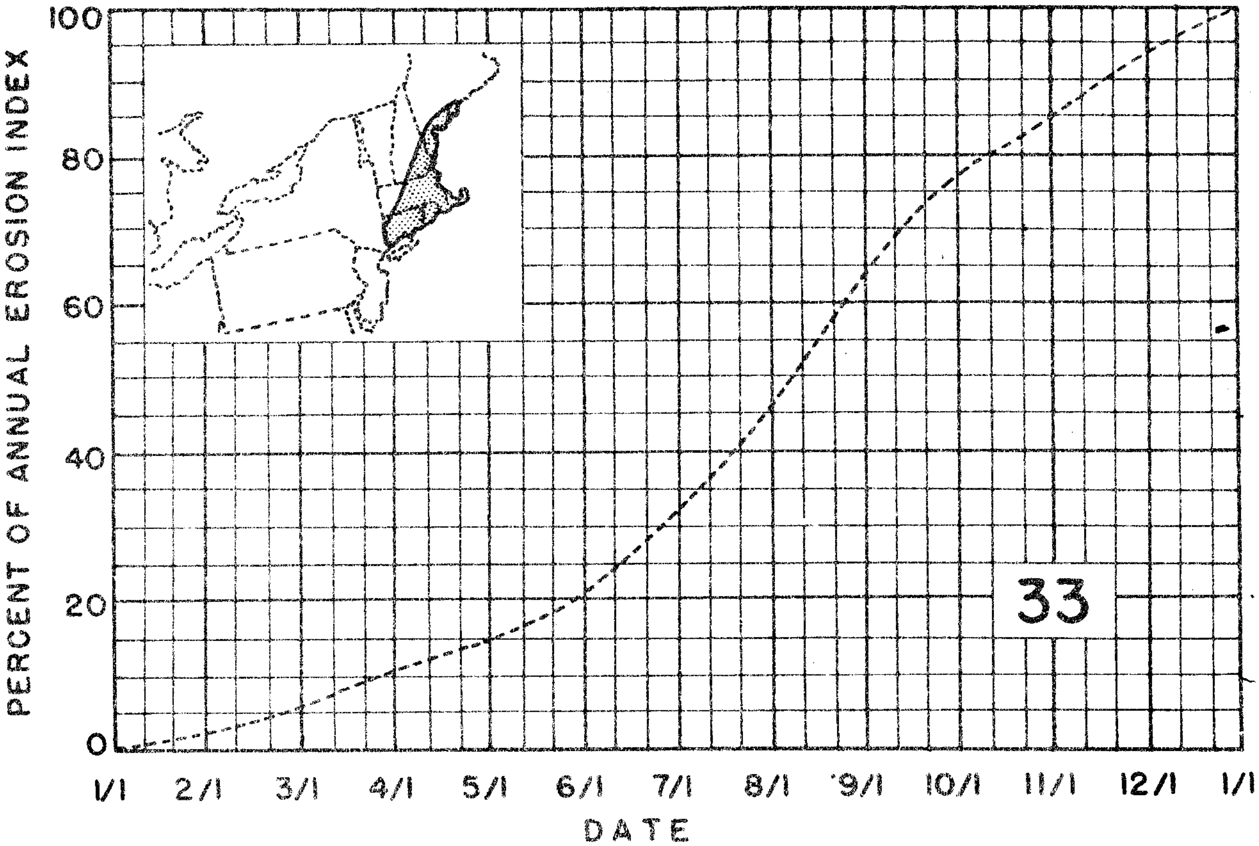


FIGURE 21.—Erosion-index distribution curve 33: Connecticut, Rhode Island and parts of Massachusetts, New Hampshire, and Maine.

method of seedbed preparation and residue management; and average crop yields including hay expected with this system on the soil involved and with the contemplated management. Tables 2 to 4 and figures 4 to 21 then supply the research data needed to complete the computation. The procedure will be explained by means of an example.

Problem.—Evaluate *C* for a 4-year rotation of wheat-with-meadow-seeding, meadow, corn, corn in central Indiana: (1) with conventional tillage and average production of 45 bushels of wheat, 4 tons of hay, and 100 bushels of corn per acre; (2) with minimum tillage and similar crop yields; and (3) with conventional tillage and yield averages of only 12 to 15 bushels of wheat, 2 tons of hay, and 40 to 55 bushels of corn. Assume that the meadow is a mixture of grass and legume, such as alfalfa and brome or timothy and clover; that crop residues are left on the field; that cornstalks are plowed under about May 1 for corn planting or disked for wheat seeding about October 10; and that wheat is harvested about July 10.

Procedure.—Set up a working table such as that illustrated in table 5, obtaining the needed information as follows:

Column 1 lists in chronological sequence all seeding and harvest dates (other than hay) involved in the rotation.

Column 2 lists the beginning date of each successive crop-stage period. A seeding date begins crop stage period 1. By definition, period 2 begins 1 month later, period 3 begins 2 months after seeding (except for winter grain), period 4 begins with crop harvest, and period F with the date of moldboard plowing. The meadow period begins 2 months after wheat harvest and extends to plowing date. Thus, all the dates in column 2 are determined by the locational seeding and harvest dates.

Column 3 records values read from the appropriate erosion-index distribution curve. Figure 4 shows that the curve applicable in central Indiana is No. 16. This curve appears in figure 12. The curve is read for each successive date listed in column 2, adding one to the "hundreds" column each time January 1 is passed.

Column 4 identifies the crop-stage period ending with the date shown on that line.

Column 5 lists the percentage of the erosion index applicable to each successive crop-stage period. The values are differences between successive curve readings recorded in column 3.

Column 6 lists the soil-loss ratio indicated in table 2, page 12, for the specific conditions and crop-stage period represented by each line in the working table. The numbers in parentheses indicate the lines in table 2 from which the values were taken.

The crop yield figure for entering table 2 is the expected *average* yield, not the yield attainable in the most favorable years. If the likelihood of meadow failure is significant, a yield figure well below the expected average is appropriate. From an erosion viewpoint, the adverse effects of a meadow failure in a rotation far outweigh the gains from occasional exceptionally good meadows.

All row-crop values in the table that are not otherwise identified assume moldboard plowing, smoothing for seedbed, and cultivation after emergence.

The *F* period precedes the crop year with which it is associated in the table. For example, the value for rough fallow after first-year corn appears in the line for second-year corn.

Column 7 is self-explanatory. (The decimals in this column derive from the percentage values in columns 5 and 6.)

Column 8 subtotals for the different crops indicate where in the rotation most of the erosion is occurring and help to suggest where additional conservation measures could be most helpful in reducing erosion. The total for this column, divided by the number of years in the rotation, is the *C* value for this rotation under the conditions assumed in columns 1 to 6.

Columns 9 and 10 replace column 6 when solving parts 2 and 3 of the problem.

The first eight columns complete part 1 of the problem. Only the addition of columns 9 and 10 is needed to derive *C* values for the management levels specified in parts 2 and 3. Wheel-track planting (part 2) reduced the value of *C* from 0.119 to 0.075, a 37-percent reduction. A productivity level as low as that specified in part 3 would increase the *C* value for the rotation to 0.186, an increase of 56 percent. Expected

TABLE 5.—*Working table for derivation of C value for 4-year rotation in central Indiana*

(1) Operation	(2) Date	(3) Readings from curve No. 16	(4) Crop-stage period	(5) *EI* in period	(6) Soil-loss ratio [1,2]	(7) Column 5 times col. 6	(8) Value of *C*	(9) Soil-loss ratio [2,3]	(10) Soil-loss ratio [2,4]
		Pct.		*Pct.*	*Pct.*			*Pct.*	*Pct.*
Pl W	10/10	91							
	11/10	96	W1	5	32(93)	0.0160		32(93)	58(95)
	5/1	114	W2	18	19	.0342		19	35
Hv W	7/10	153	W3	39	5	.0195		5	15
	9/10	183	W4	30	3	.0090	0.0787	3	3
	9/10	283	M	100	.4(122)	.0040		.4	.6(121)
TP	5/1	314	M	31	.4	.0012	.0052	.4	.6
Pl C	5/20	321	F	7	8(1)	.0056			15(5)
	6/20	339	C1	18	25	.0450		8(8)	32
	7/20	359	C2	20	17	.0340		8	30
Hv C	10/15	392	C3	33	10	.0330	.1176	6	19
TP	5/1	414	C4	22	15	.0330	.0330	15	30
Pl C	5/20	421	F	7	25(13)	.0175			42(16)
	6/20	439	C1	18	48	.0864		25(19)	57
	7/20	459	C2	20	37	.0740		25	49
Pl W	10/10	491	C3	32	20	.0640	.2419	12	28
Rotation total, 4 years				400			.4764	[5].3005	[5].7438
Annual average *C* value for rotation							.119	[6].075	[6].186

[1] For 45 bu. wheat, 4 tons hay, 100 bu. corn per acre, conventional seedbed and tillage.

[2] Numbers in parentheses refer to line numbers in table 2.

[3] Same yields as for column 6, except minimum tillage for the corn.

[4] For 12 to 15 bu. wheat, 2 tons hay, 40 to 55 bu. corn, conventional tillage.

[5] Sum of the products of *EI* increments (col. 5) and corresponding soil-loss ratios.

[6] Rotation total divided by number of years in the rotation.

soil loss from the field would be increased by the same percentage.

The *C* values computed for the rotation in the example are directly applicable only within area 16 of figure 4. For other areas or other seeding dates, the values in columns 3 and 5 of table 5 are different and the *C* value for the same rotation in other areas may be either larger or smaller.

It should be pointed out here that all these detailed computations are not required of each farm field. The procedure and basic data for derivation of the *C* values are provided primarily to enable computation of ready-reference handbook tables of values applicable in specific States or geographic areas. Knowledge of the procedure will, however, lead to a better understanding of the significance of such tables and will permit field computation of values for unusual situations.

The Erosion-Control 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 practices for cropland are contour tillage, stripcropping on the contour, terrace systems, and stabilized waterways. The factor *P* in the erosion equation is the ratio of soil loss with the supporting practice to the soil loss with up-and-down-hill 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 the factor *C*.

Contouring

The practice of tillage and planting on the contour have been, in general, effective in reducing erosion. In limited field studies, the practice provided almost complete protection against erosion from individual 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 produce its maximum average effect on slopes in the 3- to 7-percent range. As land slope decreases, it approaches equality with the 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.

Practice-Factor Values for Contouring.—After available data and observations were considered, a joint ARS–SCS–AES slope-practice workshop group meeting at Purdue University in 1956 adopted the values of *P* shown in table 6.

TABLE 6.—*Practice factor values for contouring*

Land slope (percent)	*P* value
1.1 to 2	0.60
2.1 to 7	.50
7.1 to 12	.60
12.1 to 18	.80
18.1 to 24	.90

These are average values for the factor. Location values may vary with soil type, cropping, residue management, and rainfall pattern.

The full benefits of contouring are obtained only on fields relatively free from gullies and depressions other than grassed waterways. The 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 6 should be used when computing the benefits for contouring.

Contour Listing.—Contour listing, with the corn planted in the furrows, has been more effective than surface planting on the contour (*8*). However, the additional effectiveness of this practice is limited to the time from the date of listing to that of the second corn cultivation. The soil-loss ratios (table 2) that apply to this period may be reduced 50 percent in addition to reduction supplied by the contour factor. The additional credit does not apply after the lister ridges have been largely obliterated by two corn cultivations.

A similar analysis would apply to commercial potato production where the potato rows are on the contour, except that in this case the 50-percent reduction would be applied only from layby time to potato harvest.

Slope-Length Limits for Effective Contouring.—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. Terraces or the sod strips in a contour stripcrop system function to prevent serious erosion damage when excessive row breakage occurs.

After the 1956 slope-practice workshop, the Soil Conservation Service prepared ready-reference tables for use with the Corn Belt slope-practice procedure. The values shown in table 7 were given as guides to slope-length limits for effective contouring. These are judgment values. Research data are not now available to verify or correct them. It is important to bear in mind, however, that the contour factor values given in table 6 assume slope lengths short enough for full effectiveness of the practice. Use of these values for estimating soil loss on unterraced slopes that are several terrace intervals in length is speculative.

TABLE 7.—*Length limits for contouring*

Slope (percent)	Maximum slope length
	Feet
2	400
4 to 6	300
8	200
10	100
12	80
14 to 24	60

Contour Stripcropping

Stripcropping, a practice in which contour strips of sod are alternated with strips of row crop or small grain, has proved to be a more effective practice than contouring alone. A good example is found in the Mormon Coulee near LaCrosse, Wis., where some fields are reported to have been cropped in strips for more than 70 years. Where the strips were on the contour, or nearly so, good erosion control was accomplished. Where the strips were 5 percent or more off contour, very high soil losses have occurred due to the flow of runoff down the rows at high velocities.

Observations from stripcrop studies indicated that much of the soil washed from a cultivated strip was filtered out of the runoff as it 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 movement of soil but not for all movement within the field.

Practice Factor for Contour Stripcropping.—After review of available data and field observations, the ARS–SCS Workshop group meeting at Purdue in 1956 decided to compute the contour-stripcrop factor as one-half of that for contouring alone (table 6). This value was to apply with the alternate grain-and-meadow strip system possible with a 4-year rotation of corn, small-grain, meadow, meadow, with the meadow established in the small grain. Strip guidelines were to be level. With less effective stripcrop systems, larger factor values are recommended.

With a cropping system such as a 4-year system of small grain, meadow, and 2 years of row crop, the contour factor value should probably be about 75 percent of the value in table 6 for contouring alone. Alternate strips of *fall*-seeded grain and row crop were effective on relatively flat slopes in Texas (*3*), but alternate strips of *spring*-seeded grain and corn on moderate to steep slopes have not appeared to provide significant erosion control benefits beyond those attained with contouring alone. For such systems the contour values are recommended.

Buffer stripcropping consists of narrow protective strips alternated with wide cultivated strips. The location of the protective strips is determined largely 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 so effective as contour stripcropping (*2*).

Width of Strips With Contour Stripcropping.—The strip widths shown in table 8 were recommended by the 1956 slope-practice workshop.

TABLE 8.—*Strip widths recommended for contours*

Slope group (percent)	Width of strip
	Feet
2 to 7	88 to 100
7 to 12	74 to 88
12 to 18	60 to 74
18 to 24	50 to 60

Terracing

Terracing with contour farming is more effective as an erosion-control practice than stripcropping, because it positively divides the slope into segments equal to the horizontal terrace spacing. With terracing, the slope length is this terrace interval; with stripcropping or contouring alone, it is the entire field slope length. Dividing a slope length into four equal segments cuts the expected rate of soil loss per acre in half. Dividing it into six equal segments divides the soil-loss rate by 2.45. These reductions are reflected in the erosion equation by changes in the *LS* factor value.

Both with terracing and with contour stripcropping, measured soil losses have included only soil moved completely off the field. The soil saved with contour stripcropping is largely that deposited in the sod strip. With terracing, the deposit is in the terrace channel and may equal 90 percent of the soil moved to the channel (*28*). The slope-practice workshop group in 1956 decided to use neither the off-the-field soil-loss rate nor that for soil movement within the terrace interval, but a rate that shows a part of the soil deposited in the channels as not lost. The group recommended a terracing practice factor value equal to the one for contour strip-cropping.

If all furrow slices between the terraces were turned up slope periodically with a two-way plow, most or all of the soil washed into the terrace channel would be effectively moved back up the slope and a factor value based on the off-the-field rate of loss could be safely applied. Limited data indicate the terrace factor in this case should be about 20 percent of that for contouring. But in most farming operations, conventional plows are used and the soil deposited in the terrace channel is not returned to the interterrace interval to help maintain soil productivity.

It is logical to assume that the total movement of soil within a terrace interval is equal to that with contouring alone on the same length and percentage of slope. Erosion control between terraces depends upon the crop rotation and other management practices. Therefore, if a control level is desired that will maintain soil movement between terraces within the soil-loss tolerance limit, the practice factor for terracing should equal the contour practice factor.

However, if the erosion equation is used to compute gross erosion for estimates of reservoir sedimentation rates, a terracing practice factor equal to 20 percent of the contour factor values shown in table 6 is recommended. The reason for this lower value is that the soil deposited in the terrace channels, although lost from the terrace interval, does not leave the field completely to enter into the established drainageways.

Limitations

The rainfall-erosion index measures only the erosivity of rainfall and associated runoff. Therefore, the equation does not predict soil loss that is due solely to thaw, snowmelt, or wind. In areas where such losses are significant, they must be estimated separately and combined with those predicted by the equation for comparison with soil-loss tolerances.

FIELD APPLICATIONS OF THE SOIL-LOSS EQUATION

The primary purpose of the soil-loss prediction procedure described in this handbook is to provide specific and reliable guides to help select adequate soil and water conservation practices for farm fields. Where agricultural lands are a major sediment source, the procedure may also be used to compute this phase of sediment production in predicting rates of reservoir sedimentation. Specific applications of the erosion equation are discussed and illustrated below.

Predicting Field Soil Loss

Rotation Averages

The procedure for computing the expected average annual soil loss from a given cropping system on a particular field is illustrated by the following example.

Assume a field in Fountain County, Ind., on Russell silt loam, having an 8-percent slope about 200 feet long. The cropping system is a 4-year rotation of wheat, meadow, corn, corn with tillage and rows on the contour and with corn residues disked for wheat seeding and turned under in spring for second-year corn. Fertility and residue management on this farm are such that crop yields are rarely less than 85 bushels corn, 40 bushels wheat, or 4 tons alfalfa-brome hay, and the probability of meadow failure is slight.

The first step is to refer to the charts and tables discussed in the preceding section and to select the values of R, K, LS, C, and P that apply to the specific conditions on this particular field.

The value of the rainfall factor, R, is taken from figure 1, page 6. Fountain County, in west-central Indiana, lies between iso-erodents 175 and 200. By linear interpolation, $R=185$.

The value of the soil-erodibility factor, K, is taken from table 1, page 5, supplemented by K-value tables prepared at regional Soil-Loss Prediction Workshops.[6] Soil scientists in the North Central States consider Russell silt loam equal in erodibility to Fayette silt loam, for which table 1 lists $K=0.38$.

The slope-effect chart (fig. 2, p. 8), shows that, for an 8-percent slope, 200 feet long, $LS=1.41$.

Figure 4 (p. 17), shows that Fountain County is within the geographic area to which erosion-index distribution curve No. 16 applies. Using curve No. 16, figure 12, and soil-loss ratios taken from table 2 (p. 12) or table 4 (p. 16), compute the C value for the rotation by the procedure illustrated in table 5 (p. 35). For the productivity level and management practices assumed in this example, factor C for a W–M–C–C rotation in area 16 was shown in table 5 to equal 0.119.

Table 6 (p. 36) shows a practice-factor value of 0.6 for contouring on 8-percent slope, and table 7

[6] See footnote 3, p. 2.

(p. 37) indicates that the 200-foot slope is not too long for this factor to be applicable. Therefore, under the conditions assumed in this example, $P=0.6$.

The next step is to substitute the selected numerical values for the symbols in the erosion equation and solve for A. In this example, $A=185\times0.38\times1.41\times0.119\times0.6=7.1$ tons of soil loss per acre per year.

If planting had been up and down slope, instead of on the contour, the factor P would have equaled 1.0, and the predicted soil loss for this field would have been $185\times0.38\times1.41\times0.119\times1.0=11.8$ tons per acre.

Had contour farming been combined with minimum tillage for all corn in the rotation, the value of the factor C would have been 0.075 (see table 5). The predicted average annual soil loss from the field would then have been $185\times0.38\times1.41\times0.075\times0.6=4.5$ tons per acre.

Crop-Year Averages

The soil losses computed in the example are rotation averages over a long time period. Thus, the heavier losses experienced during the corn years are diluted by trivial losses during the meadow year. Please refer again to the first solution above, in which the rotation average was 7.1 tons per acre per year. The 4-year loss from each complete rotation cycle would average 4×7.1, or about 28.4 tons per acre.

Use of the values in column 8 of table 5 enables one to compute the average soil loss for each of the 4 crop years. Column 8 shows a computed C value of 0.0787 for the wheat period and a C of 0.4764 for the entire 4-year period. The average yearly soil loss from wheat in the above example, with contouring, would be $28.4\times0.079/0.476$, or 4.7 tons per acre. First-year corn, including the winter period, would average $28.4\times0.151/0.476$, or 9.0 tons. The second-year corn would average $28.4\times0.242/0.476$, or 14.4 tons, and the 20-month meadow period would average less than 0.5-ton soil loss per acre.

Soil-Loss Probabilities Other Than Average

Because rainfall differs from year to year, the actual value of the factor R also differs from year to year at any given location. Appendix table 11 lists 50-, 20-, and 5-percent probability values of R at 181 key locations. These may be used for further characterization of soil-loss hazards. Fountain, County, Ind. (where our example was located), is not listed in the table, but figure 1 shows that the R value there is essentially the same as the R value at Indianapolis. Table 11 shows that, over a long period, the value of the factor R will equal or exceed 225 at Indianapolis in 20 percent of the years. This is $225\div185$, or 1.22 times the average value. Returning once more to the example, soil loss from second-year corn on the assumed field would be expected to exceed $1.22\times14.4=17.6$ tons per acre in 20 percent of the years. The 5-percent probability value of R at Indianapolis is shown in table 11 to be 302, or 1.63 times the average value of 185. Therefore, soil loss from the second-year corn on the field assumed for our example would be expected to exceed $1.63\times14.4=23.5$ tons per acre in 5 percent of the years if the corn is contoured. Without contouring it would exceed $23.5\div0.6=39.2$ tons per acre in 5 percent of the years.

Individual-Storm Soil Losses

The assembled plot data show conclusively that the relation of soil loss to such major factors as slope, cropping, management, and conservation practices is not the same from storm to storm or from year to year, even on the same field under a continuing rotation. In a particular rainstorm, the factor relations are influenced by such variables as antecedent moisture, tillage, tractor and implement compaction, soil crusting by prior rains, and progressive changes in plant cover. Daily soil moisture and temperatures are more favorable to rapid development of good protective cover in some years than in others. The factor values reported in the preceding section and used in the foregoing examples represent average factor relations derived from research measurements over an extended period. Therefore, the erosion equation is particularly designed to predict average annual soil loss from any specific field over an extended period.

Predictions of individual-storm soil losses will be less accurate, because effects of the minor variations in antecedent conditions cannot be precisely evaluated at this time. However, valuable estimates of single-storm losses can be computed by the following procedure.

Instead of taking the value of R from figure 1, let R equal the computed erosion-index value for the specific rainstorm. Instead of the C value for the rotation, let C in the equation equal the soil-loss ratio shown in table 2, 3, or 4 for the specific conditions existing on the field at the time of the rain. For example, appendix table 12 shows that a 10-year rain at Indianapolis has an erosion-index value of 75 or more. Assume that such a rain occurred about 3 weeks after planting the second-year corn in the preceding example. The existing condition is then described by line 13 of table 2. Since the rain occurred within 30 days after corn planting, the value of C at the time of this particular rain is 48. The value of R is 75. Other values in the equation remain the same as in the first solution. The estimated soil loss from this single rainstorm on the second-year corn, without contouring, is then $R\cdot K\cdot L\cdot S\cdot C\cdot P=75\times0.38\times1.41\times0.48\times1.0=19.3$ tons per acre.

Specific-Year Soil Losses

Soil loss from a particular field in any specific year cannot presently be predicted in advance, primarily because it is not presently possible to predict the size and time of the rainstorms that will occur in that year. Deviations from average are very great. Surface conditions, quality of cover, and minor factors in tillage and management may also differ significantly from the average for that field. However, the erosion equation can provide reasonably reliable estimates of soil loss in a particular *past* year, if detailed rainfall records were obtained. Storm *EI* values need to be computed from the specific year's rainfall records, and the soil loss must be computed for each crop-stage period separately. This is done by letting *R* equal the erosion index measured for the crop-stage period and letting *C* equal the soil-loss ratio taken from table 2, as in the example for estimating individual-storm soil losses.

Even though a particular year's precipitation may have been essentially equal to the average annual rainfall in inches at that location, this fact is not justification for selecting *R* and *C* values from figure 1 and table 11 to estimate the soil loss for that particular year. Even with normal annual precipitation, the erosion index may have been well above or below normal because of abnormal intensities. The monthly distribution of the erosive rains may also have deviated significantly from normal.

Significance of Average Field Soil Loss

Knowledge of quantitative rates of erosion and soil-loss tolerances provides specific guidelines for effective erosion-control planning. Such values are, however, to be looked upon as guides that sometimes need to be tempered with judgment. It is important to bear in mind that the accepted expression for average rate of erosion from a field—tons of soil loss per acre—is not intended to imply uniform soil movement over the entire field area. Since soil loss increases as the 0.5 power of slope length, the erosion rate on the upper quarter of a field with a single uniform slope is about half the field average and that on the lower quarter is about 1½ times the field average. Because of the erodibility of the lower ends of long uniform or convex slopes, it may be appropriate to recommend subdividing such a slope even though the estimated average soil loss for the entire length is within the tolerance limit. On irregular topography, serious erosion may occur in some parts of a field while deposition occurs in others. In such cases, the erodible slopes need to be taken as the limiting factor for the field.

Determining Alternative Ways in Which a Particular Tract of Land May Be Used and Treated Successfully To Conserve or Improve It

The soil-loss prediction procedure provides the practicing conservationist with concise ready-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. The factor *L* is modified only by terracing. The other three factors—*R*, *K*, and *S*—are essentially fixed so far as a particular field is concerned. When erosion is to be limited to the maximum allowable, or tolerance rate, the term *A* in the equation is replaced by *T*, and the equation is rewritten in the form: $CP=T/RKLS$. Substituting the locational 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 conservation practices, the most intensive cropping plan that can be safely used on the field is one for which the factor *C* just equals this value. When a conservation practice such as contouring or stripcropping is added, the computed value of *T/RKLS* is divided by the practice factor, *P*, to obtain the maximum permissible cropping-management factor value. With terracing, the value of *T/RKLS* is increased by decreasing the value of *L*.

A special slide rule recently designed in Tennessee (*17*) enables rapid and systematic computation of *T/RKLS* for any specific situation after pertinent values of the factors have been selected from the tables and charts.

Since a practicing conservationist usually works within the limits of a single county or other small geographic area, he will usually be concerned with only one value of *R*, one erosion-index distribution curve, *K* and *T* values for only a few soils, and *C* values for only a limited number of cropping systems. Therefore, the *R* value for his county, a list of *T* and *K* values for the soils in his work area, a few brief tables of pertinent *T/RKLS* values, and a table of *C* values for pertinent rotations will provide all the information he will need to use this procedure as a guide to selection of conservation practices. He will rarely, if ever, need to solve the equation or to perform computations in the field.

The *T/RKLS* values are the maximum allowable *C* values for the various soil and slope combinations in the conservationist's work area. They may be included in his handbook in the form illustrated by table 9, with a table for each major soil type with which he is concerned.

C values for rotations may be centrally computed for all cropping systems encountered within a given erosion-index distribution area (fig. 4), based on average seeding and harvest dates within that area. The factor for each cropping system needs to be computed for each of several crop-productivity levels and for each of several methods of residue management and seedbed preparation. The results are then listed in a table in order of declining magnitude of *C*, as illustrated in table 10.

To illustrate the selection process, we will assume a field in a county having a rainfall factor of 180, located within the erosion-index distribution area in which the *C* values of table 10 apply. Assume that the soil on this field has a *K* value of 0.33 and a soil-loss tolerance of 4 tons per acre per year. Past yields on the field have been from 2 to 3 tons hay and from 40 to 60 bushels corn per acre, with conventional seedbed preparation and tillage.

The land slope averages about 3 percent over the upper half of a total 400-foot slope, but the lower half steepens considerably and ranges from 5 to 7 percent. The field is planted as a single unit. In conservation farming, soil movement from the most vulnerable part of the field should be held below the tolerance limit, *T*. Therefore, the gradient of the lower half of the field is the significant percentage of slope for the soil loss estimate. However, surface runoff from the upper half passes over the lower half. Therefore, the overall length will be the effective slope length. Thus, a slope length of 400 feet and a slope gradient of 6 percent would be used to enter the ready-reference table.

For this soil and slope combination, table 9 lists a maximum *CP* value of 0.050. Entering table 10 with this value, the farmer finds that with straight rows and conventional tillage at the Y_2 yield level, the most intensive cropping system he can safely use is 1 year of corn in 5 years (C–O–M–M–M). Any system having a *C* value less than that for C–O–M–M–M should provide better than the tolerable level of erosion control under the conditions assumed for this example.

With contour farming, the maximum *C* value would be 0.10 (table 9), and he could move up the list in table 10 to a C–C–O–M–M–M system.

Improvement in his general level of fertility and residue management would enable the farmer to use a more intensive cropping system safely or to attain a higher level of conservation, while at the same time increasing his crop yields. If he were able to reach and maintain average yields equal to Y_3 in table 10, he could move up to a C–O–M–M rotation without contouring or to C–C–O–M–M with contouring. If he then also added wheeltrack planting and minimum tillage for corn, he could move up the list to 2 years of corn and 1 year meadow in a C–C–O–M rotation. Thus, the tables, show the farmer how he can improve his erosion-control program and still increase yields or decrease labor and tractor costs.

A system of terraces would break the slope length and permit a higher degree of conservation or more intensive cropping systems. Terraces at about 100-foot horizontal intervals would reduce the effective slope length from 400 feet to 100 feet. For a 6-percent slope 100 feet long, contoured, table 9 shows a maximum *C* value of 0.20. This would permit any of the cropping systems listed in table 10 up to 3 years of corn in 5 (C–C–C–O–M) or a 2-year system of corn and oats with sweetclover intercrop. With wheeltrack planting, a 3-year rotation of corn, corn, oats-and-sweetclover would also appear satisfactory.

Estimating Source Sediment From Watersheds

Cultivated farm fields are a major sediment source in the general agricultural area of the humid and subhumid zones. The soil-loss prediction equation may be used effectively in making predictions of the magnitude of this sediment source. Other sources of sediment production that must be considered in making estimates of total sediment loads include gullies, roadside areas, and residential subdivisions.

The erosion equation provides a methodical means of bringing the effects of expected rainfall pattern, soil properties, and land use into computation of that part of the sediment production that is attributable to sheet and rill erosion. The drainage area may be broken down into a series of tracts having relatively homogeneous land use and treatment. The erosion equation is then used to approximate the average annual rate of soil movement from each tract.

However, sediment estimates computed in this manner are estimates of average annual sediment production over a period of at least 25 years or more. Gross erosion on the watershed in any one particular year may be at least three or four times this average rate. In other years it will be less. This is true for a number of reasons. Table 11 shows that in one year out of 20, the rainfall erosion index is at least twice the average for that location. At the same time, abnormal distribution of erosive rains may result in a greater than average portion of the erosive rainfall occurring when the fields are most vulnerable to rainfall erosion. Breakover of contour rows in a severe rainstorm may increase greatly the gross erosion from that storm and also from succeeding storms until the break is obliterated by tillage. Adverse

TABLE 9.—*Maximum permissible C values (T/RKLS) for indicated gradient and slope length with straight and with contoured rows for soil type with the K, T, and R values as listed*

For soil type with K=0.33, T=4 or K=0.25, T=3, and R=180.

Gradient (percent)	Values for slope length (in feet) of—							
	60	80	100	150	200	250	300	400
	STRAIGHT ROW							
2	0.45	0.35	0.33	0.26	0.22	0.20	0.17	0.15
4	.22	.19	.17	.13	.11	.10	.092	.081
6	.13	.11	.10	.083	.072	.065	.058	.050
8	.089	.077	.068	.055	.048	.043	.039	.034
10	.064	.056	.050	.040	.035	.030	.028	.024
12	.048	.042	.037	.030	.026	.023	.021	.018
14	.038	.033	.029	.024	.020	.018	.017	.014
16	.030	.026	.024	.019	.016	.015	.013	.012
18	.025	.022	.019	.016	.014	.012	----------	----------
20	.021	.018	.016	.013	.011	----------	----------	----------
	CONTOURED							
2	0.75	0.58	0.57	0.43	0.37	0.33	0.28	0.25
4	.44	.38	.34	.26	.22	.20	.18	0.16
6	.26	.22	.20	.17	.14	.13	.12	.10
8	.15	.13	.11	.092	.080	.072	.065	.057
10	.11	.093	.083	.067	.058	.050	.047	.040
12	.08	.070	.062	.050	.043	.038	.035	.030
14	.048	.041	.035	.030	.025	.022	.021	.018
16	.038	.032	.030	.024	.020	.019	.016	.015
18	.031	.027	.024	.020	.018	.015	----------	----------
20	.023	.020	.018	.014	.012	----------	----------	----------

weather in one year may cause widespread meadow failure within the watershed area. Gross erosion from the first-year and second-year rotation corn after a poor meadow will then be substantially greater than normal and may nearly equal that from continuous row cropping. Furthermore, one segment of the watershed may receive a severe rainstorm while another segment of the same watershed receives little or no rain. Location of the storm center will differ from one storm to another, so that the long-time average rainfall may be nearly uniform. However, specific-storm or specific-year values of both R and C may deviate a great deal from their average values for that location. When gross erosion is to be estimated for a specific short-term period for evaluation of sediment delivery rates, the specific EI value and soil-loss ratio for each successive crop-stage period must be used in lieu of the annual erosion index and the rotation C value. (Refer to page 39 for details.)

Correct interpretation of watershed conditions for selection of appropriate values of the factors L and S is also very important, but interpretation is frequently quite difficult because of complex topography. Complex soil and land use patterns superimposed upon a complex topography present problems in interpretation and factor evaluation that need further research analysis. However, the definition of slope length, page 9, and the discussion of convex and concave slopes, page 8, provide helpful guides. Slope shapes and drainage patterns need to be carefully considered. A steep gradient at the lower end of a slope should not be averaged with a gentle gradient at the upper end. A slope length does not terminate simply because of a wire fence or a change in cropping. If runoff from an area above a field is allowed to enter the field as sheet flow, the upper area is part of the slope length for computing erosion on the field. However, sufficient flattening of the slope to cause deposition to begin indicates the end of a slope length.

The sum of the estimates for the individual tracts making up the watershed approximates the quantity of soil moved from its original general position. This initial sediment estimate must be adjusted downward to compensate for deposition in terrace channels, in sod waterways, in field boundaries, and at the toe of field slopes. Further changes in sediment content of runoff water will occur during the stream transport phase.

The appropriate value of the factor P for a terraced field is considerably lower for purposes

TABLE 10.—*Partial list of C values for common rotations for a specific erosion-index distribution area* [1]

Cropping system [2]		C values for RdL, disked for small grain, spring-plowed for corn				
		Conventional plant and till [4]			Minimum tillage [4]	
Rotations	Limits [3]	Y_1	Y_2	Y_3	Y_2	Y_3
Continuous corn		0.48	0.43	0.38	0.33	0.27
C-C-C-O_x		.36	.31	.27	.23	.19
C-C-O_x		.32	.27	.24	.19	.17
C-C-C-O-M		.25	.20	.19	.14	.12
C-O_x	c	.25	.18	.17	.13	.12
C-C-O-M		.19	.14	.12	.10	.082
C-C-O-M-M		.15	.12	.10	.081	.066
C-C-O-M-M-M		.13	.096	.082	.068	.057
C-O-W-M		.13	.083	.058	.064	.049
C-O-M	b	.12	.079	.058	.052	.037
C-O-M-M		.088	.060	.045	.040	.029
C-O-M-M-M		.071	.049	.036	.033	.024
C-O-M-M-M-M	a	.060	.042	.031	.028	.020

[1] Area shown in fig. 12 for curve No. 16.
[2] Abbreviations: C—corn, O—oats, O_x—oats with sweet clover intercrop, W—fall-seeded grain, M—grass and legume meadow, RdL—residues left.
[3] Dashed lines indicate cropping system limits for: *a*, straight-row farming; *b*, contouring; *c*, terraces. Acceptable rotations are those below the lines.
[4] Y_1—average yields of 1 to 2 tons hay, 40 to 59 bu. corn.
Y_2—average yields of 2 to 3 tons hay, 60 to 74 bu. corn.
Y_3—average yields of 3 to 5 tons hay, 75 to 100 bu. corn.

of watershed sediment prediction than it is for purposes of erosion-control planning. As much as 90 percent of the soil eroded from the area between terraces may be deposited in the channels (*28*). For sediment prediction, the important consideration is the quantity of soil moved completely *off* the field. For this purpose, *P* values equal to about 20 percent of the contour practice values shown in table 6 are recommended.

When runoff from a cropped field enters a grass waterway or crosses a sodded fence row or streambank area to enter a main drainageway, part of the silt load is filtered out by the sod, as it is in a cultivated field with contour stripcropping. If the gradient decreases significantly between the lower end of the cropped field and the point where the runoff enters the drainageway, deposition may occur even if the area is not sodded. Factors to adjust gross-erosion estimates for these situations have not been evaluated.

SUMMARY

The soil-loss prediction procedure presented in this handbook provides a methodical means for using all available research information to help guide land use and management decisions on any particular farm field where soil erosion by rainfall and runoff is a problem. The soil-loss prediction equation presented is universally applicable wherever locational values of the equation's individual factors are known or can be determined. Research data assembled from all major agricultural areas of the United States were analyzed and summarized in ready-reference tables and graphs. These provide a source of information for approximating the factor values needed to apply the equation to the specific conditions in the various geographic areas.

Data and procedures are presented in considerable detail, to help the user interpret the guides supplied by solutions of the equation. Applications of the procedures are illustrated in specific examples.

Use of the equation, tables, and figures for predicting soil erosion losses on any particular field, under each of various alternative cropping systems and management practices, is not a complicated procedure. Comparison of the predicted erosion rates with the applicable soil-loss tolerance provides very specific guidelines for effecting erosion control within specified limits. For the selection of practices on an individual farm, the procedure can be reduced to use of a few reference tables derived for the particular geographic area.

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APPENDIX

TABLE 11.—*Observed range and 5-, 20-, and 50-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

TABLE 11.—*Observed range and 5-, 20-, and 50-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
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
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.

TABLE 11.—*Observed range and 5-, 20-, and 50-percent probability value 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
Pennsylvania—Con.				
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
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 ARS-SWC rainfall records. All others are based on Weather Bureau records.

TABLE 12.—*Expected magnitudes of single-storm erosion index values*

Location	Index values normally exceeded once in—				
	1 year	2 years	5 years	10 years	20 years
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

TABLE 12.—*Expected magnitudes of single-storm erosion index values*—Continued

Location	Index values normally exceeded once in—				
	1 year	2 years	5 years	10 years	20 years
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
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
Charlotte	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

TABLE 12.—*Expected magnitudes of single-storm erosion index values*—Continued

Location	Index values normally exceeded once in—				
	1 year	2 years	5 years	10 years	20 years
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

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